Detecting Land Use and Land Cover Changes in Mandalay City Using Landsat Images

Tin Moe Lwin[1]

Abstract

Mandalay City has been experiencing a fast urban growth in the past three decades which has been rapid by losing cultivated land/open space and water body. Land use and land cover maps of Mandalay City were produced from Landsat images for 1989, 1999, 2009 and 2019, a period of 10 years interval. Changes in land use and land cover have occurred remarkably, with loss of cultivated land/open space, and water body to urban land uses. Particularly, low-density residential area and high-density urban or built-up area have obviously increased by about 25 percent and 7 percent between 1989 and 2019. Significantly, land covered by vegetation has slightly increased which has been about 4 percent. These land use and land cover changes have drastically altered the land surface characteristics. An analysis of Landsat images revealed an increase of 33 percent of urban residential area and a decrease of 34 percent cultivated land/open space and over 3 percent of water area during the 40 years periods. This paper illustrates the usefulness of a remote sensing approach for monitoring land use and land cover changes and these technologies can save resources such as time, effort, and money comparing with traditional urban approaches.

Keywords: Land cover, Land use, Landsat images, remote sensing, monitoring

Introduction

Urban areas are the most dynamic regions on earth. Their size has been constantly increasing year after year. Cities and urbanized areas are the social centers of our modern life and they provide all of our daily needs. They promise security, welfare and a place where people may find better life conditions compared to rural areas. As a consequence urbanized areas have become the densest populated regions on earth in the past and the present century. Urban areas also serve as hubs for development, where the proximity of commerce, government and transportation provide the infrastructure necessary for sharing knowledge and information (United Nations, 2019). The concentration of people in every dense populated urban area mainly located in less developed countries. Landsat satellite images can be used mainly for planning purpose and can be enable reporting the overall growth of urban area on a detail level. It can also be enable the comparison of different time series or different cities in term of changes.

The term ‘Land use’ usually relates to the human activity associated with a specific area of land while ‘Land cover’ generally denotes the type of features covering some area of the surface of the earth. Land use is a dynamic phenomenon and needs a continuous

[1] Associate Professor, Dr, Department of Geography, University of Mandalay

monitoring as some changes are cyclic, others are short-term and a few occur slowly over a long period of time. Landsat imagery provides up-to-date land use and land cover information, at small scale, at reasonably low cost and better accuracy (Sharma K.P.,et.al, 1984). By using Landsat TM images, detecting urban land use and land cover changes in Mississauga was studied by J. Li and H. M. Zhao in 2003.

In this study, the main aim is to create Land Use and Land Cover (LULC) maps by using Landsat images for Mandalay City which can be used to study urban land use and land cover changes and predict its urban growth for future development. This paper examines four periods of Landsat images for 1989, 1999, 2009, and 2019 primarily based on the present administrative boundary area of Mandalay City (Figure 1). The major LULC were identified by using five land use and land cover categories: (1) Cultivated Land/Open Space, (2) High-density Urban or Built-up, (3) Low-density Residential Area, (4) Land covered by Vegetation, and (5) Water.

Aims and Objectives

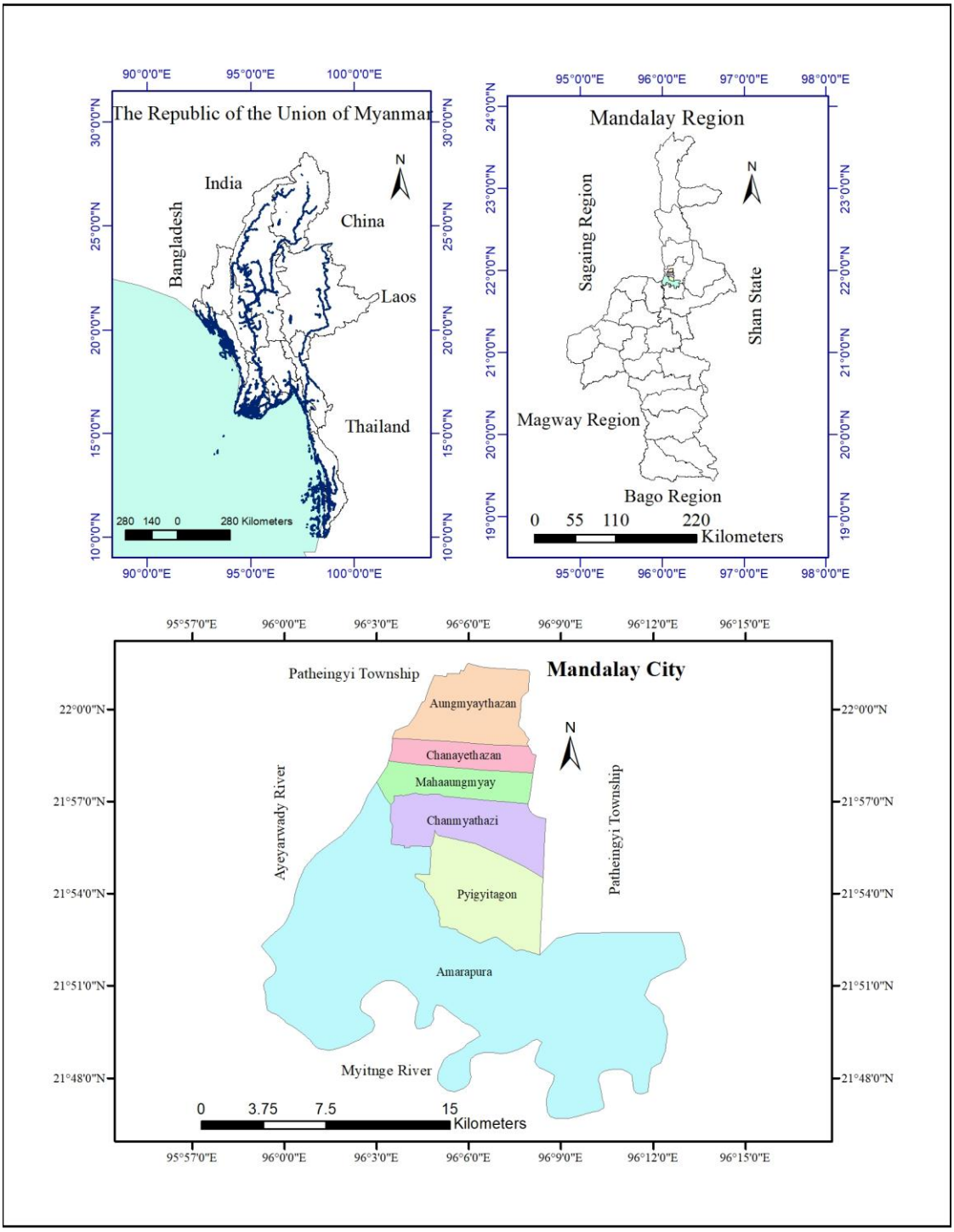
The main aim is to analyse the spatial-temporal changes in the land use and land cover of Mandalay City by using geospatial technology

The major objectives of this paper are

1. to provide geospatial data to local government
2. to examine time series of LULC map for the verification of changes patterns as well as for the prediction of future development.
3. to update land use and land cover information for a better urban planning and development.

Study Area

Mandalay City, Regional Capital of Mandalay Region and the second largest City of Myanmar, is located in the dry zone of Central Myanmar. It lies generally on the alluvial flat plain constructed by the Ayeyarwady River and its tributaries. The City is composed of six townships, including Aungmyetharzan, Chanayetharzan, Mahaaungmye, Chanmyatharzi, Pyigyidagun, and Amarapura townships. Mandalay City is generally located between 21° 46' 22.5" and 22° 01' 31.86" N latitude, and between 95° 59' 36.20" and 96° 12' 6.30" E longitude. The City area is about 220 mi^2 (570 km^2). It is bordered on the north and east by Patheingyi Township, the Ayeyarwady River is the water boundary on the west and Myitnge River is the water boundary on the south.



Source: Department of Geography, Mandalay University

Figure 1 Study Area of Mandalay City

Data and Methods

In this study, ENVI 4.7 software was used to integrate the available data source. Landsat satellite images from United State Geological Survey (USGS) (https://earthexplorer.usgs.gov) for four periods (1989, 1999, 2009, and 2019) were used for

this study. The study area is contained within the Landsat path 133, row 045. In this study, Landsat No. 4,5,7,8 and TM, ETM+, and OLI/TIRS Sensor Types, three thermal bands (band 5, band 4, and band 2), were used to extract for LULC classification. The resolutions of all images are 30 metres (Table 1). The characteristics of sensor types of Landsat 4, 5, 7, and 8, and spectral (μm), spatial (m) bands characteristics are explained in Table 2. To get the real ground truth surface data, the month of February was selected to perform LULC classification. ArcGIS 10.1 software was used to produce LULC mapping. The present administrative boundary of Mandalay City was used to generate by using ArcGIS 10.1 based on topographic map and the scale is 1: 150000. The population data was taken from Census 1983, and for 1993 and 2003 the population data were estimated from the Department of Immigration and Registration of Mandalay, for 2014 the population data was taken from Census of Myanmar (2014).

Table 1. Landsat Image, Scene ID, Acquisition Date, Path/Row, Bands, Pixel and Source

Scene ID	Landsat No.	Sensor Type	Acquisition Date	Path / Row	Bands	Pixel	Source
LT04_L1TP	4	TM	17-Feb-1989	133 / 045	5,4,2	30m	USGS
LT05_L1TP	5	TM	02-Feb-1999	133 / 045	5,4,2	30m	USGS
LE07_L1TP	7	ETM+	08-Feb-2009	133 / 045	5,4,2	30m	USGS
LC08_L1TP	8	OLI/TIRS	22-Feb-2019	133 / 045	6,5,3	30m	USGS

Source: United State Geological Survey (USGS) (https://earthexplorer.usgs.gov)

Table 2. Characteristics of Sensors Types of Landsat 4, 5, 7, and 8, Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS), Band Designation

Band	Landsat 4/5 Spectral (μm)	TM Spatial (m)	Landsat 7 Spectral (μm)	ETM+ Spatial (m)	Landsat 8 Spectral (μm)	OLI/TIRS Spatial (m)	Band
						30	1 Coastal
1 Blue	0.45-0.52	30	0.45-0.52	30	0.45-0.52	30	2 Blue
2 Green	0.52-0.60	30	0.52-0.60	30	0.52-0.60	30	3 Green
3 Red	0.63-0.69	30	0.63-0.69	30	0.63-0.69	30	4 Red
4 Near Infrared	0.76-0.90	30	0.76-0.90	30	0.84-0.88	30	5 Near Infrared
5 Short Wave Infrared 1	1.55-1.75	30	1.55-1.75	30	1.55-1.75	30	6 Short Wave Infrared 1
6 Thermal Infrared	10.40-12.50	120	10.40-12.50	60	2.10-2.30	30	7 Short Wave Infrared 2
7 Short Wave Infrared 2	2.08-2.35	30	2.08-2.35	30			
8 Panchromatic	nail	nail	0.50-0.68	15	0.50-0.68	15	8 Panchromatic
					1.38-1.39		9 Cirrus
					10.30-11.30		10 Long Wave Infrared 1
					11.50-12.50		11 Long Wave Infrared 2

Source: http://landsat.usgs.gov/tools_spectralViewer.php.
https://landsat.gsfc.nasa.gov/landsat-data-continuity-mission/

Land Use and Land Cover Mapping Method

In this study, the land use and land cover classification scheme, shown in Figure 2, was adopted with a main focus on differentiating among five land use and land cover categories, (1) Cultivated Land/Open Space, (2) High-density Urban or Built-up, (3) Low-density Residential Area, (4) Land covered by Vegetation, and (5) Water.

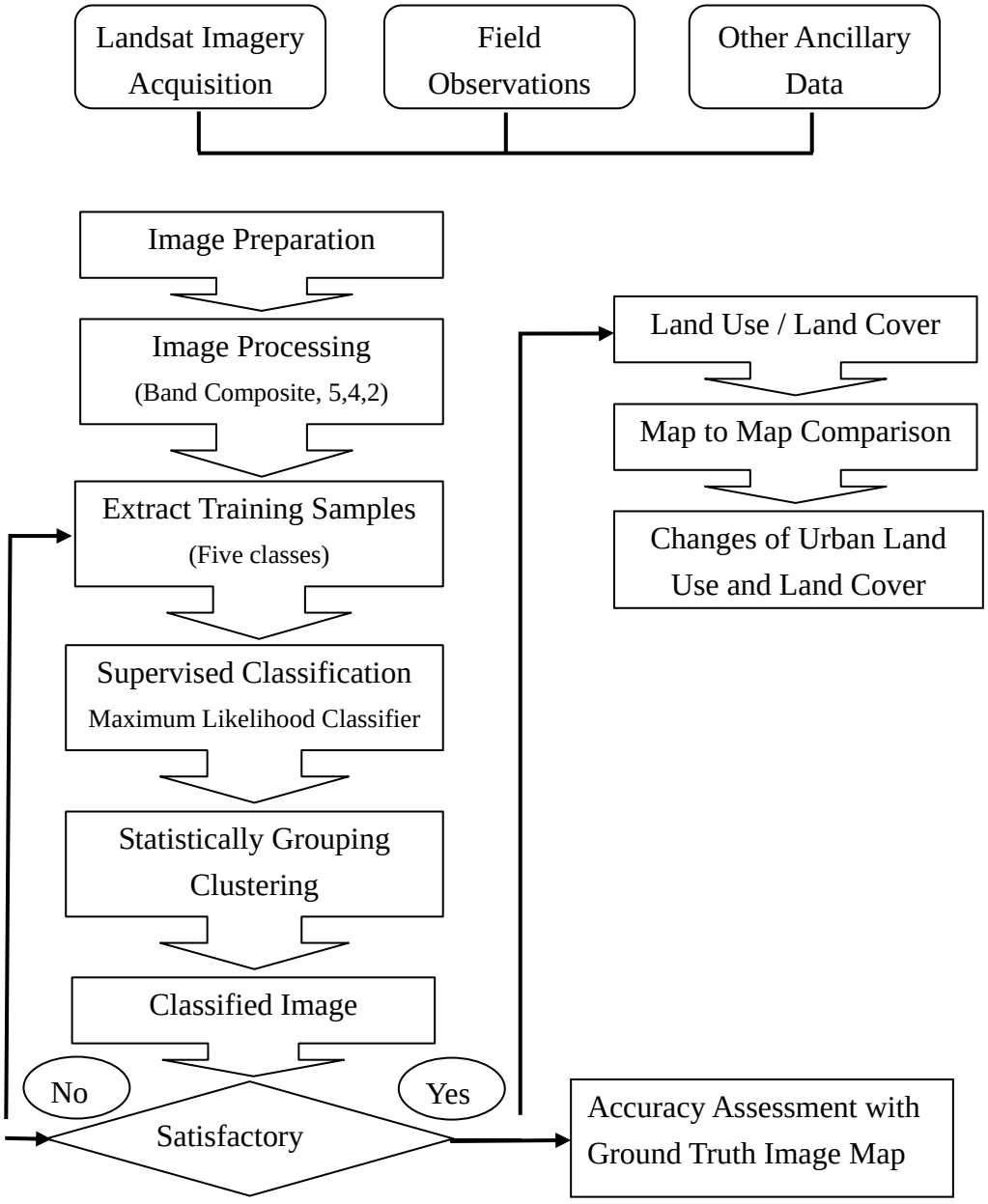


Figure 2 Working procedure, primary and secondary data acquisition, image processing, image classification, accuracy assessment, and changes detection

Results and Discussion

Land Use and Land Cover Changes of Mandalay City

As Mandalay City was founded by King Mindon with a population of less than 90,000 people in 1857, its land area included a large proportion of religious land, and agricultural land (Kyaw Myint Aung, p-28). According to the changing national policy in economic liberalization after 1988 and all round development of the country, restructuring of the existing urban centers were performed throughout the whole country of Myanmar. Mandalay, being the second largest city, has experienced various developmental works and its urban land use pattern changes. After Mandalay City was reconstituted with six townships in 2011, the city area has increased to over 220 mi^2 (570 km^2) from 25.55 mi^2 (66.2km^2) before 1989, because it has a vast rural area of Amarapura Township. From 1983 to 2014 population of the city has also increased at about 930215 persons (Table 3). This increased population has changed the areas of urban and cultivated land/open space and water areas of Mandalay city. These changes can be identified on the Landsat images for 1989, 1999, 2009 and 2019. By using ENVI 4.7, the overall accuracies of Landsat images are about 93% for 1999, and 96% for 1989, 2009, and 2019. The Kappa coefficients are 0.95 for 1989, 0.90 for 1999, and 0.95 for 2009 and 2019 respectively (Table 4).

Table 3 Total population of Mandalay City (1983-2014)

Year	Population	Increased Number of Population
1983	532949	
1993	710027	177078
2003	842330	132303
2014	1463164	620834
	Total =	930215

Source: Immigration and Population Department of Mandalay City, Census 1983, and Census 2014

From the analysis of Landsat image of 1989, the present boundary area of Mandalay City was covered mostly by the cultivated land/open space (yellow colour) with 49.65 percent and it was followed by vegetation cover (green colour) 23.51 percent and low-density residential area (brown colour) 12.48 percent, the high-density urban/built-up area (red colour) was only 4.82 percent and water body (blue colour) 9.55 percent (Table 4). As the city area was not extended before 1989 and it was studied by overlapping with the present boundary area which was extended to 220 mi^2 (570 km^2) in 2011. In 1989, the cultivated land/open space, land covered by vegetation and low-density residential areas formed the largest proportion to the land use and land cover of Mandalay City. High-density urban/built up area was slightly concentrated mainly in the west and southwest portion of the Mandalay Palace Wall [Figure 3(a)].

In the end of 1992, Mandalay City was reconstituted with 5 townships and the urban

area of Mandalay City has been extended to 41.35 mi^2 (107.1km^2). In these extended areas, which lies in the south and southeastern portion of the old Mandalay City and which were covered mainly by vegetation cover and cultivated lands/open space, the fire victims of 1980s, the squatter house from the inner parts of the Mandalay City and the government employees were allocated and the industrial zone of Mandalay City was established in 1990s. The industrial works from various parts of the city were shifted to that industrial zone to prevent industrial pollution and for environmental conservation in the downtown areas. As a result, the areas of cultivated lands/open space were changed into urban built up lands [Figure 3(b)]. Therefore, the area of high-density urban lands increased to 4.82 in 1989 to 6.42 percent in 1999 and 7.66 percent in 2009 (Table 4). During the period from 1989 to 1999, the area of land covered by vegetation of Mandalay City increased from 23.51 percent in 1989 to 29.28 percent in 1999 and 36.41 percent in 2009. This vegetation cover area was related to the government policy of the Greening Project for the Dry Zone of Central Myanmar. Under this project reforestation, afforestation and forest conservation works were performed by the leadership of the state government and regional authorities.

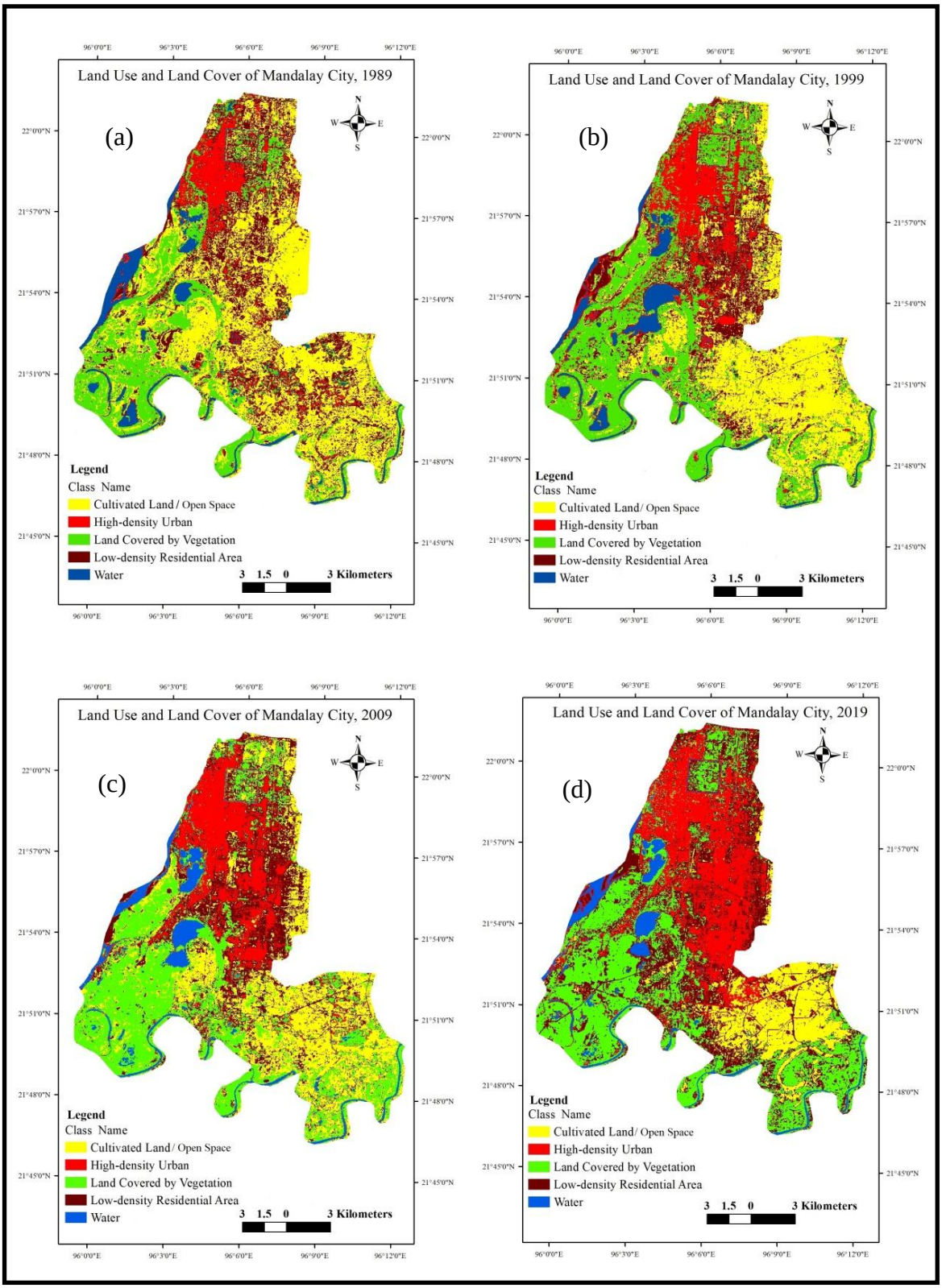
Table 4 Land Use and Land Cover of Mandalay City for 1989,1999,2009, and 2019

	Land Use/Cover Class	1989 (%)	1999 (%)	2009 (%)	2019 (%)
1	High-density Urban/Built-up	4.82	6.42	7.66	12.42
2	Low-density Residential Area	12.48	11.14	13.63	38.11
3	Cultivated Land / Open Space	49.65	45.30	36.28	15.55
4	Land Covered by Vegetation	23.51	29.28	36.41	28.15
5	Water	9.55	7.86	6.02	5.77
	Total	100.00	100.00	100.00	100.00
	Kappa Coefficient	0.95	0.90	0.95	0.95
	Overall Accuracy	96.09%	93.21%	96.56%	96.18%

Source: Calculation from Landsat images processing, 1989, 1999, 2009, 2019

As population is increasing year after year and new economic opportunities are created in the newly extended Area, more human settlement occurred in these areas and formerly cultivated land/open space annually inundated areas were continued to be changed into urban built-up and low-density residential lands. In the mean time, the downtown areas in the Mandalay City were used more intensively than in the past and distinct urban land marks were also found in these areas particularly around the downtown areas [Figure 3(c)].

From the analysis of 2019 Landsat image, the high-density urban and low-density residential land areas of Mandalay City were continued to be extended while the area of cultivated land/open space are continuously declining. During ten years periods from 2009 to 2019, the land covered by vegetation area also declined to its area of 36.41 percent in 2009 to 28.15 percent in 2019 of the total area (Table 4).



Source: Derived from the processes of Landsat images, 1989, 1999, 2009, 2019

Figure 3 Land Use and Land Cover Map of Mandalay City (1989, 1999, 2009, 2019)

Table 5 Land Use and Land Cover Changes of Mandalay City (1989 to 2019)

	Land Use/Cover Class	1989 (%)	2019 (%)	Change (%)
1	High-density Urban/Built-up	4.82	12.42	(+) 7.60
2	Low-density Residential Area	12.48	38.11	(+) 25.63
3	Cultivated Land / Open Space	49.65	15.55	(-) 34.10
4	Land Covered by Vegetation	23.51	28.15	(+) 4.64
5	Water	9.55	5.77	(-) 3.78
	Total	100.00	100.00	

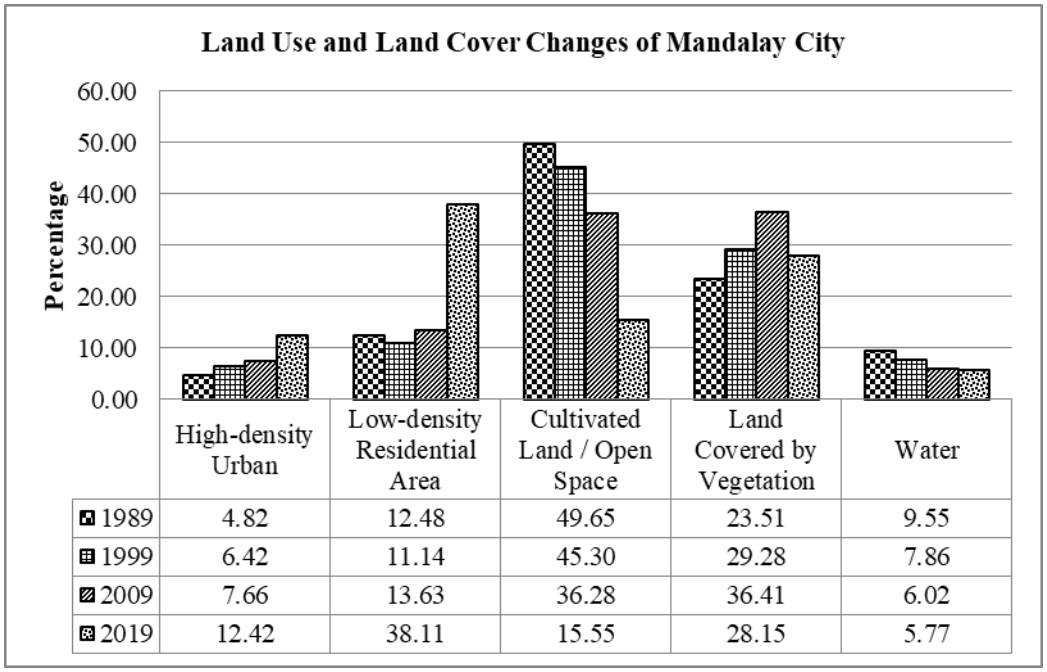
Source: Calculation from Landsat images processing, 1989, 2019

By comparing the analysis of Landsat images of 1989 and 2019, figure 3(a) shows the land use and land cover pattern in 1989, including the area of present administrative boundary of Mandalay City. The large areas of cultivated land/open space and land covered by vegetation could be seen, especially in the eastern and southern parts of the city. These two areas are the largest areas of land, occupying about 73.16 percent of the total area (Table 5). These seem to be cultivated lands and open space with street trees and garden trees. The next largest area of lands at 12.48 percent of the total area is those colored brown, which were judged to be land with a low density of houses. This land was mainly distributed in the eastern and southern suburbs of the city. In addition, in the north and northeast suburbs of the palace, low-density residential land could also be seen, showing hills and a cantonment. High-density urban or built-up areas occupied about 4.82 percent which was concentrated in downtown area. Land under water was 9.55 percent in 1989. These were to be the western part of Ayeyarwady River, the southern boundary of Myitnge River, Taungthaman Lake, and Kandawgyi Pond.

Figure 3(d) shows the land use and land cover maps for Mandalay in 2019. Compared to those in 1989, a large scale decrease of about 15.55 percent in cultivated land/open space areas can be seen (Table 5). After that, cultivated land/open space in inner areas were largely converted into high-density urban built-up areas. The amount of decrease of cultivated land/open space was about 34.10 percent. Thai is, it is seen that a large number of low-density houses was converted from this cultivated land/open space. In the south and southeastern suburbs, two new townships were established in 1992. With the establishment of new townships, many housing plots and large scale industrial estates were constructed through conversion of cultivated lands/open space. Besides, due to the conurbation of Mandalay and Amarapura Township, the township was absorbed into Mandalay City to become greater Mandalay in 2011. Therefore, the city has to become the area of about 220 mi^2 (570 km^2).

Figure 3(d) shows a large expansion of high-densely urban built-up areas in the inner area. The percentage of this type of land use increased from 4.82 percent in 1989 to 12.42 percent in 2019 (Table 5). Furthermore, high-densely built-up lands are seen in Amarapura Townships. Along with the extension and absorption of new townships, several sub centers were also developed in the suburbs. In addition to high-densely urban built-up area,

low-density residential lands remarkably increased mainly through the conversion of cultivated lands/open space in suburban areas. These included construction of new business buildings, low-cost housings and moderate-cost housings, and other urban facilities such as stadium, and supermarkets. Unexpectedly, land covered by vegetation was increased from 23.51 percent in 1989 to 28.15 percent in 2019. This is, due to replantation of road side trees and garden trees, and trees are planted in open spaces which are mostly found in the southwestern and southeastern areas of the City. In the case of water body, the area has decreased form 9.55 percent in 1989 to 5.77 percent in 2019 (Figure 4). That is, the expansion of residential land is approaching to land under water.



	High-density Urban	Low-density Residential Area	Cultivated Land / Open Space	Land Covered by Vegetation	Water
1989	4.82	12.48	49.65	23.51	9.55
1999	6.42	11.14	45.30	29.28	7.86
2009	7.66	13.63	36.28	36.41	6.02
2019	12.42	38.11	15.55	28.15	5.77

Figure 4 Land use and land cover changes of Mandalay city (From 1989 to 2019)

Conclusion

In Mandalay City, the large areas of cultivated land/open space and water body have been converted to high-density urban built up and low-density residential land uses, following the urban expansion policy of the government after economic liberalization of 1988. According to the analysis results of Landsat images from 1989 to 2019, high-density urban built up land increased 7.6 percent and the low-density residential areas have expanded significantly 25.63 percent and land covered by vegetation increased 4.64 percent respectively. In contrast, the large area cultivated land/open space decreased by 34.10 percent and the water body decreased by 3.78 percent. The growth of urban population pressure and government policy has been changing on land use and land cover of Mandalay City. This condition related with the extension of the urban area as the government policy. As urban development works created new jobs and income earning opportunities and as population is ever increasing year after year, the urban land use and land cover of Mandalay City will continue to change and urban land use can be expected to be more intensified in the future.

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