# Urban Landscape Dynamic Analysis on Mandalay City, Myanmar

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## Abstract

Cities across Asia are developing and expanding at an unprecedented rate. As expansion is typically left up to market forces and the private sector, local and national level planning is often overlooked as developers search for development sites and land, which can ultimately stimulate the economy of the city and entire region. As Mandalay City has a history with various disasters, this Land Cover / Land Use (LCLU) will provide both opportunities and challenges for resilience urban action plan and planners. In this study, urban land cover pattern derived from Landsat TM/ETM satellite data for two decades (1998–2014) using Google Earth Engine. These maps show that built-up increased by 5288.40 ha in first time period (1998–2002) and 2695.77 ha during next period (2002–2014) of study. Three major land covers classes mapped are; (i) built-up, (ii) water and (iii) other or non-built-up. The two-time maps were compared to qualitatively and quantitatively capture the dynamics of urban expansion in the city. Along with urbanized area and urban footprint maps, the new development areas during the study time periods were also identified. The assessment on new development areas consisted of three major categories of developments, (i) infill, (ii) extension and (iii) leapfrog. It was found that during urban growth in 1989 - 2002 period, massive reduction of drainage capacity due to extension and in fill. Large portion

of flood built-up area consists of informal settlement along the river (ribbon) and on the sand dunes.

## Introduction

As both Mandalay City and Myanmar have a history with various disasters, the new urban growth information will provide both opportunities and challenges for urban and regional planners. Development sites can be implemented on land, which is prone to natural disasters or utilize unsafe materials for building construction; both actions result in increased disaster risk. Cities also offer employment opportunities, which result in extensive rural-urban migration for which often no sufficient housing capacity. This often leads to unplanned and unregulated housing referred to as informal settlements, shanty towns or "slums". Typically, these areas are established on land that has been environmentally degraded or is vulnerable to natural hazards. The new development also encompasses the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air. Land Cover Change Detection (LCCD) is a significant tool that can be used to increase resiliency to natural disasters. LCCD enables municipalities and communities to make knowledgeable decisions about how to use its land in ways that are beneficial to current and future residents.

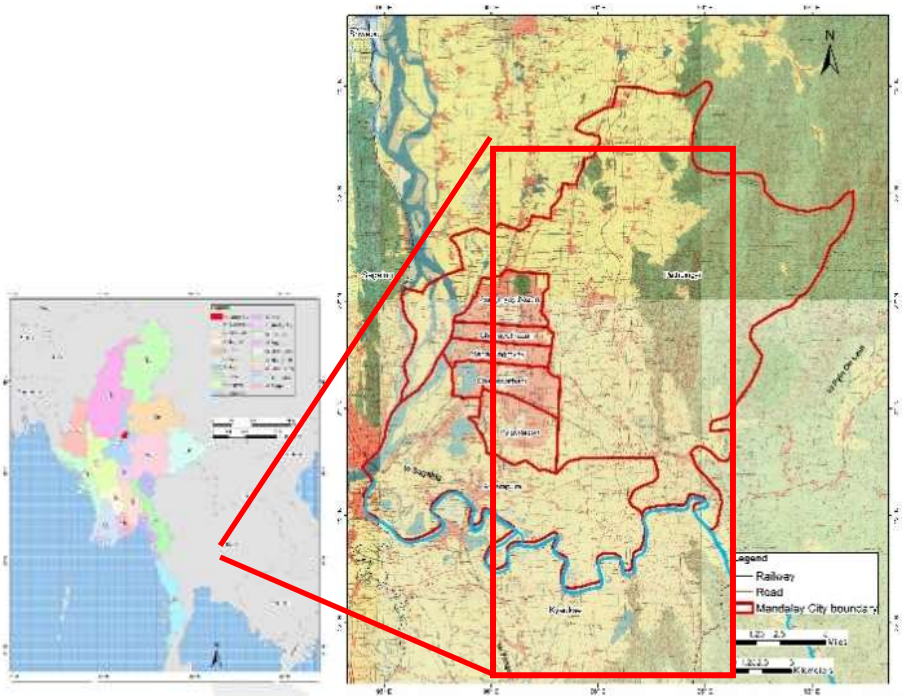
In recent years, Mandalay City has been rapidly developing without due consideration of the adverse impacts on the environment and the water cycle. Urban expansion alters the natural landscape, land uses and land cover, for example by changing water flows and increasing impermeable areas, thereby adding to the flood hazard problem (Satterthwaite 2011). High levels of urbanization in river flood plains and other areas of catchments might also change the frequency of occurrence of flooding. Urban Land Use Planning (ULUP) is a significant tool that can be used to increase resiliency to natural disasters. ULUP enables municipalities and communities to make knowledgeable decisions about how to use its land in ways that are beneficial to current and future residents, along with buildings and infrastructure integrating disaster risk

information into ULUP allows for consideration of potential hazards when developing plans and regulations and for planner and policy makers to make choices to protect population, property and other assets from risk. Mandalay City was chosen as a pilot site in order to understand how the current context of local land use planning can implement disaster risk information due to its size, location, history with disasters and projected future growth.

## Study Sites

The study area, Mandalay City, is located at the center of Myanmar and is the second largest city hosting the biggest industrial and commercial center in Central Region of Myanmar. The built-up areas in Mandalay city can be classified into two regions: Mandalay is bounded by the Ayeyarwady River in the west, Shan Mountainous area in the east and the Myint Nge River in south (Figure 1). The city population has increased from about 500,000 in 1998 to over a million in 2002 and to 1.4 million in 2014. The population is expected to reach 2.86 y 2030. Apart from increasing size of the urban area, the city is also witnessing the problem of haphazard and unplanned growth resulting in problems to provide basic amenities like water supply, sanitation, transport, housing etc.

Figure1. Study area




## Methods

In order develop appropriate policies and plans to limit environmental hazards and limit disaster risk, it is essential to develop precise land use and land cover maps. If (uncontrolled) urban growth will be one of the main drivers of future disaster risks, it is important to obtain quantitative data about the magnitude and spatial distribution of the actual growth. Furthermore, such data is essential for the development of future growth scenarios since they are typically based on extrapolation of past growth trends.

The prime step of this methodology was land use and land cover (LULC) characterization which was done using water index and built-up index in google earth engine. Three major land cover classed mapped were; built-up, water and other. Two indices were used to map built-up and water. The rest area was categorized as the 'Other' class. Built-up index (Zha et al. 2003) was computed to map out built-up areas from the remote sensing data. Band 5 (MidIR) and band 4 (NIR) of Landsat Satellite Image were employed to compute this:

$$\text{Built-up Index} = \frac{\text{Band5} - \text{Band4}}{\text{Band5} + \text{Band4}}$$

Another index used was Water Index (WI) that efficiently maps out water covered areas (Parent et al. 2008);

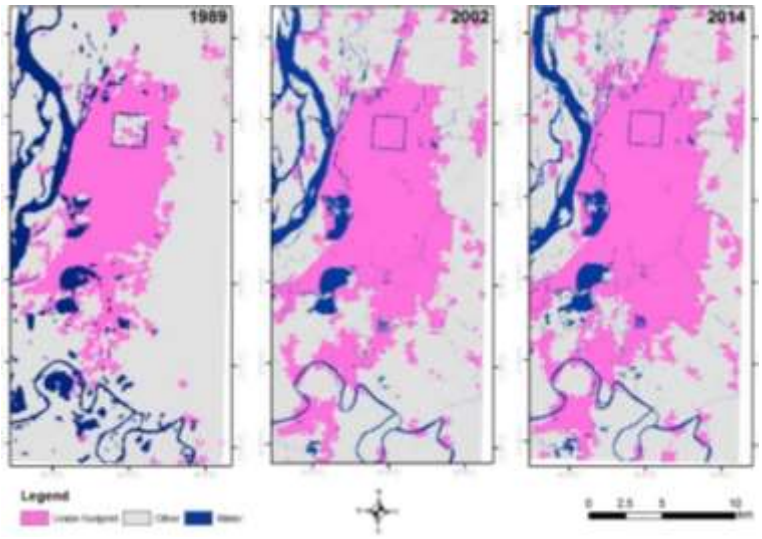
$$\text{Water Index} = \frac{\text{Band1} + \text{Band2} + \text{Band3}}{\text{Band4} + \text{Band5} + \text{Band6} + \text{Band7}}$$

After developing built-up and non-built-up area map, Urban Landscape Analysis Tool (ULAT) (Parent et al, 2008) was used to characterize patches built-up areas based on their spatial characteristics. Furthermore, the Urban Footprint (UF), Urbanized Area (UA) and New Development (ND) were calculated based on the urban landscape analysis of maps covering two base years.

## Land Cover and Land Use (LULC) Characterization

Analysis of the obtained LULC maps indicates that the urban area grew 60% between 1989 and 2014 (Fig. 2). Built-up area increased by 5288.40 ha (25%) in 1989-2002 period and 2695.77ha (10%) during 2002-2014 phase. The area covered by surface water remained relatively stable over the period, with initial decrease in amount of water covered area which again increased in 2014 (Fig. 2). The built-up areas increased linearly over the years by extension of new township due to migration from rural to urban and getting opportunity for employee offered by new medium industries.

Figure2. Urban built-up area changes in 1989, 2002 and 2014

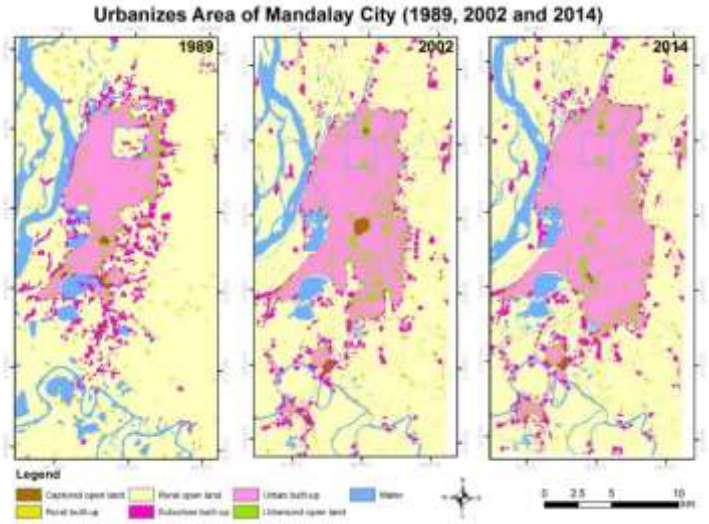



## Urbanized Area Mapping

The urbanized area is combination of built-up area (impervious surfaces) and urbanized open space where heavily influenced by urbanization (i.e, built-up area is occupied more than 50 % of the open space in defined region). Seven classes were mapped for urbanized area: urban built-up, suburban built-up, rural built-up, water, captured open land, rural open land and urbanized open land (Fig. 3). It was found that urban built-up area is the majority one and relatively fewer suburbs in study area. Suburban areas remain stable while urban built-up grows basically as a big urban cluster from 1989 to 2014 by striping suburb in eastern part of the city and swallowed by urban built-up area. Urbanized open land is a class that is important from viewpoint of high degradation vulnerability of undeveloped land patches, present in between developed lands. In new developments, it was found that conversion of large portions of rural open land to urbanized lands. This resulted in increase of urban built-up area is 2.2 times in 1989-2002 period. During the same period, urbanized open land decreased by 579 ha and it is almost same in later period. This was due to limited availability of undeveloped lands for creating urbanized open land patches as most of undeveloped lands had got degraded during 1989– 2002. Reducing urban open land and rural open land lead to the less in capacity of water storage and increase

in run-off in urbanized land. This is one of influence factor for urban flood (water logging) in the urbanized area.

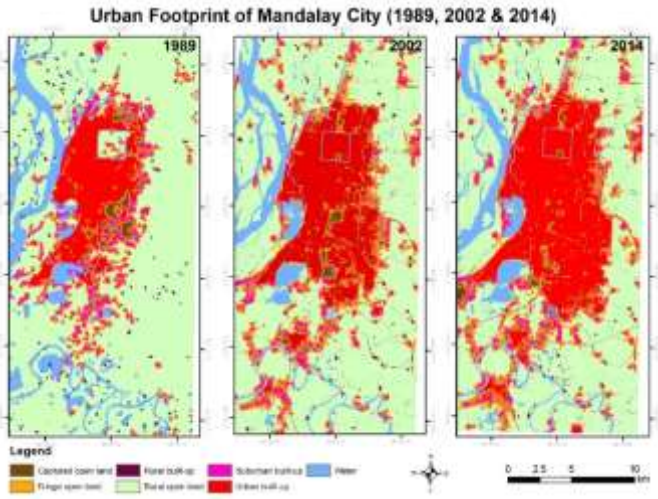
Figure3. Urban Area Map




## Urban Footprint Mapping

The urban footprint consists of urbanized area and peripheral open space (open space less than 100m from the built-up area). The urban footprint identifies levels of spatial density in the built-up area. Urban Footprint maps consisted of seven categories based on urbaneness (percent of neighborhood that is built-up within 1 sqkm.) values and their land cover attributes. Urban and suburban built-up land increased by 5288.40 ha and 2695.77 ha during 1989-2002 and 2002-2014 time periods with simultaneous fall of 4661 and 2471 ha in rural open land. Urbanization of villages has initially resulted in increase of rural built-up from 314 ha to 439 ha but has later decreased by 65 ha. The decrease could be due to conversion of rural built-up to suburban and urban built-ups. Due to greater role of leapfrog development in first time period of study an increase of 3622 and 29 ha was noticed for fringe and captured open lands (Fig4).

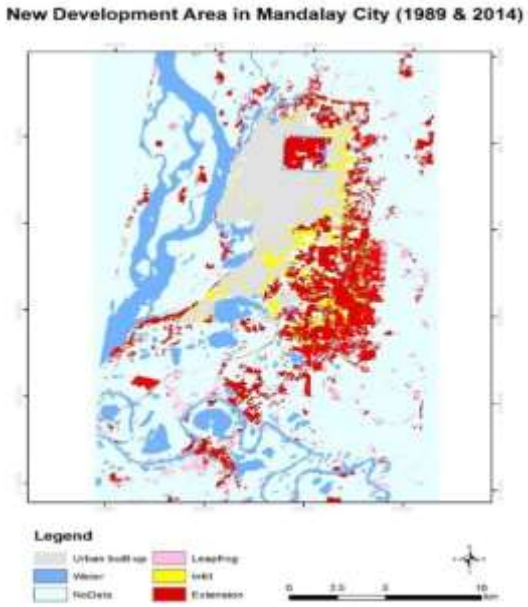
Figure4. Urban Footprint Area Map




## Identifying New Developments Areas

The identification of patches of new development helped in analyzing the pattern and type of urban growth that is taking place in city. The new tracts of residential area were extended to southern part of the town after 1988. As the need of the urban development, highway bus station and trade centers were built in southern part of the town. In 1998, Mandalay International Airport was opened in Tadaoo Township 30 miles west of Mandalay, and so the development led to southern part of the town. Establishing administrative city "Nay Pyi Taw" between Yangon and Mandalay in 2003 and constructing Yangon - Mandalay Highway made the development of Mandalay get accelerated. From 1989 to 2014, greater part of new development could be attributed to extension that accounts for more than 69 % of new developments. Leapfrog contributed 15.05 % to new development area and the rest 15.5 % developed through infill (Figure 5).

Figure5. New Development Map of Mandalay city between 2002 and 2014

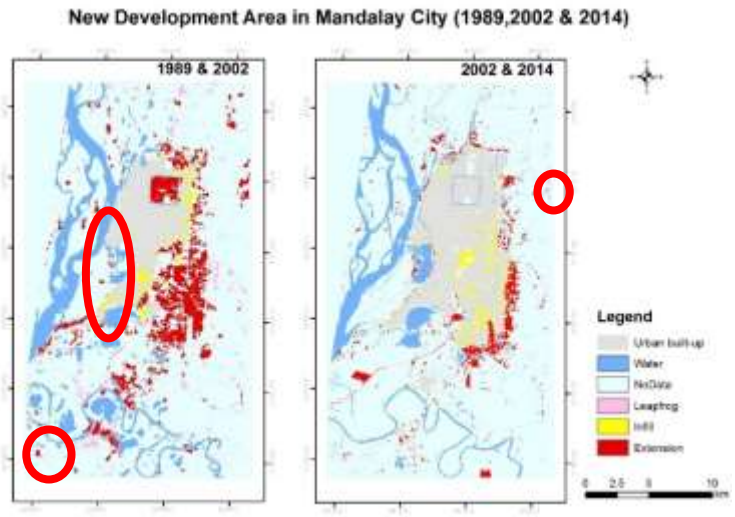



From 1989 to 2002, greater part of new development could be seen in southern and south-east part of the Mandalay City. Analysis result attributed to extension that accounts 70.53 % of new developments. Qualitative analysis of new development maps (Fig. 6) indicates that, from 1989 to2002 development in eastern and south eastern parts of the city has been dominated by extension process which could be attributed to coming up of new establishment of new townships which extended by Mandalay City Development Committee (MCDC) After 1990, many small and medium enterprise developed especially in industrial zone in the southern part of Mandalay and population of industrial workers had also grown up by migration from rural or other cities in this place. Also, the transportation lines (i.e. primary roads) are also increased during these periods. In the downtown area, high rise buildings were appeared for residential and commercial purpose. Furthermore, urbanization occurs inside of the old Palace compound due to occupation by the Military in 1988. This occupation leads to the construction of new buildings with military purposes in that area. In this period, the urbanized open land in eastern and south east part of the City was transformed into urban built-up area and totally 578.61 ha of urbanized open land was reduced. In this period, leapfrog contributed 20.07 % to new

development area and the rest 9.39 % developed through infill. In the period 1989-2002, the direction of urban expansion of Mandalay city seemed to point in the direction of the lower elevation in the western part of Mandalay City, adjacent to the Ayeyarwady (Fig 6).

Detailed land use/land cover maps as of 2002 and 2014/2015, as well as related change, transportation infrastructure and assets were extracted from very high resolution imagery over Mandalay city area. The maps show status and development of urban areas and population density. Land use structure of urban extension as well as internal urban developments was quantified in support of qualified decision making. Mandalay has recently undergone rapid development: the extent of urban artificial classes has extended by almost 23% while internal land use changes occurred on 28% of originally built-up areas during the last 13 years. The red circle in Figure 6 shows that urban extension is also occurred in south-west and northern part along the Ayeyarwady River, closed to flood prone area, but also in island of the river.

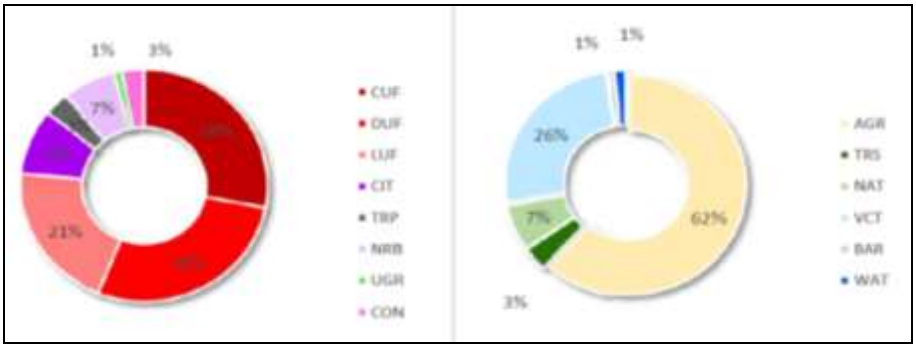
Figure6. Land use map of Mandalay city (a) for 2002 and (b) for 2014




In the 2002-2014 periods, proportions of formation and consumption of urban extension flow are given hereafter (Figure7). Apparently, urban classes have been extended predominately at expense of agriculture and vacant land. While the first process occurred at the city border, the later could be related with infilling of

large non-built-up (unused, vacant land) areas remaining with the city border. The contribution from leapfrog development increased to 3.99 %, extension decreased to 66.85 % of new development and rest 29.15% was infill. Initially, vast tracts of land were available at peripheries which eventually got developed by leapfrog process.

Figure7. Formation (left) and consumption (right) of urban extension (100% = area of Urban extension)




CUF = Continuous urban fabric

DUF= Discontinuous urban fabric

LUF= Low Density Urban Fabric

CIT= Commercial and industrial Unit

TRP= Transportation units

NRB= Non- residential urban fabric

UGR= Urban Greenery

CON=Construction sites

AGR= Agricultural land

TRS= Trees

NAT=Other Natural and Semi-Natural Areas

VCT=Vacant land

BAR= Bare land

WAT= Water bodies

Figure8. New Development Map

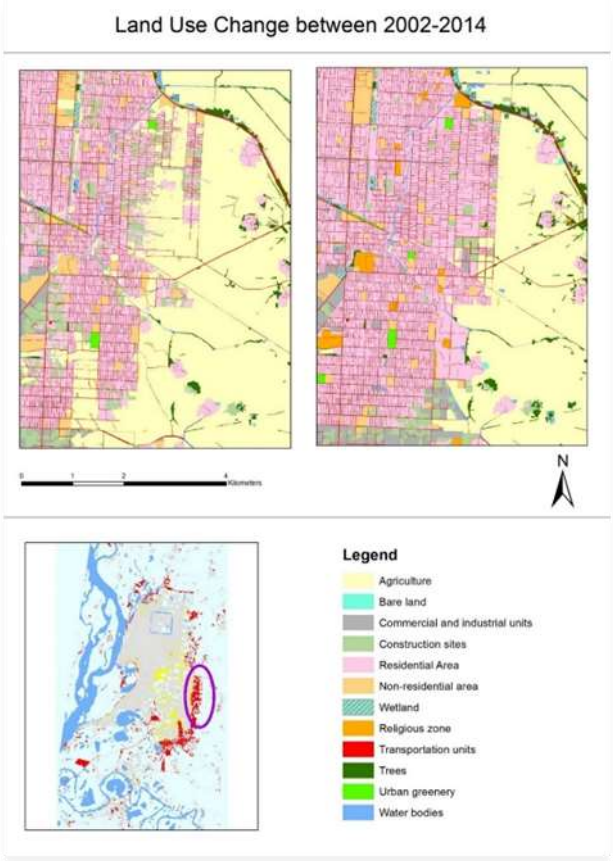



Figure 8 shows that urban extension occurred in south east of the city and the agriculture land is changed to urban built-up area during 2002-2014 period. The dominant directions of urban expansion were South East and South in 2002-2014; the growth in these directions was influenced by the physical factors of highways, industrial site, new constructions and population direction that accelerated the growth in these directions. It clearly shows that the southern direction has the highest value of 37.5 % increase in urban expansion followed by south east for over 20 % in 2002 and 2014. Fig 9 shows that urban infill development is mainly occurred: "Mingalar Mandalay Elite Community" new development site (blue rectangle) and new international stadium have established in this second period. Urban extension mainly occurred in eastern and southern part of old airport and some agricultural land and urban open space in these region were converted to urbanized area in this period. We could also find new commercial and industrial units, new construction site, and new residential area in

southern part of the city (Figure 10). These new urbanized areas are apparent by withdraw of agricultural land in this period (Figure 10).

Figure9. New Development Map

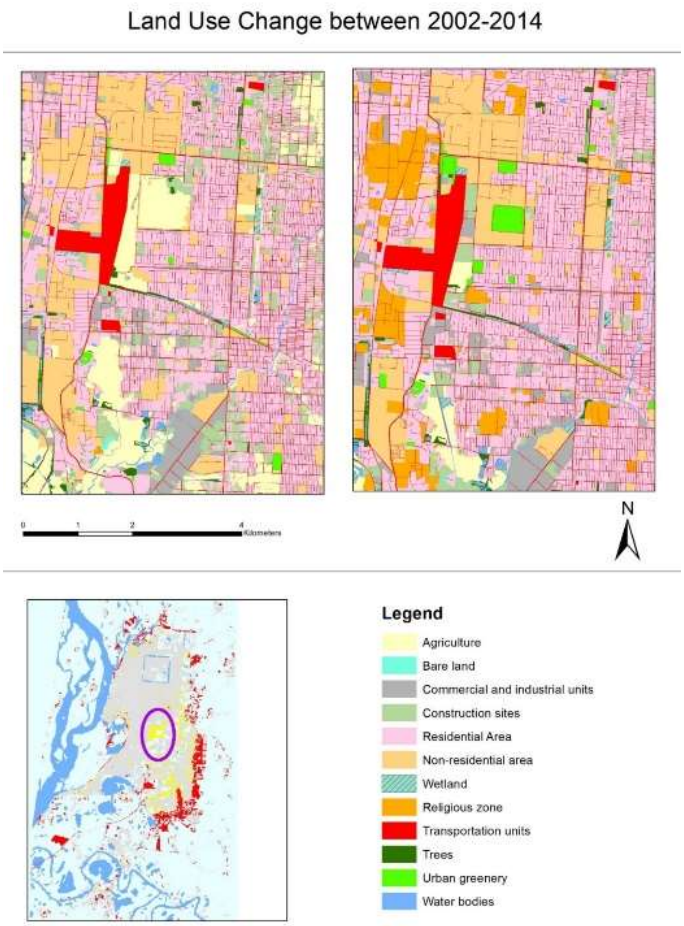
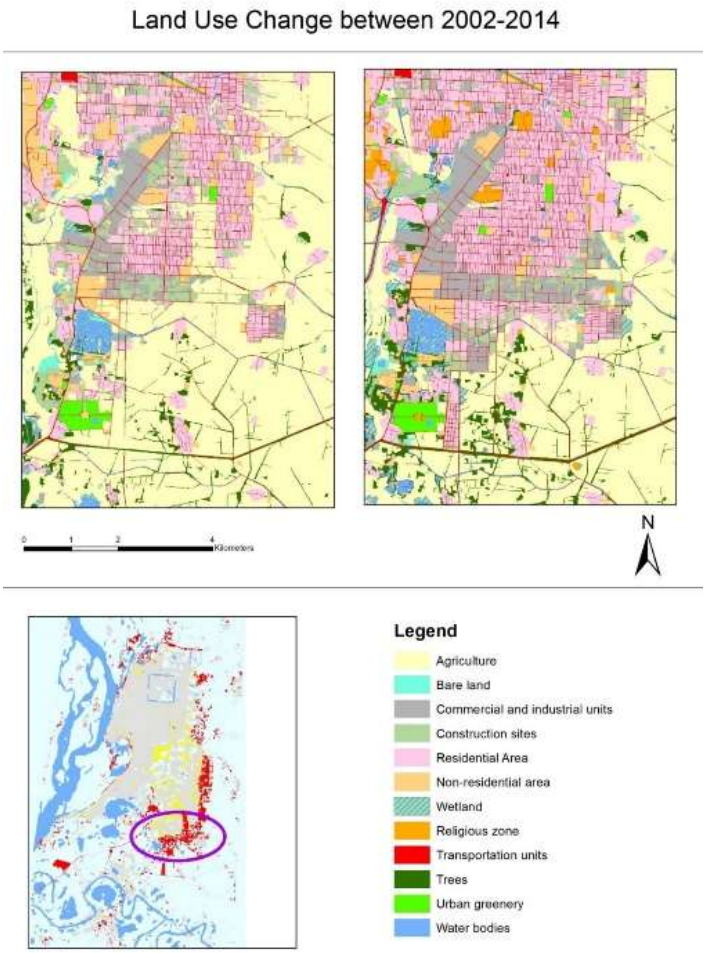


Figure10. New Development Map




## Result and discussion

The LCLU mapping is basic requirement for monitoring and management of natural resource and environment to make a better decision making on sustainable society. Since the objective of this research was to develop land use plan in increasing resilient city. It indicates the urban built-up area is increased 1.6 times between 1989 and 2014. Built-up area increased by 5288.40 ha from 1989 to 2002 and 2695.77 ha during 2002 to 2014 phase. Water composition in land cover was more or less same, with initial decrease in amount of water covered area which again increased in 2014. Detailed land use / land cover maps as of 2002 and 2014/2015, as well as related change, transportation infrastructure and

assets were extracted from very high resolution imagery over Mandalay city area (Fig. 4 and Table I).

Mandalay has recently undergone rapid development: the extent of urban artificial classes has extended by almost 23% while internal land use changes occurred on 28% of originally built-up areas during the last 13 years. The internal changes could be related mostly to densification of current urban fabric within contemporary urban blocks.

Detailed land use / land cover maps as of 2002 and 2014/2015, as well as related change, transportation infrastructure and assets were extracted from very high resolution imagery over Mandalay city area. The maps show status and development of urban areas and population density. Mandalay has recently undergone rapid development: the extent of urban artificial classes has extended by almost 23% while internal land use changes occurred on 28% of originally built-up areas during the last 13 years. The internal changes could be related mostly to densification of current urban fabric within contemporary urban blocks. Land use structure of urban extension as well as internal urban developments was quantified in support of qualified decision making.

## Conclusions

The study clearly illustrated how an urban development pattern is taking over in Mandalay City. ULA tool was mainly used in this study and it is useful investigate tool measuring the trend of spatial pattern in development area and also how development influences the impact on natural resources. Findings of this study despite most of changes concentrated to the very near surroundings of the Mandalay agglomeration, other areas have been identified which might represent potential future regional centers of development or environmental degradation hot-spots. This result can also be used as input data for urban planners for more efficient planning.

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