Change Detection Study of Lae Urban, The Second Largest City of Papua New Guinea using Multi-temporal High Resolution Remote Sensing Data

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ABSTRACT

The urban areas are changing due to various human activities, natural conditions and development activities. According to the user requirements, updating of land use map at a suitable frequency is required by various line departments for pursuing their developmental activities. Identifying changes in urban landscape is vital for this development purposes. Analysis of land use changes between 2006 and 2012 using very high resolution remote sensing images of LIDAR DATA, othorphoto (2012) and Quickbird satellite image (2006) was done on the study. The objective of the study is monitor the land use/land cover changes in Urban areas and identifying hotspots of land cover changes using multi temporal Remote sensing data and also studying relationship between the burgeoning human pressure on land use/land cover and its impacts on the Urban habitats. In this study, land use changes have been detected by digitizing on very high resolution airborne LIDAR and satellite image. Finally effort was made to predict the changes in urban sprawl and accompanying land use / land cover changes. Monitoring of land use/ land cover changes linked to urban sprawl would help to plan development activities such as major schemes in accordance with users' requirement.

Keywords

Change Detection, GIS, Lae Urban, Remote Sensing, Urban Change

1. INTRODUCTION

With the rapid increases in the development of Morobe Province in Papua New Guinea, its capital Lae is currently facing many urban related problems in regards to Land availability. Lae, being the country's largest industrial hub has vast manufacturing, and diverse range of industries including private and public business firms, institutions and surrounded by settlements in almost entire corner of the city. Currently the city is expanding, due to continued influx of the settlers and developers coming from various parts of the country as well as overseas. Also the city is located at the gateway to highlands highway which connects large land mass of Momase and highlands regions. This poses strain on the available land. That is industries and business firms are increasing along with settlements and institutions.

With the passage of time the available land mass are slowly eating up due to continues expansion of industrial, commercial, institutional, residential zones as well as public utilities and transport zones. The influx of population in urban area put more pressure on these activities. In such case, knowing how much land mass is used up by certain activities through time are equally important as it generates basic ideas of change detection studies.

Remote sensing is a proven technology that is effective for mapping and characterizing cultural and natural resources [1,2,5]. Processing of multi-temporal images and change detection has been an active research field in remote sensing for decades [3].

However, there are certain problems in modelling urban land use changes. One of the most frequently occurring problems in every urban center has been the lack of spatially detailed data. GIS and Remote Sensing have the potential to support such models by providing data and analytical tools for the study of urban environments. Urban land cover type associated with their aerial distributions are fundamental data required for a wide range of studies in physical and social sciences as well as well as for planning purposes [4].

Geographic Information Systems (GIS) and Remotes Sensing technologies can be combined to detect and most importantly to control changes in urban areas. This method is proven to be fast and efficient method than traditional methods of surveying the urban environment.

Most importantly urban land use characteristics were combined with some plans aiming at urban developments and thus it is proposed for future land use decision to local

authorities. Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of urban planning. Today, with growing population pressure, land degradation is an ongoing issue and to minimize this, designing better urban plan with proper GIS analysis tools is of paramount importance.

1.1 Significance of the Study

This study is equally important as it offers the most important options of using GIS and RS technologies to design urban planning basing on change detection analysis using very high spatial resolution data. The spatial analysis on the land use/land cover of urban area would provide valuable information and increase the understanding of making better urban planning. This study will essentially help researchers to carry out research and identify some of the factors that have tampered with the aesthetic look of Lae urban area and basing on these findings, the researcher has drafted the strategic urban planning that will revert the beauty of the city in the years to come. It is also important to note that over a period of time, changing population and commerce needs often necessitate concomitant zoning plan. With Remote Sensing and GIS we need to understand how cities sprawl and then plan and protect it aesthetic beauty.

1.2 Objectives:

1. To identify Land use category of Lae urban area
2. To identify types of changes taking place in Lae urban area over time.
3. To design urban development plan map based on change detection analysis.

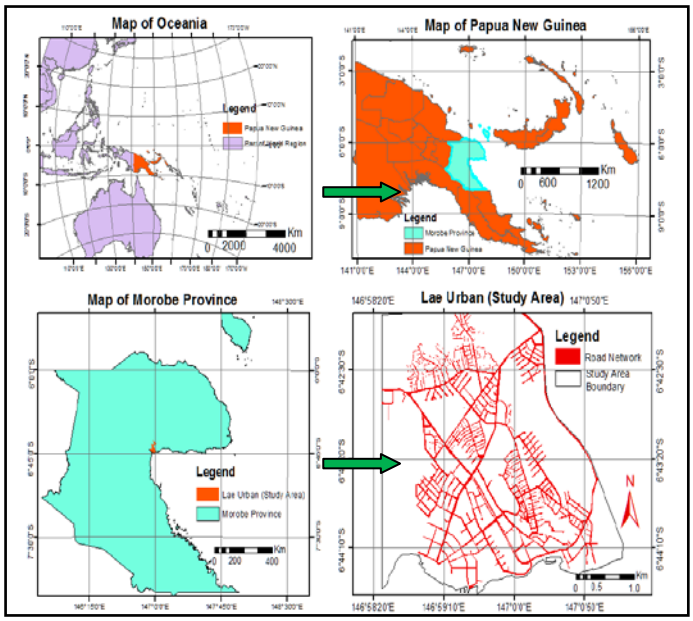
1.3 Study Area

The study area is Lae urban centre, which is the main head quarter of Morobe Province and it is the second largest city of Papua New Guinea. It is located at the start of the highlands highway, which is the main land transport corridor from the highlands region to the coast and near the delta of the Markham River. Lae is the largest cargo port of the country and is the industrial hub of Papua New Guinea. The city is known as garden city because of its greenish vegetation and is the city of the country's premier University of Technology.

Like all other urban centres in Papua New Guinea, the growth of Lae City marks the originality of urban growth which resulted from the intrusion of urbanization brought about by early explorers and missionaries in the 16th and 17th centuries. In the earlier days transformation/ urbanization occurred without any proper planning mechanism and much of the urban functions were dictated by the early road networks established primarily for accessibility to mineral exploitation and missionary convents.

In global scenario, Lae is located along the tropical region in the Southern Hemisphere. It has Latitude and Longitude of 06°42'24" S and 146°59'44"E, (WGS 84 coordinate reference system). It has an elevation of above 8 meters (25 ft) above Mean Sea level (MSL). (Figure 1.3.1. Location Map)

Figure 1.3.1: Study area/location map



2. DATA AND METHODOLOGY

In order to do change detection study of a particular area, several remote sensing images of the same area captured at different years are needed. For the case of this research study, the data used was high resolution Quick bird satellite image at 3.9 meter spatial resolution of Lae city captured in 2006. Thus from there the study area (Part of Lae Urban) was cropped. Every individual feature of the study area was digitized to extract vector layer. The Second data used for the study area was LIDAR image (othophoto) of Lae city captured in 2012 at 20 cm spatial resolution. Again the study area was cropped and each and every individual features of the study area was digitized to extract vector layers. The two types of data were collected for different year (2006 & 2012) and were of 6 years intervals. The data collected was rectified and the study area was cropped using ERDAS Imagine 8.5 and was geo-referenced to WGS84 with projection system UTM zone 55 southern hemispheres. That is once different temporal maps are overlaid after digitization the differences can be found out. Upon this GPS (global positioning system) was used for verification study.

The digitization procedure was carried out using MapInfo Professionals 10.5 software. After extraction of the vector layer using MapInfo software, individual vector file in tab

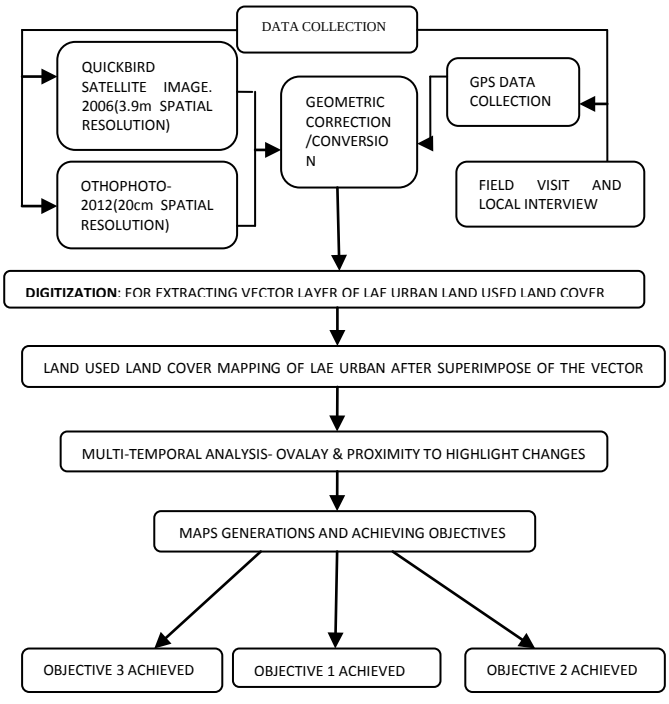
format was converted to shape file which is readable by ArcGIS 10. Thus ArcGIS 10 was used to perform overlaying analysis and proximity analysis of land use land cover of part of Lae urban and the changes or extent of the city was highlighted.

As was discussed above, the land used / land cover of the study area was extracted throughout digitization procedure and was ovalaid on one another for change detection of Lae Urban. Changes of city was mapped and analysis was done to find out the land availability for development or residential use and also to assess the rate of increase in population and development. The following data and methodology were adopted.

2.1 Data Used

data type	scale/resolution	source of data
Quickbird satellite image-2006	3.9m spatial resolution	Lands and physical planning Department
othophoto(LIDAR) data-2012	20cm spatial resolution	Lae city council office
Data from local interview and GPS		

2.2 Methodology



3. RESULTS AND DISCUSSION

This study was carried out with the help of remote sensing data and GIS software namely; ArcGIS 10.0 and MapInfo Professionals 10.5. All data collected were individually processed and analyzed in a GIS environment. After comparing two output maps (LU/LC maps), the changes in Lae urban area was identified and analyzed. The area calculations for each and every LU/LC class indicate impressive changes that have occurred over the six years period (2006-2012). The comparative results for individual classes of two generated output maps were shown in Table 3.1 with their area difference in Hectares as well as in percentages. Based on this analysis, the proposed planning map was generated with the recommendation for implementations period. The planning exercise is purposely carried out to minimize some of the problems that are occurring in Lae urban due to rapid urban expansion. The detailed results in terms of maps and Statistical representations of change detection studies are discussed below.

3.1 Land Use Land Cover of Lae Urban (2006-2012)

The main emphasis of this study is particularly on land use/land cover category identification and change detection from 2006-2012 using High spatial resolution imageries (Quickbird and Lidar data). Based on the objectives of this study, different land use categories were identified through manual digitization process using two very high spatial resolution imageries. Since both images are of high spatial resolutions, they provide clear and detailed features which make it easier for digitization activities. Hence, the accurate digitization were carried out to classify each and every feature into assigned class names. At this stage visual interpretation was done all over the study area to confirm every digitized feature is categorized into corresponding classes.

To have familiar idea on land use status of Lae Urban Centre, several important categories were identified and used for Land Use/Land Cover map preparations. The important categories which were identified through field survey at ground level investigation were used for land use classification. There are total of eight (8) categories identified, namely; public & academic zone, industrial zone, residential zone, sports and recreational area, road, water body and open land with Vegetation_bareland.

Almost all eight classes mentioned above were digitized from two high resolution images (2006 Quickbird and 2012 Lidar). However there have been massive changes found in 2012 images, indicating greater expansion of Industrial and residential area and decrease in open land with respect to increase in other land use land cover. The results for each category were given separately below.

3.1.1 Land Use/Land Cover identification for the year 2006

The LU/LC classification of Lae urban area for the year 2006 gives the clear idea of different land use practice. During the process of digitizing, classifying and area calculation, it was found out that the highest category of LU/LC is open space area with vegetation and bare land, which covers the 627.00 hectares and it shares 28.76% of total land used or land cover. The total land area calculated after spatial analysis in ArcGIS is given as 2180.32 hectares. Beside this category Residential area covers the second highest portion of land mass with 571.00 hectares or 26.19% of total study area. The remaining categories are road, industrial zone, water region, public and academic zone, sports & recreational area and commercial centre which share 10.81%, 9.31%, 9.19%, 8.85%, 4.01% and 2.88% respectively. (Table 3.2.1). This scenario shows the land use/land cover status of Lae urban in year 2006.

3.1.2 Land Use/Land cover identification for the year 2012:

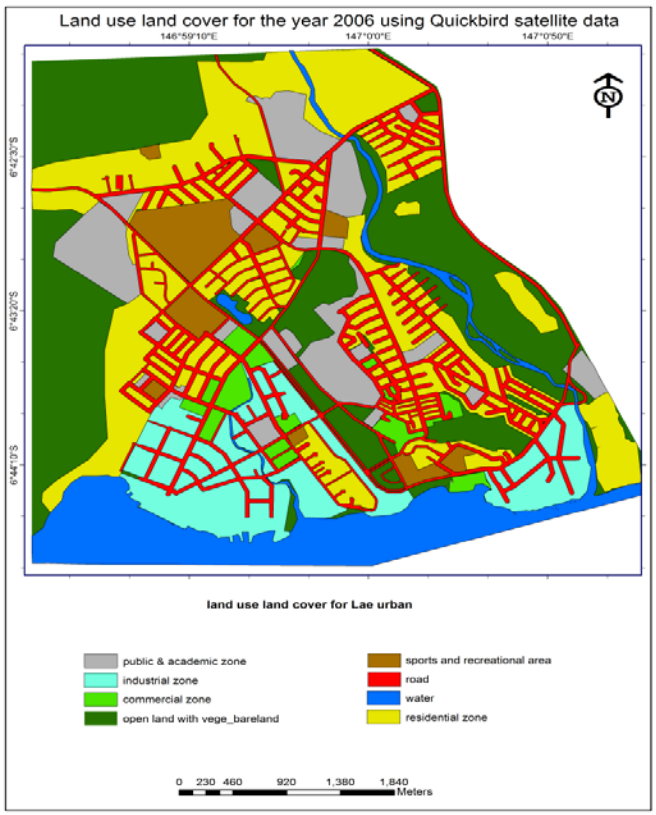
The similar land use/Land cover categories were obtained from the 2012 classification. However the total land mass covered by each category was completely different. This could see either increase or decrease in land mass covered by each class due to increase or decrease of development, population, business firms and many other. Important indication here shows gradual decline in open land mass due to urban expansion.

Here the LIDAR imagery based quantitative data of the year 2012 shows that, residential area has highest dominant land use category which shares 26.93% of the total land of the study area. Out of total 2180.32 hectares of land, second highest share of land use is Industrial Zone which shares 18.46% of the Land. The remaining land use categories are open space, road, water region, public and academic zone, sports & recreational area and commercial centre which shares 14.91%, 11.48%, 11.81%, 10.65%, 3.31% and 3.08% respectively (Table 3.2.1). This scenario shows the land use/land cover status of Lae urban in year 2012.

Thus from these comparison as stated above, it can be concluded that there was a considerable change in Lae urban between year 2006 and 2012. How much each LU/LC increased or decreased have been summarized in table 3.2.1.

Both LU/LC map of the area for year 2006 and 2012 was generated and these are shown below. It can be viewed directly on the map what has change and what is not.

Figure 3.1 Land Use Land Cover for the year 2006 using Quickbird Satellite Data

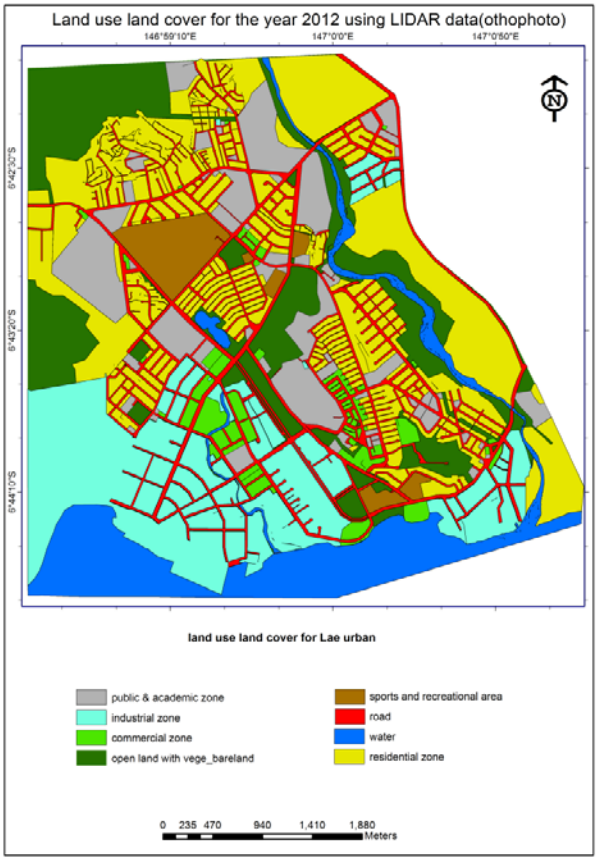


3.2 Means and ways in which land use land cover of the study area have changed between year 2006 and 2012.

From the study that was carried out it was found out, that several LU/LC have been changed between year 2006 and 2012. Various reasons were found out behind this study for the LU/LC change of the Lae urban.

For the case of industries, it can be seen that in 2006 the total of land used by industries was 202.9 hectare, however the figure has nearly doubled to 402.4 hectare in 2012. Thus it can be inferred due to the blooming economy of the Papua New Guinea in spite of recession in developed countries. PNG is a home of different kinds of minerals and raw product. These have attracted exposed of the industries in the city.

Figure 3.2 Land Use Land Cover for the year 2012 using LIDAR Data



These practices have lead to relocation of settlements and residential areas as can be confirmed on the map as well as from the area. Calculated values provided table 3.2.1, that is there is a substantial changes in land use or residential purposes between year 2006 and 2012. In 2006 it was 571 hectare and because of increase in industries the settlement were relocated and some have a permanent migration. So the land used for settlements has little bit increased to 587.2 hectare in year 2012. For the public place and institutional zone, the area has increased from 193 hectare in 2006 to 232.3 hectare in 2012. This is simply because of technology is increasing nowadays and people are demanding for more academic places, police force to control crime, rural people to market their vegetables, etc.. For the land cover, open land with vegetation_bareland has decreased From 569 hectare in 2006 to 324.85 hectare in 2012. Thus this has clearly highlighted that the Lae urban is increasing rapidly. Commercial centers are also increasing rapidly. This can be confirmed in the table 3.2.1. For the road networks, the land used by road network in 2006 was 235.7 hectare however this has increased to 250.4 hectare in 2012. The reason behind this is increase of industries and commercial centers. Moreover the study area is surrounded by two rivers and they have slowly eaten away the land availability up to 2012. Thus when the change detection study was done, it was found out that the land used by water area in 2006 was 200.4 hectare, however the land used by water has increase to 243.7 hectare in 2012. This has proved that there has been a erosion activity taken place that have eaten away the land availability.

Table below summarized everything that was discussed above relating to the change detection study of the Lae urban that was done. The area in hectare and in percentage for each land use land cover was calculated using ArcGIS 10.1(calculate geometry and attribute table). All result was tabulated as shown above. From this table and the map that was generated, the increase and decrease of each land use land cover was highlighted with identification of how much each features have increased or decreased. From these figures, the proposed planning of Lae urban town was done.

Figure 3.2.1: Percentage changes of each land use land cover

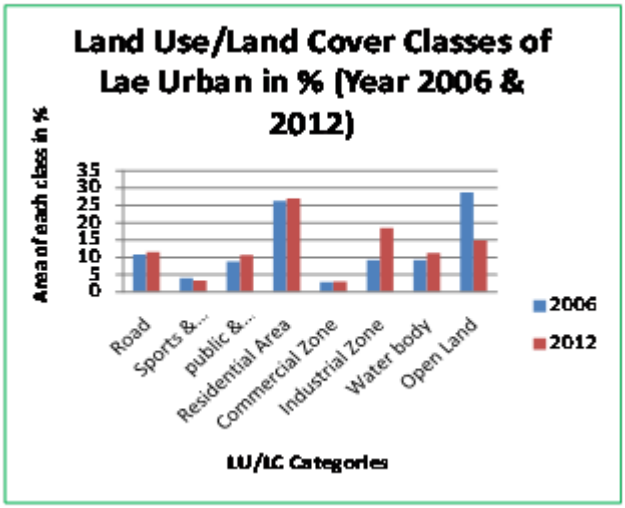


Table3.2.1: Area in hectare and percentages of each land use land cover

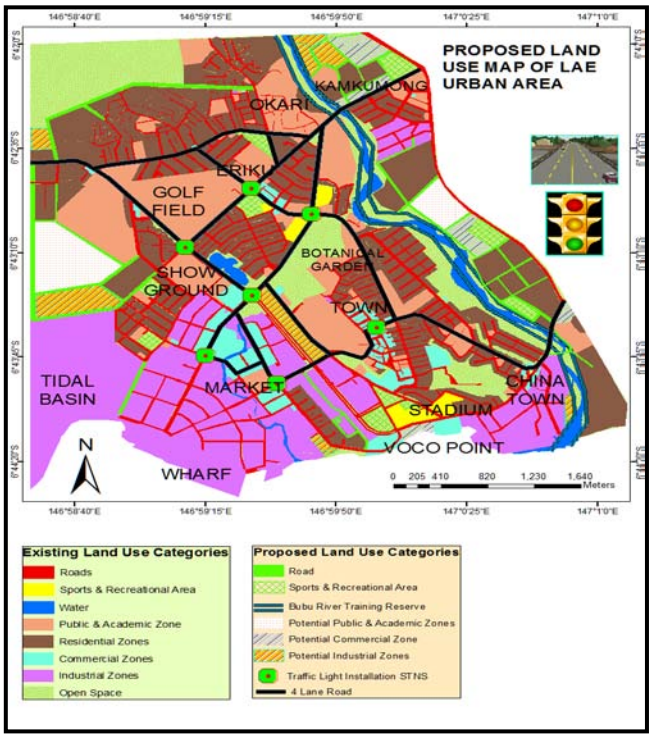
SL No.	Land Use Land Cover	2006 (Hectare)	%of Area	2012(Hectare)	%of Area	Change Area Between (2006-2012)	% of Change Area (2006-2012)
1	Roads	235.7	10.81	250.4	11.48	(+)14.7	(+) 0.67
2	Sport and Recreational area	87.53	4.01	72.24	3.31	(-) 15.29	(-) 0.7
3	Public & academic zone	193.0	8.85	232.3	10.65	(+)39.3	(+) 1.8
4	Residential Area	571.0	26.19	587.2	26.93	(+)16.2	(+) 0.74
5	Commercial zone	62.79	2.88	67.23	3.08	(+)4.44	(+) 0.2
6	Industrial zone	202.9	9.31	402.4	18.46	(+)199.5	(+) 9.15
7	Water	200.4	9.19	243.7	11.18	(+)43.3	(+)1.99
8	Open Space with vegetation_bareland	627.0	28.76	324.85	14.91	(-)302.15	(-) 13.85
	Total	2180.32	100	2180.32	100		

3.3 Proposed Land Use planning for Lae Urban

From the result that was generated above it was found out that Lae urban is increasing. Due to increase of the city there must be proper decision and planning for future development. These can help the city council or government to know how and where to increase the city forward to generate and increase the economic activity of the country. Thus GIS is the tool for planning and decision making and hence was the motif of current study.

Figure 3.3.1 below highlights the proposed planning of the city. The all idea behind proposed plan is to cater for growing economic boom and expansion of urban area. This was planned based on land use land cover of the year 2006 and 2012, for how the changes have occurred.

Figure 3.3.1 Proposed Land use map of Lae urban area.



4. RECOMMENDATIONS FOR IMPLEMENTATIONS OF PROPOSED PLAN

It is clearly seen from the two generated maps and calculated results from the above table that over the last six years period, many changes have occurred. There is clear indication of rapid urban growth, which resulted in using up of freely available lands.

Urban population is also growing at an alarming rate, this has a significant impact on the city which resulted in creating demand for more houses, betters roads, more schools and hospitals and betters services. Hence implementing above proposed plan within a short period of time, say would make more sense. If it takes longer, then there is possibilities that city will be over-crowed and some of the chronic problems faced in Lae city now like traffic congestion will become worse and unmanageable if the implementation of proposed plan is delayed further.

5. CONCLUSION

Since mid 1980's, Lae has been experiencing rapid urban growth due to natural increase and urban migration, and in recent years much of the growth has been done in unplanned urban areas. This has created many problems in and around the city of Lae.

This study mainly focuses on Land Use /Land Cover in Lae urban areas using remote sensing data and GIS technology. The results from two generated LU/LC maps clearly shows that there were significant changes occurred during the period from 2006 to 2012.

The result has clearly shown that much of the past freely available land has been eaten up mostly by industrial activities and residential buildings. On the other hand it has been noticed that there is decrease in Open space land.

This study proves that integration of GIS and Remote Sensing technologies is effective tool for urban planning and management. It helps us to better understand how urban area has grown over the certain period of time. By carrying out change detection analysis in GIS environment we are able to design better urban planning that will have positive impact on its developments.

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