An Assessment of Urban Expansion through the Integration of Remote Sensing Data and the Relative Shannon Entropy Model in GIS: A Case Study of Mirissa Tourism City in Sri Lanka

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Abstract- *Urban expansion, defined as the increase in the built-up area of settlements accompanied by population growth, has a long history influenced by human activities. However, in densely populated areas, urban growth can occur without physical expansion, while urban expansion can occur without substantial population growth due to densification. The developing world has experienced rapid growth across various industries, with tourism emerging as a significant and expanding global sector. Unplanned urban expansion has led to the issue of urban sprawl, which has become a prominent topic in various scientific disciplines.*

This study focuses on investigating the expansion of Mirissa Tourism City. The primary objective is to determine urban land expansion using Shannon's Entropy value. Remote sensing and Geographic Information Science (GIS) techniques offer methods to assess expansion indices using satellite imagery. Satellite images from 2005, 2010, 2015, and 2020, obtained from USGS Earth Explorer, and were used as primary data sources. The Normalized Difference Built-up Index (NDBI) was employed to extract the built-up areas and calculate urban expansion/urban sprawl, enabling the identification of expansion patterns in the study area.

The findings include the generation of maps depicting the expansion of built-up areas in Mirissa Tourism City, revealing the urban expansion using Shannon's entropy value. Incorporating such analysis into town planning allows for the identification of extension patterns that promote sustainable development. The results indicate that the region experienced slight expansion between 2005 and 2010, followed by a moderate rate of expansion from 2010 to 2015 and 2020. Ultimately, the output highlights that urban expansion predominantly occurred from the beachside towards the city center area in Mirissa Tourism City.

Keywords: Remote Sensing, GIS, NDBI (Normalized Difference Built-up Index), Shannon's Entropy, Urban Expansion, Urban Sprawl

I. INTRODUCTION

Urbanization and the expansion of urban areas have long been considered important indicators of a country's economic progress and development (Mohapatra, 2014). Urban expansion refers to the increase in the built-up area of a settlement or group of settlements, often accompanied by a rise in urban population. However, in densely populated areas, urban growth can occur without physical expansion, while urban expansion can take place without significant population growth due to densification.

The increase in urban expansion can be attributed to the rapid growth of industries, especially in developing countries, where significant progress has been observed across multiple sectors (Kumasaru, 2019). Notably, the tourism industry has emerged as a prominent and rapidly expanding sector on a global level.

The tourism industry has a direct relationship with the built environment, and its evolution is closely intertwined with the history of urbanization, making it an important component of an interdisciplinary approach to tourism (Gohar, 2021). As the tourism industry develops, towns, cities, and rural areas are often subjected to urban expansion. In the developing world, there has been a rapid increase in the built-up areas of urban regions. The expansion of built-up areas in cities and towns signifies the process of urbanization. Over the past few decades, cities' physical dimensions have significantly grown in line with population and economic growth. Consequently, this urbanization trend has led to significant changes in land use and landscape patterns in the region. Urban land expansion plays a central role in shaping land movement and land use, directly reflecting the progress of urban expansion (WuDunn, Marc, Zakhor, & Touzani, 2018).

The estimation of urban centers using traditional surveying and mapping techniques can be costly and time-consuming, particularly in developing countries. Consequently, there is a growing interest in research focused on mapping and monitoring urban sprawl through the utilization of GIS and remote sensing techniques (Krishnaveni, K. S., Anilkumar, 2020). These advanced technologies offer more efficient and cost-effective means to assess and analyze urban expansion patterns, enabling researchers and planners to gain valuable insights into the dynamics of urban growth.

Remote sensing is an extensive and non-intrusive technique that utilizes the characteristics of electromagnetic waves to detect and record details of objects from considerable distances. Through image analysis, it reveals the characteristics and changes of various elements (Wickramathilaka et al., 2021). This cost-effective and technologically advanced technique is increasingly employed in the analysis of urban sprawl.

GIS (Geographic Information System) provides a flexible platform for the display, storage, and analysis of digital data necessary for detecting changes. The combination of satellite remote sensing and GIS technology has witnessed advancements, particularly in applications related to land use and land cover surveys, with a specific focus on urban growth areas. (Krishnaveni, K. S., Anilkumar, 2020)

The selection of Mirissa Tourism City as the research study area is motivated by its ongoing urban expansion year after year. The identification and monitoring of urban expansion in Mirissa are vital for urban planners, enabling them to understand the changing trajectory of urban growth in the region. Such information serves as a basis for making informed decisions regarding sustainable urban development in Mirissa.

The primary objective of this research is to determine the direction of urban expansion in Mirissa Tourism City. Specifically, the study aims to analyze the increasing built-up area and identify patterns of urban expansion and sprawl within this case study area. By examining these factors, the research seeks to gain insights into the dynamics of urban growth and provide valuable information for urban planners and policymakers involved in sustainable development initiatives in Mirissa Tourism City.

This study aims to define urban expansion by examining changes in the built-up area. To achieve this, the research utilizes the Normalized Difference Built-up Index (NDBI) methodology (WuDunn, Marc, Zakhor, & Touzani, 2018). The NDBI approach is based on the understanding that built-up areas exhibit higher reflectance in the Mid Infrared (MIR) spectrum compared to the Near Infra-Red (NIR) spectrum. In contrast, water bodies do not reflect the infrared spectrum, and green surfaces have higher reflectance in the NIR spectrum.

Given the complexity and time-consuming nature of image classification technology, the study focuses on the application of the NDBI to identify the built-up area. This approach involves a synthetic scope and multiple operations to arrive at the final result, ensuring accurate delineation and characterization of the built-up areas within the study area.

Shannon's entropy values range from 0 to loge (n), where lower values indicate a compact distribution of urban growth, and values closer to loge (n) indicate a dispersed distribution of sprawl. Higher entropy values signify areas characterized by urban sprawl. To categorize areas as sprawl or non-sprawl, a threshold value is employed. If a city surpasses its threshold entropy value, it is considered a sprawling city. The magnitude of urban expansion transition can be determined by calculating the difference in entropy between two time intervals, T1 and T2 (Krishnaveni and Anilkumar, 2020). This approach allows for the quantification and characterization of the extent and pattern of urban expansion over time.

The Mirissa Tourism City, located in the southern coastal strip near Weligama Bay in the Matara Southern area, has been designated as the planning boundary for this study. Mirissa is a prominent tourist destination within the southern coastal region. The Mirissa Tourism City encompasses five divisions of GN (Grama Niladhari) and spans an area of 3543.8 hectares according to the Urban Development Authority (UDA, 2019). The study area includes the surrounding five GN divisions in close proximity to the Mirissa Tourism City. Weligama, situated strategically in Weligama Bay, has undergone development primarily driven by the tourism industry and the fishing industry in the region (UDA, 2019).

Several possible areas can be used and advancing in the urbanization through the urban sprawl and expansion of the development with regarding the tourism and the fishing industry.

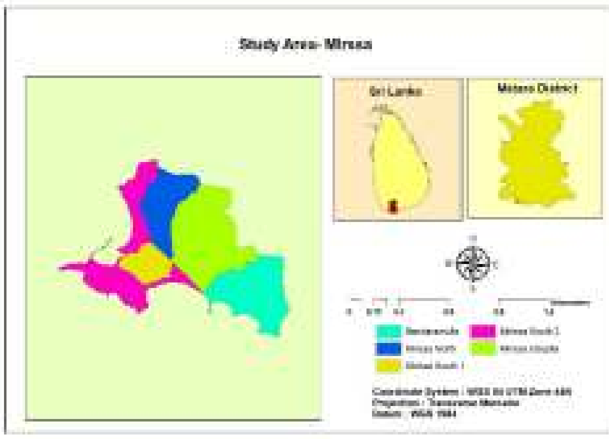

Figure 1 is shown the Study area of this research

Figure 1: Mirissa Tourism City

Source: Urban Development Authority

II.METHODOLOGY

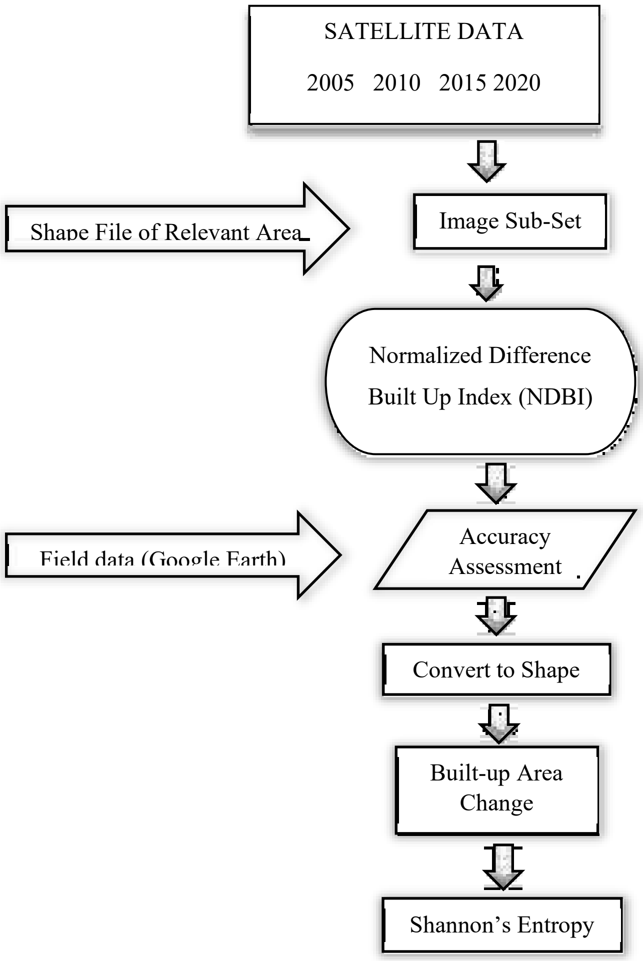

Figure 2: Flow Chart

Figure 2 illustrates the flow chart depicting the methodology employed in this research. The approach adopted for this case study is based on raster-based building extraction using the NDBI (Normalized Difference Built-up Index) as the building index. The analysis conducted in this study primarily focuses on the changes in the built-up area for the years 2005, 2010, 2015, and 2020.

To gather the necessary data, satellite images from the years 2005, 2010, 2015, and 2020 were utilized as the primary data source. These satellite images provide the foundation for investigating the built-up area and analyzing the changes that occurred in the study area from 2005 to 2020. The data collection process involved acquiring information at the end of each year, ensuring comprehensive coverage of the annual changes. The resolution of the satellite images used in this study was 30 meters, enabling detailed analysis of the study area and facilitating accurate assessment of urban expansion patterns over time.

In this research, the NDBI formula (equation 1) is utilized to extract the built-up areas from Landsat images captured in 2005, 2010, 2015, and 2020. The objective is to detect the expansion of the build-up area in the study area by analyzing the data every five years from 2005 to 2020. The urban expansion is classified into three stages: 2005-2010, 2010-2015, and 2015-2020.

To extract the build-up areas, Google Earth is employed as a tool to identify and collect point locations. Approximately one hundred points are gathered for each respective year. These point data are then compared with the NDBI extraction results obtained from the satellite images.

The NDBI formula, shown in equation 1, is used to calculate the NDBI index for the analysis. Figures 3, 4, 5, and 6 provide visual representations of the built-up area for the respective years.

$$NDBI = (MIR - NIR)/ (MIR + NIR) \longrightarrow 1$$

In the Landsat 4-5 thematic mapper (TM), band 4 represents the Infrared (IR) band, while band 5 represents the Mid Infrared (MIR) band. In Landsat 8, band 5 corresponds to the Near Infrared (NIR) band and band 6 corresponds to the MIR band.

On the basis of the second rule of thermodynamics, Rudolph Clausius introduced the concept of entropy in 1867. (Claudius, 1867). In 1948, Shannon developed the theory of entropy as a measure of randomness and disorganization. Given the complexity of urban development, expansion, and evolution, the entropy value must remain within the range indicated by the lower limit limits denotes vulnerable and unstable, and the upper limit provides unsustainable.

To calculate Shannon's Entropy, the following equation (Equation 2) was used:

$$Hn = Pi*\log (1/Pi) \longrightarrow 2$$

Here, Hn gives entropy value, Pi gives from $Xi/\sum_{1}^{n} Xi$ and Xi is the observed value in the i^{th} zone in a total of n zones (proportion of the built-up area in the zone/ grid) and n is the total number of zones/grids.

Shannon's Entropy has a range of values from 0 to loge (n). Closer to zero values indicate a compact dispersion of urban expansion. Entropy values close to loge (n) indicate a dispersed distribution of sprawl. Expansion areas are represented by higher entropy ratings. The threshold value distinguishes between sprawl and non-sprawl areas. A city is said to be expansive if its entropy value exceeds a certain threshold.

III. RESULTS and DISCUSSION

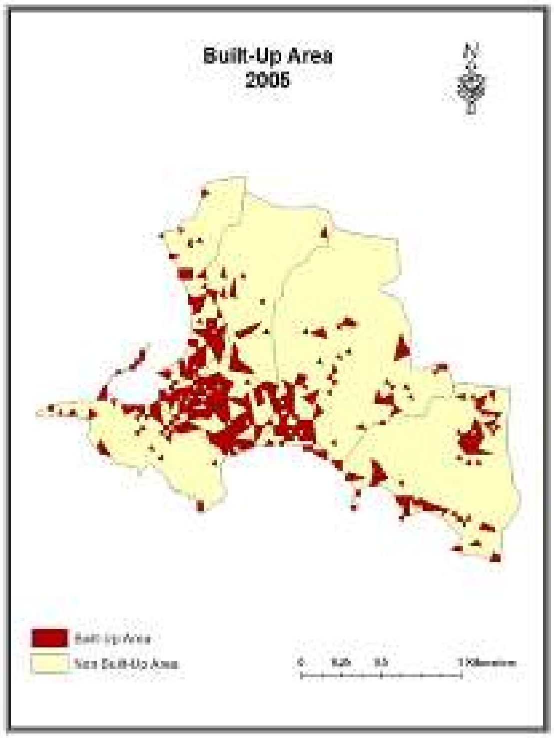

Figure 3. Built-up Area 2005

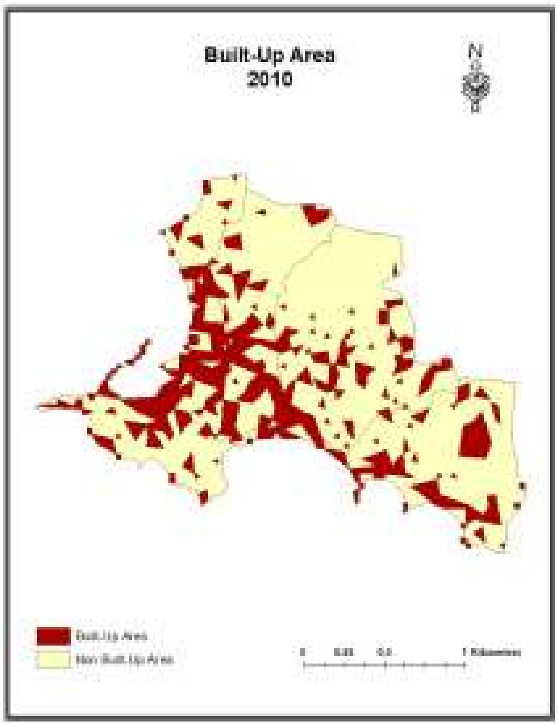

Figure 4. Built-up Area 2010

Figure 5. Built-up Area 2015

Figure 6. Built-up Area 2020

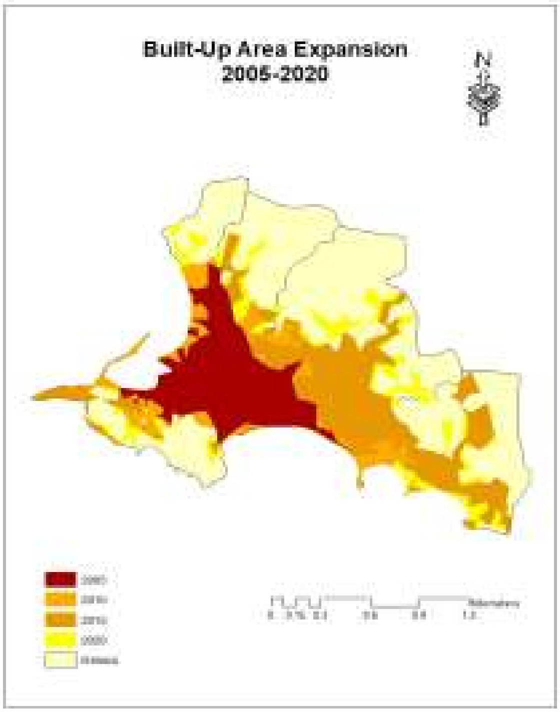

Figure 7. Built-up Expansion 2005-2020

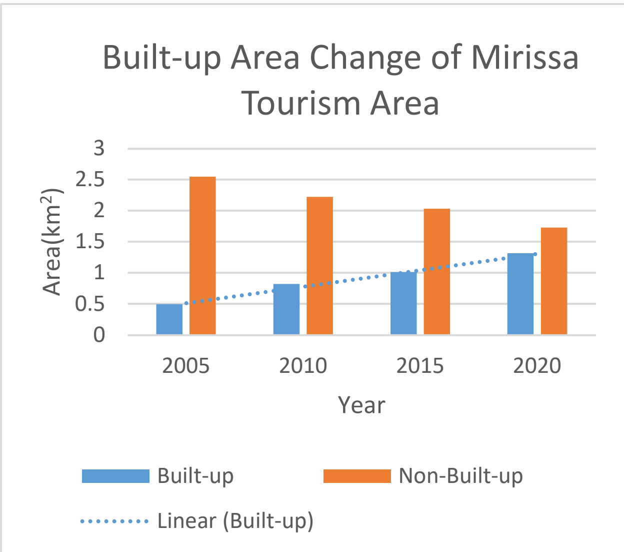

Figure 8: Built-Up Area Change Bar Chart

The provided figure illustrates the growth of the urban region over time and the corresponding changes in the ratio between built-up and non-built-up areas. The expansion of the built-up area has had a direct impact on the previously bare lands in the study area.

Table 1: Type of Data Used

No.	**Type of Data used**	**Resolution**	**Year**
1.	Landsat 4,5 TM	30m	2005
2.	Landsat 4,5 TM	30m	2010
3.	Landsat 8	30m	2015
4.	Landsat 8	30m	2020

The table provides information on the types of satellite images used in the study, along with their respective resolutions and the years they were captured. The primary source of the data was satellite imagery obtained from USGS Earth Explorer.

Table 2: Shannon's Entropy Calculation

GND Division	Pi*log(1/Pi)			
	2005	2010	2015	2020
Bandaramulla	0.08480	0.1266	0.139932	0.149479
Mirissa North	0.04568	0.07504	0.130627	0.151103
Mirissa South-1	0.09761	0.14231	0.099931	0.06339
Mirissa South-2	0.10837	0.14829	0.139778	0.14572
Mirissa Udupila	0.05826	0.08504	0.127294	0.150151
Shannon's Entropy	0.39473	0.57737	0.637562	0.659842

Table 3: Shannon's entropy with the magnitude of urban expansion change

Year	Shannon's entropy	ΔHn
2005	0.3947377	-
2010	0.577377118	0.182639
2015	0.637562	0.060185
2020	0.659842	0.02228
log(n)=0.69897		

The Mirissa Tourism City is composed of five GN (Grama Niladhari) divisions. Shannon's Entropy was calculated for each of these divisions individually, considering the years 2005, 2010, 2015, and 2020. Each GN division was treated as a distinct geographic entity. The total number of GN divisions in the study area is n=5, and the upper limit for entropy value is log (n) = 0.69897. Table 3 and Figure 9 present a summary of the calculated Shannon's Entropy values.

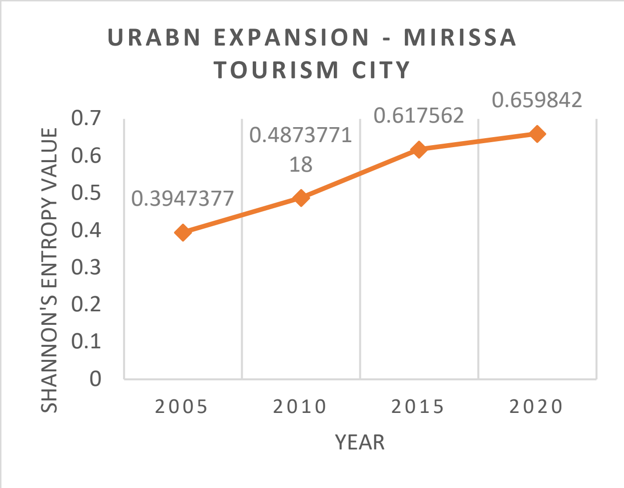

Figure 9: Urban Expansion through Shannon's Entropy Value - Mirissa Tourism City

The graph depicts the graphical representation of Shannon's Entropy values for the years 2005, 2010, 2015, and 2020. Over the period from 2005 to 2020, there is a noticeable upward trend in Shannon's Entropy values. This increase indicates a higher level of dispersion in the distribution of built-up areas, indicating urban expansion. The built-up regions in the area are becoming more spread out as the entropy values approach the maximum limit of 0.69897.

Examining the Shannon's Entropy calculation for the individual divisions reveals the urban expansion pattern in terms of the built-up area. The Bandaramulla division shows a gradual increase in Shannon's Entropy rate from 2005 to 2020. Similarly, Mirissa North exhibits a similar upward trend over the years. On the other hand, Mirissa South experiences significant expansion in 2010, followed by a decline in the subsequent 10 years. In the Mirissa Udupila division, there is a notable increase in the Shannon's Entropy rate. Overall, considering the entropy values for the entire region, it is evident that the area has undergone substantial urbanization and expansion over the past 15 years.

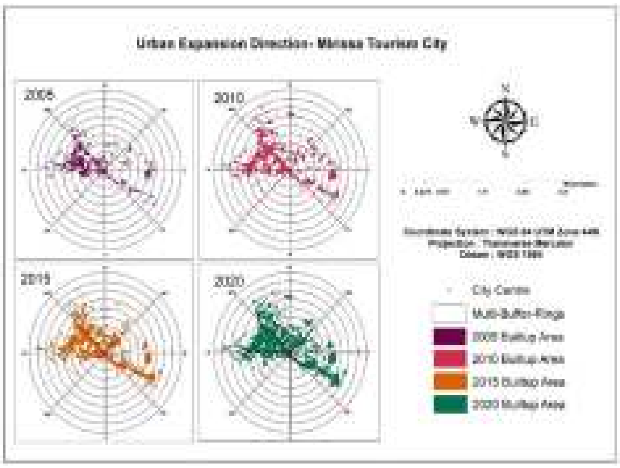

Figure 10: Urban Expansion Direction of Mirissa Tourism City

Figure 10 provides a visualization of the Urban Expansion Direction of Mirissa Tourism City. The city is bounded by a coastal belt extending from the South East East to the North West region, which plays a significant role in shaping the direction of urban expansion. The beautiful Mirissa beach serves as a major attraction and contributes to making Mirissa a prominent tourist destination in the southern region. Consequently, many tourism-related businesses and buildings are concentrated near the coastal line, resulting in the expansion of the urban area along the beachside. The figure demonstrates the evolution of the urban expansion direction in Mirissa Tourism City.

In 2005, the urban expansion primarily occurred in the West and North West directions. The built-up areas were mainly concentrated around the city center, with most of them located a short distance from the beachside. It is worth noting that in 2004, a significant portion of the built-up areas was destroyed due to the Tsunami disaster, which might have influenced the expansion direction observed in 2005.

By 2010, substantial construction had taken place over the previous five years, resulting in an expansion of the built-up area towards the West and North West regions. In 2015, there was a rapid and extensive expansion observed in the South West and North regions, indicating accelerated development. In 2020, considerable urban expansion was identified in all directions, indicating the continuous growth of the city.

Overall, the urban expansion direction of Mirissa Tourism City has been influenced by its coastal location and the proximity to the attractive Mirissa beach. The expansion has occurred primarily along the beachside, with different directions experiencing varying levels of growth in different years.

After analyzing the extensive evaluation of urban expansion in Mirissa Tourism City from 2005 to 2020, it is evident that the built-up area expanded predominantly from the beachside towards the city center. As a result, the density of the built-up area was generally higher in comparison to other regions. The findings of this case study provide insights into the urbanization patterns occurring along the beachside and shoreline in the Mirissa area.

Table 4: Accuracy Assessment

Accuracy Assessment of NDBI					
		2005	2010	2015	2020
Producer Accuracy (%)	Built-up	93.84615	92.40506	92.40506	90.19608
	Non Built-up	87.5	81.53846	81.53846	82.17822
User Accuracy (%)	Built-up	94.57364	85.71429	85.88235	83.63636
	Non Built-up	85.96491	95.89041	89.83051	89.24731
Overall Accuracy (%)		91.93548	89.72973	87.5	86.2069
Kappa Coeffient		0.809348	0.791506	0.745533	0.724024

Based on the results, an overall accuracy of over 85% was achieved in all the years of analysis. Additionally, Cohen's kappa coefficient, a measure commonly used to assess interrater reliability, can be applied in the test-retest context. In this context, the kappa coefficient quantifies the agreement between the frequencies of two data sets collected on different occasions (Chong Ho Yu, 2005). Generally, a kappa coefficient within the range of 0.6 or higher indicates a good level of agreement strength..

IV. CONCULSION

This research aimed to evaluate the urban expansion of Mirissa Tourism City using the methodology of Shannon's Entropy theorem and GIS technology. The study focused solely on the built-up areas of the city in the relevant years, which were extracted using satellite images obtained from USGS Earth Explorer. The integration of Shannon's Entropy theorem, remote sensing data, and GIS technology was instrumental in obtaining the final results. The analysis was conducted using ArcMap 10.5 software.

The built-up areas served as indicators of the urban expansion phenomenon, and the use of NDBI proved effective in extracting the urban expansion of the Mirissa Tourism City. The study relied on the changes in the built-up area to assess the expansion of urbanization in the area. The NDBI technique was employed to extract the relevant information from Landsat satellite images, and the thematic index-based extraction of NDBI proved to be the most accurate and efficient method for this purpose. While image classification methods are suitable for extracting multiple land cover and land use classes, this study specifically focused on built-up areas and found NDBI to be the optimal approach for automatic extraction.

Shannon's Entropy theory was employed as an indicator to quantify and evaluate urban sprawl and expansion in developing urban areas. The analysis clearly demonstrated the widening boundaries of Mirissa Tourism City over time. The utilization of satellite and remote sensing technology enables rapid monitoring, tracking, and analysis of urban expansion. The stages of 2005-2010, 2010-2015, and 2015-2020 in Mirissa Tourism City highlighted the land expansion status of each GN division, indicating a gradual expansion every five years with a few decreases due to changes in administrative divisions.

The findings of this research indicate that the accelerated urbanization process has contributed to continuous urban land use expansion in Mirissa Tourism City. The period of 2010-2015 witnessed a higher rate of urban expansion, likely attributed to the development of the tourism industry after the civil war in 2009. The accuracy assessment yielded an overall accuracy of 90.76 percent and an average kappa coefficient of 0.79975.

In conclusion, the combination of Shannon's Entropy theorem, remote sensing data, and GIS technology has provided valuable insights into the urban expansion of Mirissa Tourism City. The study demonstrates the effectiveness of using NDBI for built-up area extraction and the potential of satellite and remote sensing technology for monitoring and analyzing urban expansion.

The NDBI technique, in conjunction with Shannon's Entropy theorem and GIS technology, offers valuable opportunities for urban planning authorities and the tourism industry. It enables the extraction of built-up areas and the analysis of urban expansion, thereby facilitating effective city planning, control of sprawl, and sustainable development of the tourism sector. By utilizing this approach, decision-makers can gain insights into the spatial patterns of urban growth and make informed decisions regarding resource allocation and infrastructure development. Furthermore, the technique can aid tourism authorities in understanding the impact of urbanization on tourist destinations and assist in the formulation of sustainable tourism plans. To fully leverage the potential of remote sensing data in urban environments, it is important to continuously refine existing methods and explore innovative approaches.

V. REFERENCES

Boori, M. S. *et al.* (2015) 'Monitoring and modeling of urban sprawl through remote sensing and GIS in Kuala Lumpur, Malaysia', *Ecological Processes*, 4(1), pp. 1–10. doi: 10.1186/s13717-015-0040-2.

Claudius, R. The Mechanical Theory of Heat: With its Applications to the Steam-Engine and the Physical Properties of Bodies; J. Van Voorst: London, UK, 1867; p. 376

Firozjaei, M. K. *et al.* (2019) 'Automated Built-Up Extraction Index: A New Technique for Mapping Surface Built-Up Areas Using LANDSAT 8 OLI Imagery', *Remote Sensing 2019, Vol. 11, Page 1966*, 11(17), p. 1966. doi: 10.3390/RS11171966.

Foody, G. M. (2020) 'Explaining the unsuitability of the kappa coefficient in the assessment and comparison of the accuracy of thematic maps obtained by image classification', *Remote Sensing of Environment*, 239, p. 111630. doi: 10.1016/J.RSE.2019.111630.

Gohar, A. (2021) 'Tourism and Urbanization, An Interconnected Evolution', *Sustainability in Environment*, 6(3), p. p96. doi: 10.22158/se.v6n3p96.

Kavindya, A. R. A. *et al.* (1996) 'A.r anjali kavindya', (18).

Krishnaveni, K. S. and Anilkumar, P. P. (2020) 'MANAGING URBAN SPRAWL USING REMOTE SENSING and GIS', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 42(3/W11), pp. 59–66. doi: 10.5194/isprs-archives-XLII-3-W11-59-2020.

Kumasaru, J. (2019) 'Relationship between Travel Agents' Service Quality and Tourists Satisfaction with Special Reference to Mirissa Coastal Tourism Zone', 4(February).

Miscellaneous Indices Background (no date). Available at: https://www.l3harrisgeospatial.com/docs/backgroundotherindices.html (Accessed: 27 November 2021).

Mohapatra, S. N., Pani, P. and Sharma, M. (2014) 'Rapid Urban Expansion and Its Implications on Geomorphology: A Remote Sensing and GIS Based Study', *Geography Journal*, 2014, pp. 1–10. doi: 10.1155/2014/361459.

MULLINS, P. (1991) 'Tourism Urbanization', *International Journal of Urban and Regional Research*, 15(3), pp. 326–342. doi: 10.1111/J.1468-2427.1991.TB00642.X.

Wickramathilaka, N. V et al. (2021) 'Use of Satellite Images for Urban Form Detection : A Case Study of Ratnapura MC Area', (December), p. 2021.

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