Spatial Pattern of Urban Expansion and Green Spaces: A Case Study of Tangalle Area, Sri Lanka

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Abstract: *Urbanization responses to urban expansion, and changes in green spaces. Moreover, urban expansion has a significant impact on urban management. Urban forests (Green Spaces) provide benefits of the natural environment to communities. Recognizing the spatial pattern of urban expansion and green spaces within a certain time period is vital for urban planning. This study conducts to examine the expansion in Tangalle town. Built-up expansion occurs in recent years because of the tourism industry in this study area. The remote sensing indices, Normalized Difference Built-up Index (NDBI) and Normalized Difference Vegetation Index (NDVI) have been used to extract built-up and green spaces for identifying the spatial pattern changes from the years 1990 to 2021. According to the results of the urban expansion/sprawl index, and urban areas have been expanded slightly between year 1990, and year 2000, but decreased urban expansion between year 2000, and year 2010. However, between the years 2010, and 2021, the urban area has sharply expanded by up to 13%. The study revealed that the built-up area has increased enormously. NDVI shows that the increase in this built-up area has led to a decrease in significant agricultural lands and open spaces. Thus, in the year 1990, the urban form was an isolated urban pattern and gradually became a cluster-based pattern. According to the urban expansion results, the urbanization is expanding towards the north direction from the city center.*

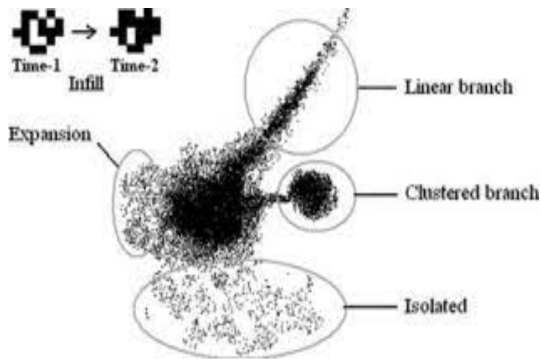
Keywords: *Urban spatial pattern, Normalized Difference Building Index (NDBI), Normalized Difference Vegetation Index (NDVI)*

1. Introduction

Urbanization is a process of increasing urban population and urban infrastructures. Due to urbanization, urban land carrying capacity is changing year by year. Most populations are trying to move to urban city areas to get high-demand facilities. However, the limited size of urban spaces, and growing population grants have become an issue in the present situation. Many environmental, geographical, and political factors, as well as economic factors, act as dynamic drivers of landscape change (Thapa and Murayama, 2011; Iqbal et al., 2012). The process of urban growth is complicated and dynamic. It entails modifications to the physical and functional components of the environment, which is constructed, and the transition of the landscape to an urban form (Castle and Crooks, 2006; Dahal et al., 2016). The scale of suburban growth and urban sprawl is used to quantify rapid urbanization (Harris and Ventura, 1995; Sajjad, 2014). Cities do not have enough resources to accommodate the population, and the new development will enable them to live in suburban areas. Urban expansion always has a negative connotation. It also affects the destruction of agriculture and nature (Ewing, 1997).

Urban expansion can be categorized as infill, edge Expansion, and outlying (Weerakoon, 2017). Mostly, outlying growth takes place in open areas, and areas sensitive to the city, and surrounding environment. Also, it separates from the existing build-up area. That outlying growth can be divided furthermore into an isolated, linear branch, and clustered branch. It was recognized as the main growth type as infill growth. It occurs in the built-up area. The next type is edge expansion, and it is centered on infill growth. Therefore, edge expansion directly relates to the existing built-up area. Three types of urban growth have been identified: infill, expansion, and outlying growth. The outlying horizontal expansion is subdivided into isolated, linear, and cluster branches. Figure 1 shows the types of urban growth patterns (Bhatta, 2010).

reading, and it is a way to identify urban expansion for future developments (Weerakoon, 2017). As a result of this expansion, forests have been destroyed, and concrete environment has been created. There is a significant relationship between changes in spatial pattern and population growth changes of urban growth for long years, its effects on changing of urban forms. It can be evaluated by combining GIS (Geographical Information System) and remote sensing. Due to urbanization, people are moving to cities to get better living conditions, education, and income. Padmanaban *et al.* (2017), state that the global population is predicted to grow by 72



Source : (Bhatta, 2010)

Figure 1: Urban growth pattern

Pixels represent isolated buildings and development in isolated growth types, and it implies that those areas may be developed in the future. Some isolated growth can be identified as non-developed areas. Linear urban development takes place from developed areas to undeveloped areas, like corridors or parallel to the new linear development. That is urban land connecting the pixel with the linear way in the visualization. Cluster urban distribution describes cluster or group development. It isn't like linear or isolated. Clusters spread out to a large urban area through a high urban density (Wilson *et al.*, 2003).

Nowadays, urbanization has spread out of city areas due to population growth. This expansion is a long-standing physical

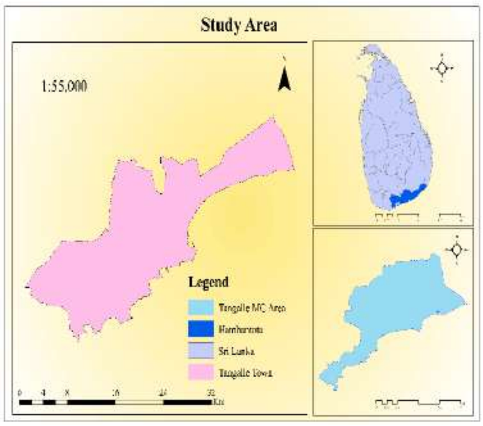
% in 2030, with a 175% rise in urban centers. All this urban sprawl takes place over large areas. So, it is not possible to measure location to location, using traditional methods such theodolite, and total station, and a significant solution to avoid this problem using aerial photography and satellite imagery. It is a modern surveying technique that can be achieved targets with less time duration and less cost. The urban sprawl pattern is very important for the proper urban management of urban areas. Therefore, this research was conducted using satellite Landsat images. This is a very important computer-based method for analyzing Landsat data, and accuracy levels are enough to do case studies (Karanam and BabuNeela, 2018). Urban sprawl is prevalent due to rapid population growth, destroying productive agricultural lands, and ancient forests, and adversely affecting ecosystem services. Quantification is critical to effective urban planning, and environmental management. Land Use and Land Cover (LULC) represent the relationship between environment and human activities and can be efficiently obtained from satellite imagery through image classification. Moreover, the availability of remotely sensitive data from multiple dates enables the study of multidimensional urban modeling. Using the algorithm, satellite imagery can automatically identify the size of urban areas as well as vegetation areas. Furthermore, spatial, and physical features of urban features, urban patterns, and their models can be quantified using several landscape measurements. It can be calculated from the images obtained, and used to scale effectively (Padmanaban *et al.*, 2017).

The Urban expansion /sprawl index (SI) is used to detect urban growth in a specific area. It can be divided into five groups. If SI <0.001%, it represents an area of no change; At 0.001% <SI <0.1%, this area shows a slight expansion; 0.1% <SI <1% This area expands moderately; At 1% <SI <5%, this district appears to have a fairly rapid expansion; SI> 5% means that this area has undergone a sharp expansion (Yang and Pu, 2008).

The confusing matrix method is the most used method for estimating the classification accuracy of remote sensing images. Previous research shows that the score should not be less than 75 to confirm the classification accuracy of a single class. Confused theories were established by comparing the classification results of these reference points at different time points with the corresponding field investigation results and the high-resolution remote sensing data from Google Earth. The manufacturer's accuracy, user's accuracy, and overall accuracy were used to measure land-use classification accuracy (Sun *et al.*, 2020).

Tangalle is an area that has developed in recent times. Its tourism industry is also booming. The government has decided to launch development projects in the tourism industry as well as other infrastructure in the area. In a short period of time, many buildings were erected, and development continued. We often see many areas such as vacant lands, barren lands, swamps, and plantations. But with the new development, it has grown into a coastal development. The main objective of this research is to identify the urban growth type in the Tangalle town area, and the sub-objectives are to identify the urban expansion/sprawl index of Tangalle town area, and represent the green area changes in this area.

Study Area



Source : (Survey Department,2020)

Figure 2: Study area

Tangalle is a town in the southern province of Sri Lanka, in Hambantota district. It is located with coordinates 6° 01′ N 80° 47′ E. Its elevation is 29 m /95 feet above the mean sea level. It has a mild climate, and sandy coastline compared to the rest of the district, and figure 2 shows the study area of the research.

This study examines the expansion of 16 Grama Niladhari Divisions in the Tangalle. In 2012, 72,500 population was in Tangalle DS Division (Department of Census and Statistics, 2022). Tangalle town has a population of 10,497 by year 2022 (Population of Cities in Sri Lanka, 2022).

2. Methodology

The above figure 3 shows the flowchart of the study.

For this, satellite images from 1990, 2000, 2010, and 2021 were used. They were under Landsat Thematic Mapper (TM) imagery, Landsat 7, Landsat 8. The resolution of the satellite images is 30 meters.

(Zha, et al. 2003).

Where, NIR = band 4 (Landsat TM) and band 5 (Landsat 8), RED = band 3 (Landsat TM) and band 4 (Landsat 8)

NDBI is an indicator for extracting built-in areas and was calculated from remote sensor data using the reflection of NIR and mid-infrared (MIR) components of the spectrum (Krishnaveni and Anilkumar, 2020). NDBI values are in the range between −1 and 1, values close to 0 indicate vegetation;

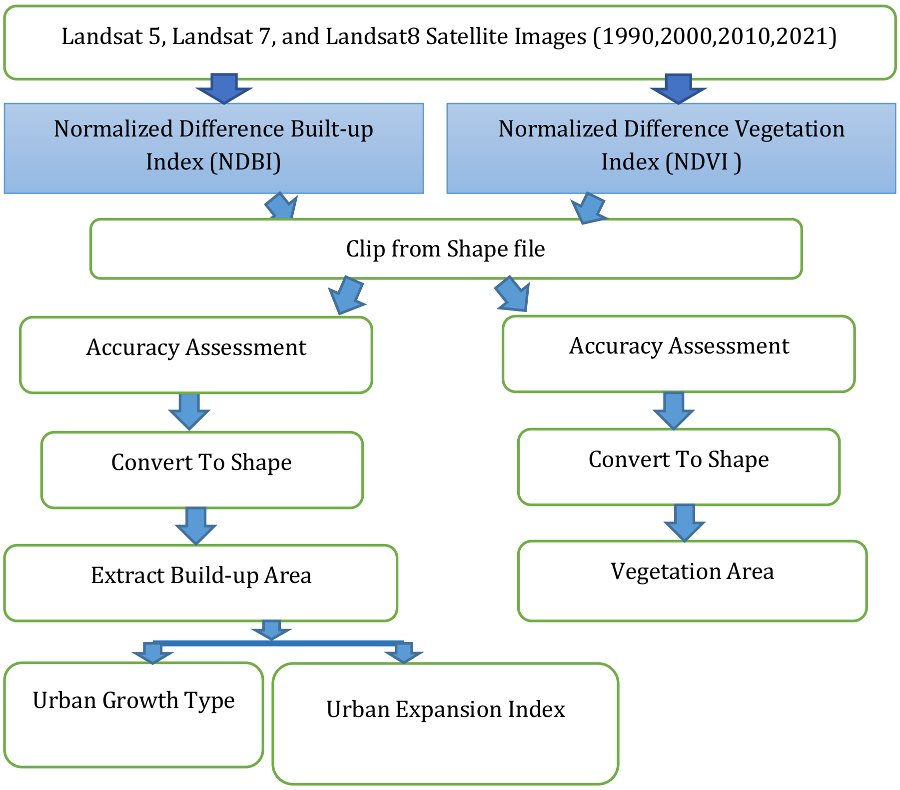


Figure 3: Flowchart of the study

NDVI is an important variable in urban expansion studies, which is obtained from remote sensing data using reflection in the red (RED) and near-infrared (NIR) segments of the electromagnetic spectrum. NDVI values indicate vegetation, as smaller positive values indicate bare soil or built-up areas. Equation 01 shows the NDVI calculation.

$$NDVI = ((NIR - RED))/(NIR + RED) \quad (01)$$

Negative values indicate water bodies, and positive values indicate built-up areas. Equation 02 shows the way to calculate NDBI (Zha, et al. 2003).

$$NDBI = ((MIR - NIR))/((MIR + NIR)) \quad (02)$$

(Krishnaveni and Anilkumar, 2020)

Where, MIR = band 5 (Landsat TM) and band 6 (Landsat 8), NIR = band 4 (Landsat TM) and band 5 (Landsat 8)

After extracting the built-in area from NDBI and vegetation area from NDVI, they were clipped using the study area shape file. The

Table 1: Built-up area from year 1990 to year 2021

Year	Built-up area (ha)		Non-Built-up area (ha)	
1990	204.542	11%	1585.661	89%
2000	555.227	31%	1235.747	69%
2010	580.262	32%	1212.418	68%
2021	817.560	45%	975.546	55%

built-up areas are then examined using ground truth values, and Figure 4, and figure 5 show the validated map of built-up areas and vegetation areas. Table 4 shows the classification accuracy of the constructed areas. Figure 5 shows the map that has been built in Tangalle town after the field verification.

During the study period, the urban expansion index, the ratio of the area of urban land expansion to the total area of a geographical unit was calculated. This indicator normalizes the yearly median expansion rate based on a spatial unit's land area, allowing for comparison. (Sun *et al.*, 2020).

According to Tian et al. (2005), the urban expansion index/ sprawling index can be calculated using equation 03.

$$SI = ((UL_{(i+n)} - UL_i)/(nTUL)) \times 100\%$$
(03)
(Tian et al., 2005).

Here, SI = Sprawling Index/Urban expansion, $UL_{(i+n)}$ = Land area at year i+n, UL_i = Land area at year n, TUL = Total land area

Verification of available building coordinates files was very important to identify built-up areas on maps. Table 1 and Table 2 show statistics of the vegetation area and built-up area from year 1990 to year 2021, and Figure 7 and figure 8 show the built-up area and vegetation area constructed using graphs for more details. The urban density or expansion was then identified in relation to the area formed over the years as defined shown in figure 10. Finally, the Urban Expansion Index was calculated for specific periods and is shown in Table 4.

3. Result and Discussion

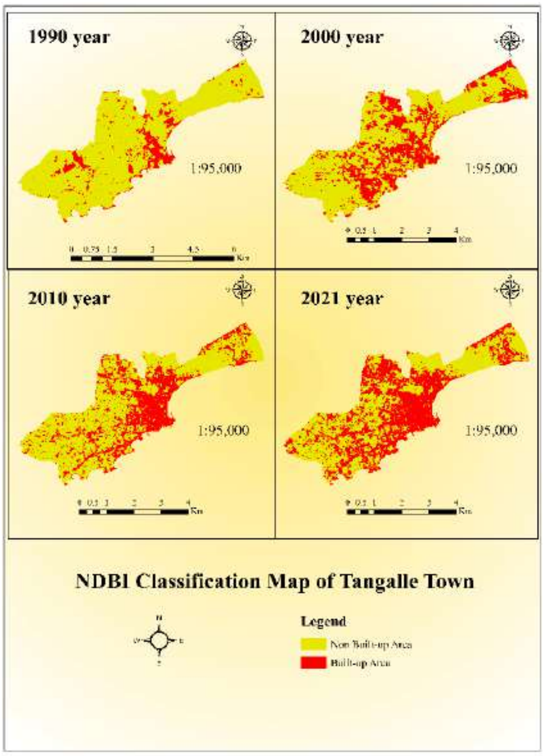


Figure 4: NDBI classification map of Tangalle

Figure 5: Built-up variation over last years

Year	Vegetation Area(ha)		Non-Vegetation Area(ha)	
1990	1622.324	91%	172.224	9%
2000	1603.861	90%	189.330	11%
2010	1571.805	88%	221.311	12%
2021	1395.207	78%	396.906	22%

Table 2: Vegetation area from year 1990 to year 2021

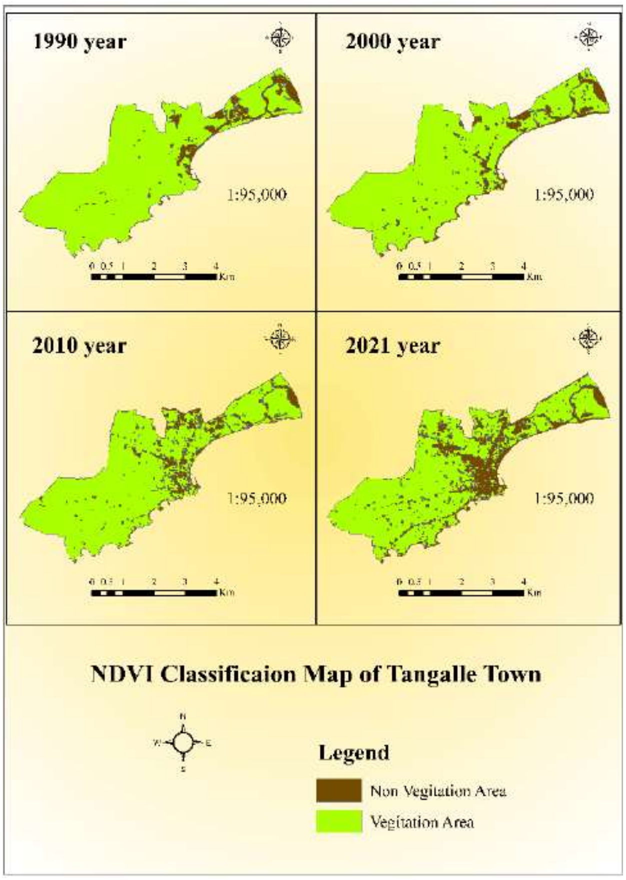


Figure 6: NDVI classification map of Tangalle

Table 3: Vegetation area from 1990 to 2021

Year	SI(Sprawl Index/ Urban Expansion)
1990-2000	20%
2000-2010	1%
2010-2021	13%

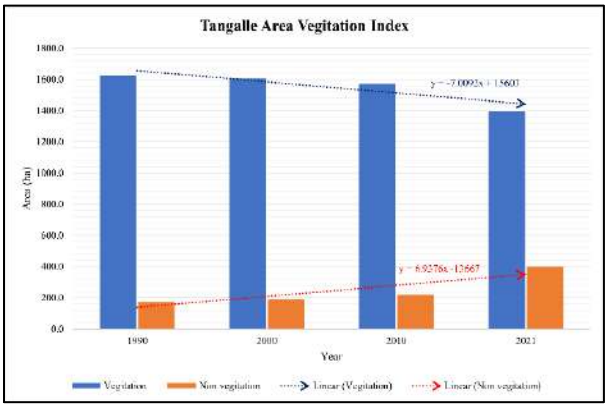


Figure 7: Vegetation area from year 1990 to year 2021

Table 4: Accuracy assessment

Year	Overall Accuracy for NDBI	Overall Accuracy for NDVI
1990	82% (Google Earth)	81% (Google Earth)
2000	86% (Google Earth)	82% (Google Earth)
2010	88% (Google Earth)	84% (Google Earth)
2021	93% (Field Verification)	90% (Field Verification)

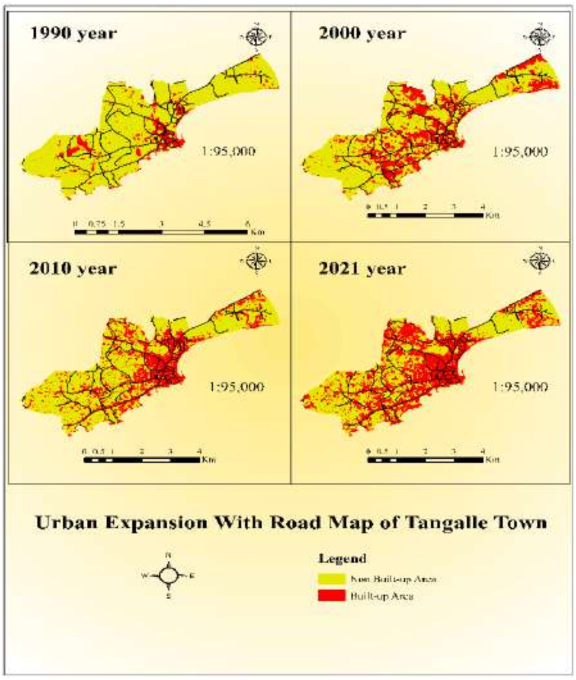


Figure 8: Urban expansion map of Tangalle town

Figure 4 shows how the urban area has changed over the past years. Also, table 1 shows the difference in areas between built-up and non-built-up areas in the study area. According to that, the area difference that occurred during the expansion of buildings in Tangalle city can be seen. However, according to the figure 5 graph details, the growth of the built-up area, and its expansion directly affect the non-built-up lands in the region. The NDBI classification map created here shows the distribution of buildings in Tangalle town from year 1990 to year 2021. Also, according to the area data obtained, the built-up area and non-built-up area are given in hectares and as a percentage. Accordingly, in year 1990 it showed 11% built-up area and 89% non-built-up area. Also, a 31% built-up area for the year 2000 shows 32% and 45% areas for year 2010 and year 2021 respectively. And 69%, 68% and 55% respectively are non-built-up areas.

Similarly, the linear equation for changing the buildup area is set using excel. It can predict built-up, and non-built-up areas in 2025. According to this study, by year 2025, 897.4 ha will be a non-built-up area and 896.125 ha will be a built-up area.

Similarly, the NDVI map is designed to achieve sub-objectives. Accordingly, in 1990 it showed 91% vegetation area and 9% non-vegetation area. Similarly, 90% vegetation area for the 2000 year, 88% and 78% vegetation area for 2010 and 2021 respectively. In comparison, the percentage of the non-vegetation area has increased.

A sharp urban expansion of 20% occurred from year 1990 to year 2000. But from year 2000 to year 2010, the result is 1%. It is a middle-speed urban spread. So, this proves that there has been minimal urban growth in 10 years. But again, from year 2010 to year 2021, there is a 13% sharp expansion result.

Figure 8 shows the built-up area with the road network in the Tangalle area. It shows an isolated urban growth pattern in the year 1990 and changed to a cluster-based one in the year 2000. But again, in year 2010, the isolated pattern shows. But Tangalle town area has a cluster-based urban growth pattern in the year 2021. This urban area has changed from an isolated urban pattern to a cluster-based pattern. This urban expansion was mainly directed in the north direction.

The study has a high precision as more than 80% of all analyzes were obtained when calculating the precision of the study.

4. Conclusion

Using satellite and remote sensing technology, urban expansion can be monitored quickly. This paper studies the urban land expansion and distribution in the Tangalle town area during the three periods years 1990-2000, years 2000-2010, and years 2010-2021. Constructed areas and green areas can be extracted from the classification of remote sensing technology. Although the urban form remained isolated in the 1990s, it has since changed somewhat linearly in the 2000s and 2010s. And 2021 shows a cluster-based urban expansion. The use of NDBI is effective in capturing the urban distribution pattern of the area. The urban sprawl index (SI) is used to measure and quantify urban expansion. With the expansion of the city, the green area has decreased. The years 1990 to 2000 show high developments in Tangalle town. But tourism developments slowed down between years 2000 to 2010 due to politics and the LTTE war in Sri Lanka. Therefore, at that time there was only 1% development. But, after the year 2010, all tourism developments were started in Tangalle city area. Moreover, developments are increasing along the beach areas.

Finally, the result shows urban expansion from Tangalle coast to the city center. It is the northward direction of urban expansion. It is due to natural and environmental reasons such as barren areas, paddy fields, and coastal lines. The urban sprawl extends less from the city center to the east and west. The land on both sides of the main road through Tangalle town is primarily affected by this. Those roads are Beliatta road, Mahawela road, and Kataragama road. All lands have affected the development of Tangalle town. If there is a high resolution of the satellite image used, the results of the study will change. Urban planning authorities can use these techniques to extract built-up areas and green areas to effectively control urban planning and spreads and to analyse urban sprawl. Further, this study can be developed to identify the relationship between the spatial forms and population.

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