Temporal Changes of Land Use Pattern in Batticaloa Municipal Council, Sri Lanka

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ABSTRACT

Batticaloa, one of the fastest-growing cities in Sri Lanka, is the most vital urban agglomeration that should concentrate on the temporal changes in land use. Seven (7) land use categories, namely commercial, residential, agricultural, scrubland, mangroves, water bodies, and barren land in Batticaloa, have changed by the different purposes of utilization. This study aims to identify the land-use changes of the Batticaloa Municipal Council from 1980 to 2018. Primary and secondary data collection methods were used to gather the data for analysis. Maximum likelihood classification method was used to interpret the maps. The comparison was made to the various land use categories in 1980, 1990, 2000, 2010, and 2018. The temporal pattern of land-use change was presented via a comparison of those periods of land use maps. ArcGIS 10.4.1 and MS Excel 2013 were used to interpret the maps and analyze data. The study revealed that there were major land-use changes identified in the study area between 1980 and 2018. Commercial and residential areas increased by 20.17 ha and 1148.57 ha, respectively. Barren land and agricultural land lost 769.54 ha and 301.99 ha, respectively. The certain extent of rest land use categories was converted into some other land use category during these periods. The effects of human activities are immediate and often radical, while the natural effects are relatively long. However, the recommendations are to the future land use planning, protecting mangrove resources through land-use strategies by the government, community participation, and encouraging the approval of urban planners to make decisions about urban development.

KEYWORDS: *Land use changes, Temporal pattern, Barren land, Planning*

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1 INTRODUCTION

The urban centers of eastern Sri Lanka are mainly located along the coast, which seems to be preferable to the economic opportunities associated with transportation. This region also includes designated entry points, the city center, many public spaces, and secondary public spaces. The three city centers, Trincomalee, Batticaloa and Ampara, represent the administrative districts of these three, namely the districts of Trincomalee, Batticaloa and Ampara. These three centers will remain and will become important growth centers during the next 25 years (Physical Plan of the Eastern Province, 2012). Urban development is within the developed areas between planned highways in these regions. The municipality of Batticaloa is the most significant urban area that concentrates the land use in this area.

Population growth, mainly inland and agricultural development due to modernization during commercialization, is a new development that has a significant impact on changes in land use in this area, although variations in the purpose of its utilization modify different categories of land use in Batticaloa. The land use was categorized as commercial, residential, agricultural, scrubland, mangroves, water, and barren land to identify the changes. Therefore, the urban region of Batticaloa Municipal Council is preferred to explore essential aspects of urban development. This urban growth highly depends on future sustainable development.

1.1. Study Area

Batticaloa is a city located in Sri Lanka within the GPS Coordinates of 7° 43' 51.5892" N and 81° 40' 29.028" E, and the elevation of this area is 8.523m. The total number of population of this area is 93,306 (Statistical Hand Book, 2019)
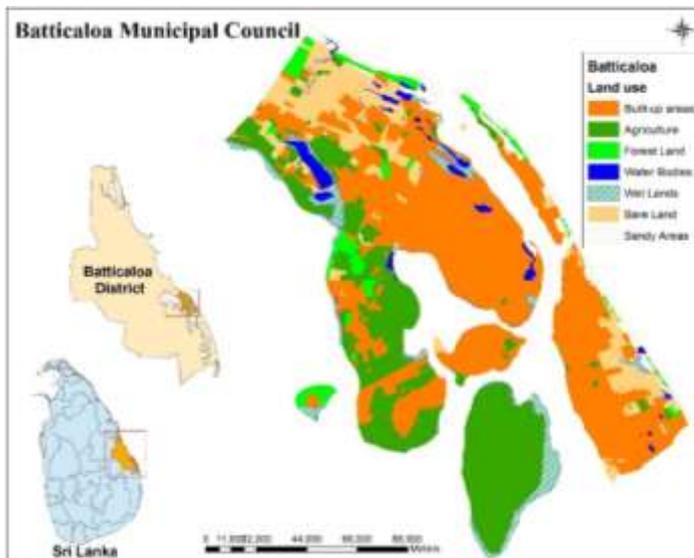

Figure 1: The Study Area (Modified from the Batticaloa MC Profile, 2019)

The Batticaloa Municipality has five (5) separate parcels with inland water bodies (figure 1). These parcels are connected to the bridges for transport. Batticaloa is a clustered city that used the land for various reasons. The land parcels have been connected with different sectors such as fishing, agriculture, small industry and commercial. These different plots have different land uses categories. This area has the cluster's development in each sector such as commercial, recreation and settlement. Thus, this area is significant to find changes in land use.

1.2 Objectives

The main objective of the study is to identify the land-use changes of the Batticaloa Municipal Council area from 1980 to 2018. The specific objectives are as follows;

•To identify the temporal changes in land use pattern from 1980 to 2018.

•To evaluate the urban expansion to the study area between 1980 and 2018.

2 MATERIALS AND METHODS

Primary and secondary data collection methods were used to gather the data for analysis.

2.2.1 Secondary Data Collection

Secondary data were collected from the published and unpublished sources. The following sources of secondary data collection were used in this study;

- Published and unpublished earlier studies related to the land-use changes.
- Reports gathered from Batticaloa Municipality, Batticaloa District Secretariat from 1980 - 2018.
- Printed Topographic Sheet No. 45 was collected to get land-use details from the Survey Generals Department of Sri Lanka.
- Satellite data from Landsat 5, Landsat 7, Landsat 8 imageries from Earth Explorer, USGS from 1980 - 2018.
- Collection from the web about the related documents of land-use changes from 1980 - 2018.

2.2.2 Primary Data Collection

The following primary data collection tools and instruments were used for this study.

- **Questionnaire Survey**

The questionnaire included the structured closed and open questions for gathering information about the past and present land-use effects. The questionnaires were distributed to the people who are farmers, businessmen, and fishermen for the study purpose. One hundred and thirty-five (135) sample questionnaires were collected from the stakeholders using stratified random sampling methods. Of these, 13 samples from agricultural stakeholders, 83 samples from commercial stakeholders, and 39 samples from fishers were collected to the analysis.

- **Global Positioning System (GPS) Coordinates**

GPS was used to find the places to take the ground samples to obtain an accuracy of ground truth. Eighty-nine (89) samples of land use locations were collected using the Mobile GPS tracker to identify the ground truth. These samples were randomly selected based on the grid method from the locations of the different places of land use categories (19 samples from Agricultural, 26 samples from Residential, 08 samples from Mangroves, 05 samples from Water bodies, 07 samples from Commercial, 09 samples from Scrubland and 15 samples from Barren land). According to these samples, the land use locations were identified correctly.

2.3 Data Analysis

Supervised Maximum Likelihood classification method and accuracy assessment methods were used for the map analysis.

2.3.1. Supervised Maximum Likelihood Classification

The Supervised classification method using the Maximum Likelihood classification was used for preparing the land use map of the study area. Seven land use classes were achieved to identify the changes in land use. These land-use classes were analyzed to extract the area through a characteristic change in land use, which are produced from 1980 to 2018 (Table 1). The Batticaloa Municipality area would be obtained from the selected years 1980, 1990, 2000 and 2018, land-use change compared to each indicator.

Table 1: Land use categories

Code	Land use class	Description
1	Commercial	Administration, Shops, Banks
2	Residential	Houses
3	Agriculture	Paddy cultivation, Home garden, Crop field
4	Scrub Land	Scrub Land, Grassland, Wetland
5	Mangroves	Mangroves, Trees
6	Water bodies	Reservoirs, River, Lake
7	Barren land	Abandon land, Sand

Source: Based on the Land use map of Batticaloa, Survey Generals Department of Sri Lanka, 2019

2.3.2. Accuracy Assessment

Eighty-nine training samples for ground truth were achieved based on the data collected as random points in specific locations during the field visits and using known GPS points. Each position has valid class values for the classified and Ground Truth fields. The tool calculates the accuracy for each class as well as an overall Kappa index of agreement. The confusion matrix analysis was used to find accuracy. The errors of omission and commission were computed with the confusion matrix. A Kappa index of agreement and an overall accuracy between the classified map and the reference data were derived using the land use data. The accuracy of the land use classes were determined to achieve the level of precision.

3 RESULTS & DISCUSSION

The high proportion of land use nowadays is allocated for buildings in this area and the next is for agriculture. As the fastest growing city in Sri Lanka, Batticaloa is significant in using urban land use.

The principal categories of land use in the Batticaloa Municipality have been commercial, residential, agriculture, scrubland, mangroves, and Barren land, which were classified to identify the spatial and temporal changes. The following maps (figure 2) show the land use of the study area in 1980, 1990, 2000, 2010, and 2018.

3.1 Temporal Changes in land use pattern

According to Table 2, the total land area was 4171.13 hectares in 1980. Agriculture had more influence in this period, and the second was Residential. Agriculture was covered around 46.28% of the total land, and residential was covered at 22.75% of the total land. There was commercial land at 0.33%, and water bodies were only 0.54%, which is the least of the land use categories. Barren land occupied at 19.08%, which is the third rank of land use in this period (see Table 2).

The land use in 1990 was shown that Agricultural land was held at 47.48% and Residential had the second-highest percentage occupying at 23.07% of the total land area. Commercial land had 0.50%, which was a slight increase compared with 1980. Water land has the lowest percentage occupying 0.19% of the total land area.

According to the survey, changes in land use have been relatively less than in periods of civil war that was gradually changed the pattern for different land uses such as commercial or residential. Rapid population growth was also influenced the residential and commercial lands, which was affecting other land use classes.

Further, the residential lands occupied the highest proportion of the total land area for the study area in 2000. It was covered around 39.13%. Agriculture land took 33.51%, which was a considerable decrease compared to 1990, and it lost much land area to the residential zone. One of the leading causes for this change

was that more people were moving into the study area from various places of the district due to the civil war. Further, the commercial lands had too increased by 0.58% in this period. Water bodies were at 0.23% the least land use in this area.

Table 2: Temporal Distribution of land use in Batticaloa Municipality (hectare)

Category	1980	1990	2000	2010	2018
Commercial	13.77	20.72	24.40	27.98	33.96
Residential	949.00	962.10	1632.13	1953.26	2097.57
Agriculture	1930.32	1980.51	1397.54	1282.29	1160.78
Scrub Land	312.47	223.55	140.86	187.67	229.63
Mangroves	147.34	130.77	198.45	140.09	140.94
Water	22.48	8.05	9.42	6.61	13.48
Barren Land	795.75	845.43	768.33	573.23	494.77

Source: Based on the classified images from Landsat images from 1980 to 2018

The reason for the high growth in residential lands after the 1990s was the civil war in the Eastern Province. The war caused people who lived in many places in the Batticaloa district to migrate to the urban area. For example, people in places like Palugamam, Porativu, Thikkodai, Mandur and Thumpamkeny have moved to the urban area due to security, the economy, education and employment.

According to the survey, construction, road expansion and drainage development are some of the main developments to change land use in the area. The construction of buildings was carried out quickly from the beginning, which is caused by the conversion of urban land use from other categories. Road expansion is one of the main processes that continues in urban areas and destroys roadside vegetation and buildings. Most of the people have more than one house to rent to others that is one of the reasons for the expansion of the building.

In 2010, residential land use was around 46.83%, which is a leading land use in this period, and the commercial area was increased to 0.67%. The increase in the residential area is strongly affected by the agricultural area. The reason was that more people moved to the agricultural areas to obtain services such as education, transportation and health. Agricultural land was around 30.74% and scrubland around 4.50%. Barren land was covered by 13.74%, and water bodies were by 0.16%, which is the least use of land.

Besides, the survey revealed that this area had changed land use, which was agreed with 80% of the population, and they said that human activities are the most important influencing factor in changing the land through the construction and expansion of the road. On the other hand, construction of houses in their garden for

real estate purposes too caused to the land-use changes. 70% of people have no ideas or knowledge about land use and its impact. 30% of peoples' opinion is the government and the individual make changes in the use of the land.

Residential land was occupied the largest proportion of the total area in the study area in 2018. This land is around 50.29%, which is the dominant land use. The agricultural area was 27.83%, which was gradually reduced from 1980. The commercial area had 0.81%, which increased gradually from the beginning. The water bodies were around 0.32%. The

present situation of land use is shown in figure 2(d). The map is shown (figure 2) has revealed that an expansion of built-up areas has been identified for these periods.

The survey revealed that economic activity in this area also affected land use. Rapid urban development increased the commercial area and shaped the changes in agriculture. The commercial area has gradually increased from 1980 to 2018 due to urban expansion. Besides, there were many changes in the agricultural economy, which were reduced to a high level compared to the last three decades.
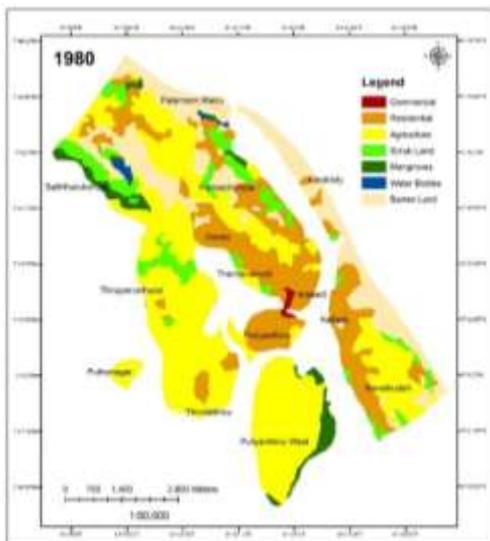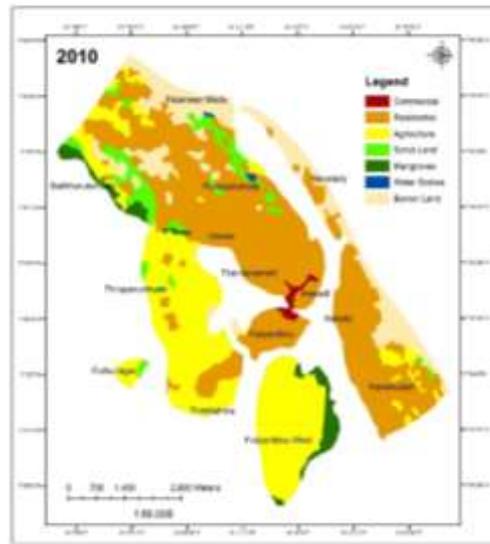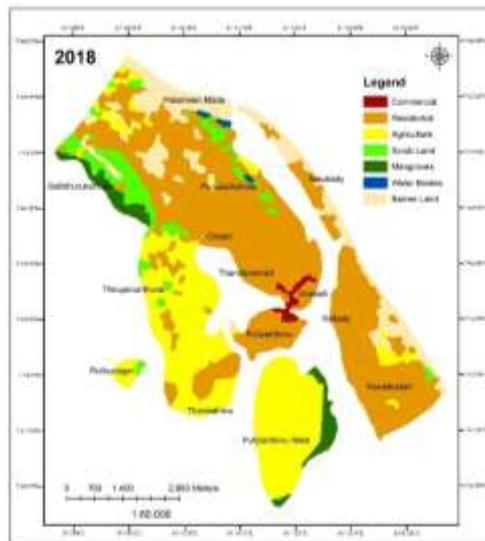

(a)
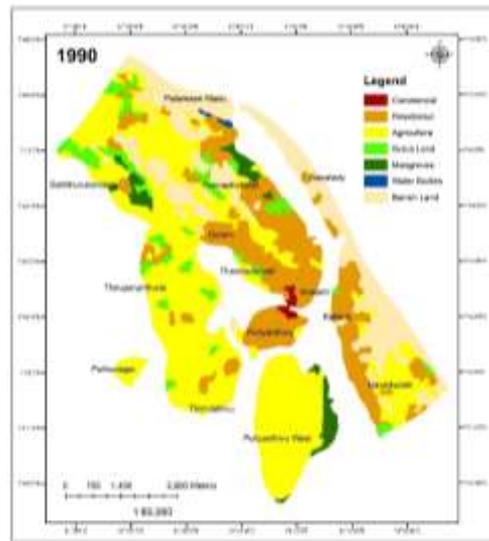
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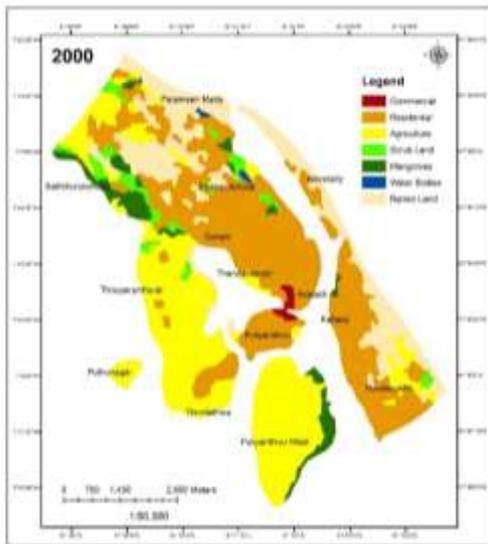
(c)

(d)

(e)

Figure 2: Land use patterns of Batticaloa Municipality (a)1980 (b) 1990 (c) 2000 (d) 2010 and (e) 2018 (Based on the Landsat images, 2019)

3.2 Land Use Change Detection

As indicated, the study established that the change detection was performed based on the classified maps of 1980, 1990, 2000, 2010 and 2018. Table 3 displays changes in land use between 1980 and 2018. Two categories gained land area, and five categories lost land area. The residential and commercial areas increased to 1,148.57 hectares and 20.17 hectares, respectively. Agriculture and wastelands areas were reduced by 769.54 hectares and 301.99 hectares,

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respectively. Rapid urbanization caused an increase in commercial and residential areas.

Table 3: Land-use conversion (ha) in Batticaloa Municipality from 1980 to 2018

Category	1980 Area (ha)	2018 Area (ha)	Conversion (+/-) Area (ha)
Commercial	13.77	33.94	+20.17
Residential	949.00	2097.57	+1148.57
Agriculture	1930.32	1160.78	-769.54
Scrub Land	312.47	239.63	-72.84
Mangroves	147.34	140.94	-6.40
Water bodies	22.48	13.48	-9.00
Barren Land	795.75	493.77	-301.99

Source: Based on the classified image from Landsat images, 2019

The land use classification in 1990 was compared to the 1980s; there was a change that showed both a decrease and an increase in land use in particular. The area categories show an increase in the commercial, residential, agricultural and barren land. The average variation rate of these was 0.20%, 0.23%, 1.03% and 1.47%, respectively. Increased population growth was the main reason for these changes. Many of those who came from different parts of Batticaloa probably utilized much agricultural land because agriculture land was their likelihood. On the other hand, the categories of land use such as scrubland, mangroves and water bodies decreased by 2.15%, 0.42% and 0.35%, respectively. The use of the population for infrastructure development was the reason for this reduction.

When the land use classification in 2000 was compared to the 1990s, the land use categories showed an increase in commercial, residential, water and mangrove areas of 0.08%, 16.15%, 0.04% and 1.64%, respectively. On the other hand, the land use categories such as agriculture, scrubland and barren land show a downward trend of 13.81%, 1.96% and 2.13%, respectively. After 1990, population growth increased considerably to bring about changes in land use. In 2000, approximately 27,443 inhabitants increased during this period from 1981 onwards. This growth was a significant increase in the chosen study period.
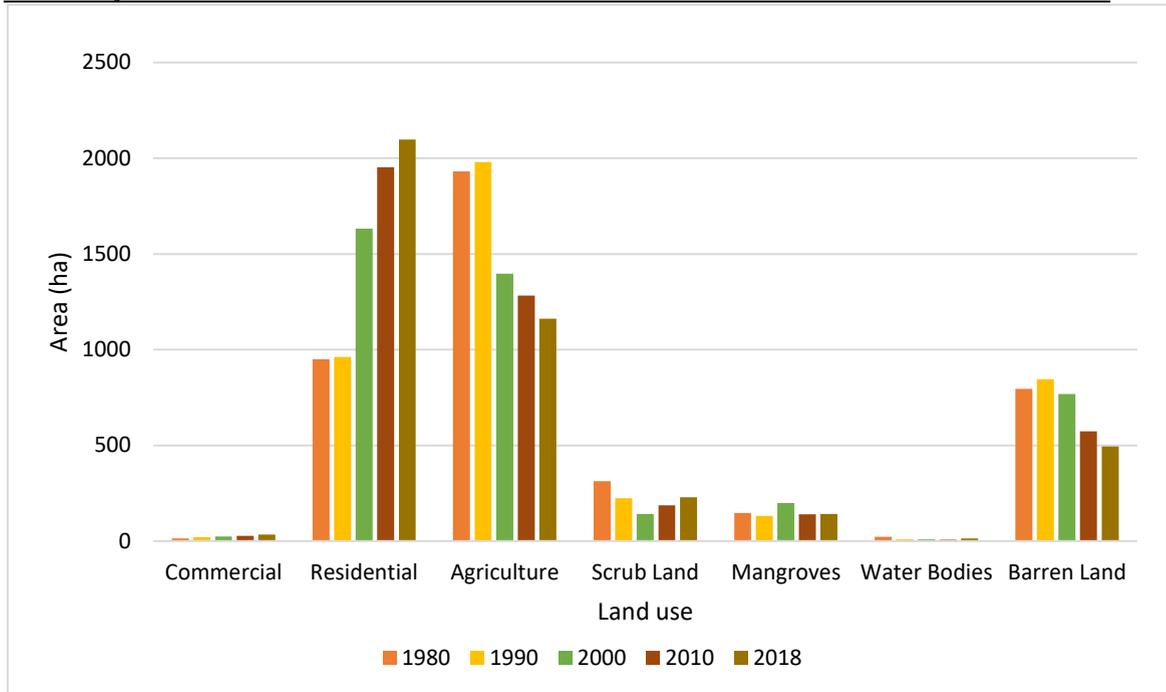
Figure 3: Land-use Changes (ha) in Batticaloa Municipality from 1980 to 2018 (Based on the classified image from Landsat images, 2019)

The land use classification in 2010 was compared with the 2000s. The land-use categories showed an increase in commercial, residential, and scrubland. The average rates for these were 0.08%, 7.60%, and 1.30%, respectively. On the other hand, the land use categories such as agriculture, mangroves, water, and barren land decreased by 2.82%, 1.41%, 0.07%, and 4.69%, respectively. The standard of living was increased the residential land during this time. They had changed their lifestyle through modernization, which resulted in the construction of large houses and single-family homes to show the standard. This increase has had a significant impact on agricultural land and rest categories. For example, Thandavanvely, Puthunagar, and Kallady areas lost their agricultural land due to residential growth (figure 3).

The 2018 land use classification was compared with 2010s map. Changes have shown a decrease or increase in particular land use. The land-use categories showed an increase in commercial, residential, scrubland, mangroves, and water were 0.14%, 3.45%, 1.05%, 0.02%, and 0.16%, respectively. On the other hand, the land use categories such as agriculture and barren land showed the reducing pattern to 2.91% and 1.92%, respectively. Rapid urban growth and infrastructure development such as road, drainage, public and private buildings, playgrounds, hotels, and restaurants have directly influenced the decline in agricultural land and barren land.

3.3 Urban Expansion

The urban expansion was gradually increased from 1980 to 2018. According

to Table 4, it was changed approximately 1168.74 hectares in the 38 years. There was some change in the buildup area during the 1980s. Then, there was a massive increase of around 673.71 hectares between 1990 and 2000.

Table 4: Urban Expansion

Period	Buildup Area (ha)	Changes (ha)	Timespan (years)
1980 - 1990	962.77 – 982.82	+20.05	10
1990 - 2000	982.82 – 1656.53	+673.71	10
2000 - 2010	1656.53 – 1981.25	+324.72	10
2010 - 2018	1981.25 – 2131.51	+150.26	08

Source: Based on the classified image from Landsat images, 2019

The increase of the buildup area was reduced from 2000 to 2010 by 324.72 hectares. This reduction was also taken more effect on urban change. Besides, compared with the previous decade, the buildup area has been partially reduced this extent. However, urban growth was increased by 1018.48 hectares from 1980 to 2010 (Table 4). Every ten years from 1980, various changes occurred in the study area and showed the growth of rapid urban development. After 2010, the buildup area has reduced the extent which showed the presence of vertical development starting from this period. This development may be the cause for the less growth of the buildings after 2010 periods.

The accuracy of the land use pattern has been identified using classified land use maps of the study area. The analysis revealed that producer accuracy and user accuracy were varied during the selected periods.

The overall accuracy of land use in 1980 was 77.5%, and the Kappa Index Accuracy is 0.71875. The reason for the low accuracy level was the satellite image that has low resolution during this time. Overall, there is a good agreement in the land use classification. The overall accuracy of land use in 1990 is 80%, and the Kappa Index Accuracy is 0.74946. Overall, there is good agreement on land use. The overall accuracy of land use in 2000 is 88.75%, and the Kappa Index Accuracy is 0.85827. In the overall analysis of accuracy, there is an excellent agreement on land use.

The overall accuracy of 2010 land use is 95 %, and the Kappa Index Accuracy is 0.93632. The overall analysis of accuracy, there is an excellent agreement in the land use. The overall accuracy of land use in 2018 is 92.5%, and the Kappa Index Accuracy is 0.90367 (Table 5). The reason for the high accuracy level in 2000, 2010 and 2018 is the high resolution of the satellite image which gathered during these periods. In the

overall analysis of accuracy, there is a firm agreement on land use.

Table 5: Land use accuracy from 1980 - 2018

Category	1980	1990	2000	2010	2018
Overall Accuracy	77.50	80.00	88.75	95.00	92.50
Kappa Index Accuracy	0.71875	0.74946	0.85827	0.93632	0.90367

Source: Based on the classified Land use maps, 2019

The error of commission in 1980 occupied around 100% in water bodies and 37.93% in agriculture lands. There are no errors that occurred to the commercial and barren land. The errors of omission were 50.0% in water and 33.33% in scrubland. There was less omission for residential, agriculture and mangroves lands as 11.76%, 10.0% and 12.50% respectively. The user accuracy was 62.07% in agriculture and 66.67% in scrubland as a low when the overall accuracy was 77.5%.

In 1990, the error of commission occupied around 50.0% in water bodies and 32.14% in agriculture lands. There were no errors that occurred to the scrubland and mangroves at 0%. The errors of omission were 50.0% in scrubland and 28.57% in the commercial lands. There was no omission for agriculture and water bodies. The producer accuracy was 50.0% to scrubland and 66.67% to barren land, which is the low accuracy of the land use. The user accuracy was 50.0% in water bodies and 66.67% in agricultural land as a low when the overall accuracy was 80%.

In 2000, the error of commission occurred around 30.0% in mangroves, 15.0% in agriculture lands, 11.54% in residential lands. There was no commission to commercial, scrubland, water, and barren land. The errors of omission were 66.67% to scrubland and 14.29% to commercial land. There was no omission for residential and water bodies. The producer accuracy was 33.33% in scrubland, which is the low accuracy of the land use. The user accuracy was 70.0% in mangroves, which is a low accuracy when the overall accuracy was 88.75%. An overall analysis of accuracy, there is an excellent agreement in the land use.

In 2010, the error of commission occurred around 10% to agriculture lands and 7.14% in residential lands. There is a commission to other categories. The errors of omission were 16.67% to scrubland and 5.26% to agriculture lands. There was no omission to other categories. The producer accuracy was 33.33% to scrubland, which is the low accuracy of the land use. The user accuracy was 70% to mangroves, which is low accuracy when the overall accuracy was 95%. Overall, there is a very strong agreement of accuracy in land use.

In 2018, the error of commission occupied around 12.90% to residential

areas, 11.11% to mangroves, and 5.88% to agriculture lands. There was no commission to rest categories. The errors of omission were 33.33% to scrubland and 14.29% to commercial lands. There was no omission for residential, mangroves, and water bodies. The producer accuracy was 66.67% scrubland, which is a low accuracy of the land uses, and the user accuracy was 87.10% to residential lands, which is a low accuracy when the overall accuracy was 92.5%. The low resolution of the satellite images was the reason for occurring more errors in the land use classes. Overall, there is an excellent agreement of accuracy in land use.

4 CONCLUSION & RECOMMENDATIONS

The detection of urban land-use changes in the Batticaloa Municipality area has become significant for local authorities in the process of urban planning. Thus, this study is carried out to identify the spatial and temporal changes in land use in Batticaloa Municipality during 1980 to 2018 through spatially identify the temporal and spatial pattern of changes in land use and identify the relationship in between the land use categories and population growth. Changes of spatial extent in different land-use classes interrelated with land-use transformations and statistical data generated. This study will assist in enhancing current land management practices and future policy formulations.

The consequences of the land-use change during the past 38 years in the study area are very significant in this study. The temporal pattern of land use changes presented via compared the five-time periods of land use maps. The analysis revealed that commercial and residential land area increased and barren land and agricultural land have been lost the land during 1980 to 2018. The certain extent of a particular land use category converted to some other land use category.

Some land-use showed increasing change during the first-period comparison and showed decreasing change during the second comparison, which was agriculture and barren land. Overall comparisons of the study, agriculture land was decreased the total land area, and commercial, residential lands were increased the land size. However, commercial, residential, and scrubland areas were displayed a similar pattern of change, which scrubs land showed decreasing change pattern and commercial, residential lands exposed increasing change pattern during the two periods of comparison.

The study implies that population pressure is believed to be one of the major driving forces for the changes of land use in the Batticaloa Municipality. Hence, in the case of this analysis, the primary driving force to changes in land use is increased population, urban growth, and public needs.

The following recommendations are given based on the study.

- Awareness programmes should be conducted to the community such as school level program to the Ordinary

Level and Advanced Level students, women club, Lions club in Batticaloa Municipality about the misuse of land use.

- Neighbourhoods should be protected from inappropriate residential, commercial, and institutional encroachment by the municipality.
- The public should be promoted to grow the vegetation at home and motivated them through the awarding in Environmental day or Wetland day and provide the trees such as coconut trees by Coconut Cultivation Board, mango tree by the Department of Agriculture.
- Participation of the community, urban planners, environmental specialists, and getting their approval is highly required before urban development decisions to avoid conflicts.
- The designated areas should be concentrated as seem now, and do not allow to take the form of strip development along the major roads in the planning area like commercial shops, houses.

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