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Monitoring of Urban Growth on Archaeological Landscape: A Case Study of Cultural Heritage Sites at Lalmai-Mainamati Region, Bangladesh

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[Abstract: The urbanization process directly impacts Cultural heritage sites because of population increase, migration, and infrastructural developments. After the establishment of Comilla University (2006), this process rapidly increases and affected regional architecture. This study intends to track the urbanization process' development dynamics over the past fifteen years in the Lalmai-Mainamati region and assess how it has affected the region's archaeological landscape and built heritage. Numerous significant archaeological sites and structures can be found in this vast area, and some of them are even included in the UNESCO list of world-built Heritage Sites. The Lalmai-Mainamati region's designated monuments have been mapped using GIS and remote sensing methods, and changes in land use over time between 2007 and 2022 have also been recorded. The final findings showed that the urban areas in the Lalmai-Mainamati region have grown significantly over the past 15 years, and as a cause, substantial density is predicted on the archaeological landscape located in the urban region.]

Keywords: Built heritage, GIS, Remote sensing, Urbanization, Land classes

Introduction

Globally, unprecedented urbanization has occurred over the past few decades, which is constituted by an empirical transition from rural to urban regions and urban land expansion. As a result, reconciling the needs of urbanization with the preservation of cultural heritage is today a problem that affects the entire world (Girard: 2009). Globally, sustainable development is highly regarded in this context. It represents a complex, diverse, and dynamic idea that also has elements related to commerce, community, evolution, and culture. Previously, the primary goal of sustainable development was to promote economic progress, and the preservation of ecosystems, culture, nature, and the surroundings was seen to that end. In addition to economic growth, social and cultural variables are now seen as vital components of the process of sustainable development (Mowla, 2019). All civilizations and cultures are seen as essential facilitators of sustainable development.

The most effective ways for information analysis, mapping, and retrieval are geographic information systems (GIS) that have been merged with remote sensing. GIS

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and remote sensing have been heavily utilized in cultural heritage conservation. Even though other research aims to monitor environmental and human threats to ancient landscapes, other researchers focus particularly on mapping contemporary urban growth and risk assessment near Cultural Heritage sites. To give local bodies access to spatial and cutting-edge technologies for effective decisions, it is also conceivable to consider merging these data sets with data from other sources, such as historical maps (Ciegis:2009). Attempts were made to employ prediction hazard models for monitoring dangers in already-existing archaeological sites despite the integrated use of remote sensing and GIS within archaeological study and management. To assist local authorities in analyzing any possible dangers to these assets, such prediction models may be used in urban areas in the future. The article reveals how remote sensing and GIS may be utilized for better management of cultural resources and urban planning while also illuminating some of the key traits they offer through a thorough case study.

Aims and Objectives in the Present Study

On the Lalmai Mainamati, urbanization is unavoidable and has a direct impact on the area's Geo-heritage and Built- heritage. This study intends to track the urbanization process' development dynamics over the past 15 years in the Lalmai Mainamati region and assess how it has affected the region's historical landscape and archaeological sites. The Lalmai Mainamati region's listed monuments have been mapped using GIS and remote sensing methods, and changes in land use through time from 2007 to 2022 have also been recorded.

Brief profile of the case study area

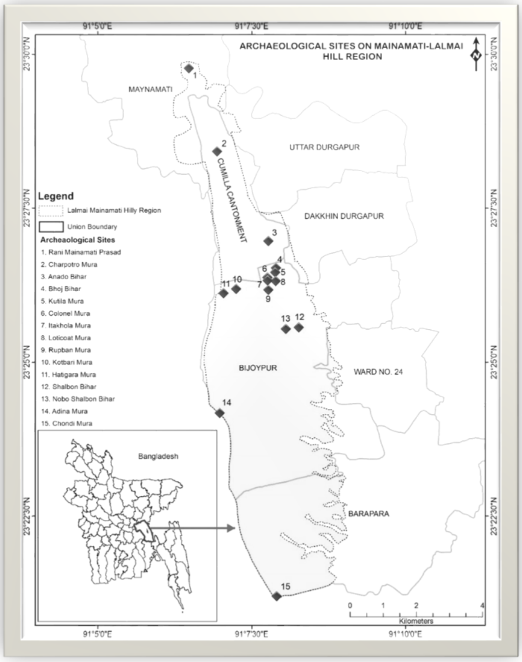
A very well-known name in our built heritage, Mainamati is a single ridge of low hills on the eastern borders of deltaic Bangladesh, about 8 km to the west of Cumilla town, where archaeological discoveries have uncovered highly valuable aspects (Imam: 2000). Due to the proximity to Cumilla Cantonment, it functions as a magnificent colonial cemetery. Thousands of Second World War burials may be found at the Mainamati Cemetery, which gives as a historical memorial. The hills are situated 8km to the west of Comilla and attain a height of 45.72m. in a few places, but the average elevation is 12.19m. above the plains; the heights peaks are Kalir Bazar and Chandimura and there are small springs near these peaks and Bijayanagar. They were formerly thickly wooded, but the forest has been considerably thinned in late years and the greater part of these slopes is now cultivated; the highest points only are still covered by a dense undergrowth (Imam, 2000:3-4). One of the most significant Buddhist archaeological sites in the area is located at Mainamati (Map:1). Through National Highway 1, Mainamati is located 114 kilometers from Dhaka and roughly 162 kilometers from Chittagong. Beside it, there is a Buddhist temple.

It is a relic of our distant past and consists of a tiny quantity of old, quasi-lateritic alluvium. The ridge runs around 17 km north-south from the Mainamati settlement on the Gumti River to Chandi Mura close to the Lalmai railway station. It is situated in the huge area of the rich lower Meghna basin (Imam: 2000). The ridge is roughly 4.5 kilometers broad at its widest points, and its tallest peaks reach a height of around 45 meters. The verdant, idyllic landscape of these highlands, which were previously heavily forested and home to a variety of species, has been severely harmed by contemporary developments.

The place's twin names, Lalmai and Mainamati, have a strong connection to the past: Lalmai, or the southern part, is the same as Lalambi-vana of the Chandra epigraphs, and Mainamati, or the northern part, is a reference to the name of the fabled Chandra queen "Maynamati," which is mentioned in local ballads and folk songs (Alam :1976). The location of the ancient political and cultural hub of ancient Vanga-Samatata (southeast Bengal) has now been conclusively proven by archaeological discoveries. Numerous monuments, mounds, excavated structures, and an extraordinary collection of stray discoveries from the area, amply demonstrate the splendor and enormity of that astonishing history. However, Mainamati is now more recognized for the Buddhist ruins that have been discovered during excavations (Alam :1976). The largest collection of ancient Buddhist antiquities in Bangladesh may be found right here.

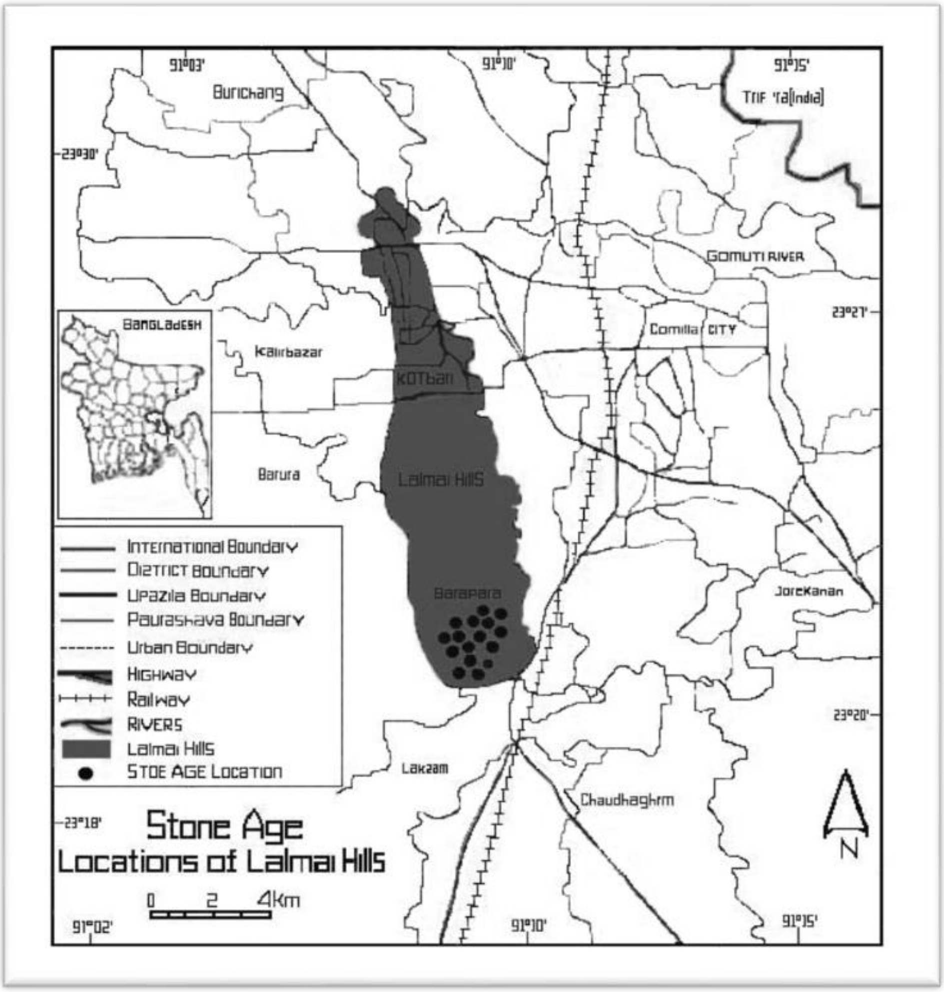
Table 1: Detail information on Latitude and Longitude to be used to prepare the Archaeological site map.

1	Archaeological sites	Latitude/ Longitude
2	Rani Mainamati prasad	23°29'46.8"N 91°06'28.6"E
3	Charpotra Mura	23°28'25.8"N 91°06'56.2"E
4	Anado Bihar	23°26'58.3"N 91°07'46.2"E
5	Kutila Mura	23°26'27.9"N 91°07'52.9"E
6	Colonel Mura	23°26'22.9"N 91°07'45.3"E
7	Itakhola Mura	23°26'20.0"N 91°07'45.5"E
8	Lolitakot Mura	23°26'19.4"N 91°07'53.3"E
9	Rupban Mura	23°26'10.9"N 91°07'46.3"E
10	Kotbari Mura	23°26'11.7"N 91°07'14.7"E
11	Hatigara Mura	23°26'07.6"N 91°07'02.5"E
12	Shalbon Bihar	23°25'34.2"N 91°08'15.9"E
13	Nobo Shalbon Bihar	23°25'34.2"N 91°08'15.9"E
14	Adina Mura	23°24'10.8"N 91°06'58.7"E
15	Chondi Mura	23°21'12.2"N 91°07'54.4"E



Map1: Archaeological sites on Lalmai-Mainamati (**source:** compiled by author)

Lalmai Hills range is an isolated narrow strip of small hills and all the locations of prehistoric archaeological records are located around the southern part roughly in a circular area within a radius of 4 km. It is included in the administrative area of Barapara Union of Comilla Sadar thana of Comilla district, Bangladesh. The geographical location of the site is roughly 23˚ 22′ to 23˚ 25′ North latitude and 91˚ 08′ to 91˚ 09′ East longitude. Dhaka-Chandpur Road and Dhaka-Chittagong railway tracks pass through the south of the location of prehistoric archaeological records (Map:2). In consideration of the location of the macroenvironmental context, the area is a part of the Chittagong-Tripura folded belt, which is counted as the youngest structural division of the Indo-Burman range.



Map 2: Stone Age Location of Lalmai hills (**Source:** author)

Data and Methods:

Remote Sensing techniques are generally used to quantify land use and land cover changes by analyzing satellite images. Landsat Satellite is a series of Earth-observing satellites which is jointly operated by NASA and the US Geological Survey. Four Landsat Satellite images were used to delineate the land use and land cover map and its changes from 2007 to 2022 in Mainamati-Lalmai Hill Region. We used Landsat 5 TM (Thematic Mapper) satellite image for 2007 and Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) satellite image for 2012 and two Landsat 8 OLI (Operational Land Imager) satellite imageries for 2017, 2022 to analyze LULC change in Mainamati-Lalmai Hill Region (Table 2). Landsat Satellite imageries were obtained from the United States Geological Survey's Earth observation website (https://earthexplorer.usgs.gov/).

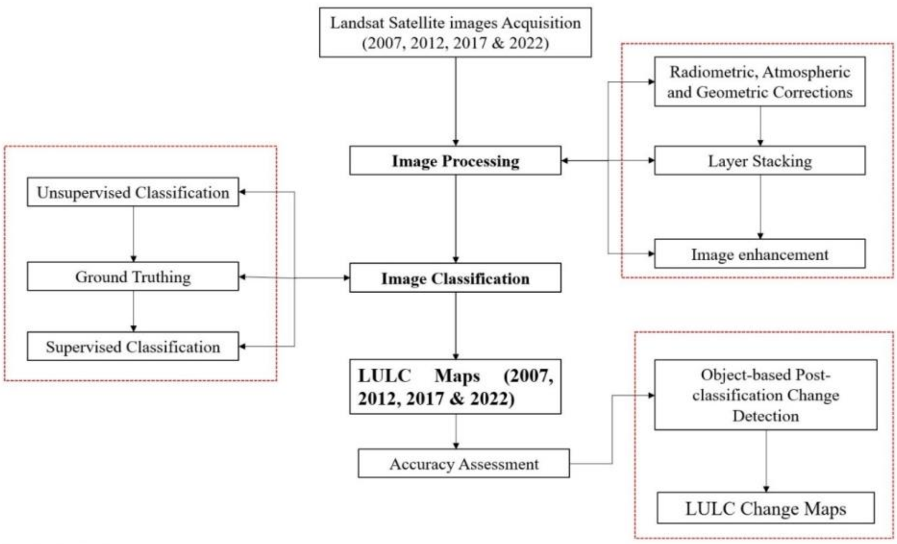
Table2: Detail information of satellite images used in this research

Satellite Imagery	Path/Row	Acquisition Date	Spatial Resolution (m)
Landsat 5 Thematic Mapper (TM)	137/44	22/01/2007	30m
Landsat 7 Enhanced Thematic Mapper Plus (ETM+)	137/44	13/02/2012	30m
Landsat 8 Operational Land Imager (OLI)	137/44	17/01/2017	30m
Landsat 8 Operational Land Imager (OLI)	137/44	31/01/2022	30m

Source: Compiled by author, 2022

Based on our study, a total of five land LULC classes which are orderly Agricultural Land, Built up Areas, Bare Land, Vegetation, and Water Bodies were identified.

Flow chart of methodology for LULC change



Source: Compiled by author, 2022

Definition of the Land Use Classes

In the study area, many forms of land use are visible. Divide the study area into five (05) classes in accordance with the mainland types for this research. The definition of all classes is given below.

Table 3: Land Classes and their definition

Class Name	Definition
Agricultural Land	Agricultural land use refers to the planting, growing, cultivating, and harvesting of crops for human or animal consumption. Agricultural land is also defined as the land area that is either arable, under permanent crops or under permanent pastures.
Bare Land	An area is a bare land if it does not have a dominating vegetation cover on at least 90% of the area or if lichens and moss cover it.
Built up Areas	The term "built-up areas" incorporates a wide range of different types of land uses, including residential areas, commercial areas, industrial areas, pits and mines, public service areas, mixed-use areas, communication, and transportation areas, technical infrastructure areas, recreation areas.
Vegetation	The term "vegetation" refers to the proportion of a specific area's soil that is occupied by natural and man-planted vegetation.
Water Bodies	Any considerable collection of water on the surface of the Earth is referred to as a water body. The phrase is most frequently used to refer to oceans, seas, and lakes, but it may also apply to smaller pools of water such as ponds and wetland areas.

Data Analysis and Results

In the table below, the five land use classes of the study area are shown at 5-year intervals from 2007 to 2022. In units of hectares (Ha), different land use classes in a particular year are often calculated. Agricultural Land, built-up Areas, Bare Land, Vegetation, and Water Bodies are the classes We've taken on land use.

Table 4: Area of Different Land use classes from 2007-2022

Class Name / Year	Area in Hectare (Ha)			
	2007	2012	2017	2022
Agricultural Land	520.59	497.085	362.803	329.52
Bare Land	163.002	140.963	115.721	106.87
Built up Areas	221.354	404.604	725.155	956.495
Vegetation	2670.44	2535.26	2380.07	2193.45
Water Bodies	56.6092	54.0412	48.2056	45.6249

Source: Compiled by author, 2022

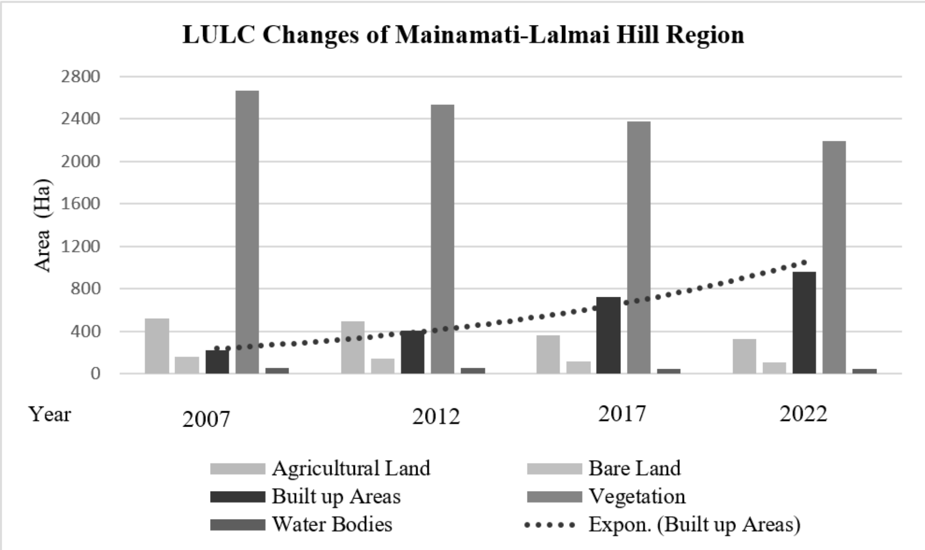


Figure1: LULC changes from 2007 to 2022 Source: Compiled by author, 2022

The above table and graphs indicate that in 2007, vegetation occupied the most significant portion of the study area, which was 2,670.44 ha That's around 73.53% of the entire area. In addition, there were 520.59 ha of agricultural land, 221.354 ha of built-up areas, 163.002 ha of bare land, and 56.56 ha of water bodies. In later years, as vegetation cover and other land types decreased, built-up areas continued to expand. Essentially, different types of land are changed into built-up areas. The vegetation decreased by approximately 130 ha in 2012 to 2535.25 ha. Apart from that, agricultural land, bare land, and water bodies are all decreasing significantly. However, the built-up areas doubled, and its total area is 404,604 ha.

We saw similar trends in the area change of land use classes in 2017. Built-up areas have replaced vegetation, agricultural land, bare land, and water bodies in this mountainous region.

In the last year of our study, 2022, we have seen a drastic change in land use classes since 2007. In 2007, where vegetation was 73.53% of the total area (2670.44 ha), in 2022, it decreased by 10% to 2193.45 ha. Besides, in the last 15 years, agricultural land decreased by 191.03 ha, bare land decreased by 56.13 ha, and water bodies decreased by 10.98 ha.

In the previous 15 years, the built-up areas alone have expanded by 3.5 times. In 2007, it was only 221.354 ha, which was only 6% of the total area. But in only 15 years, it has expanded to a total area of 956.495 ha, which is an increase of about 20%.

Table 5: Built-up Areas from 2007 to 2022

Class Name / Year	Area in Hectare (Ha)			
	2007	2012	2017	2022
Built up Areas	221.354	404.604	725.155	956.495

Source: Compiled by author, 2022

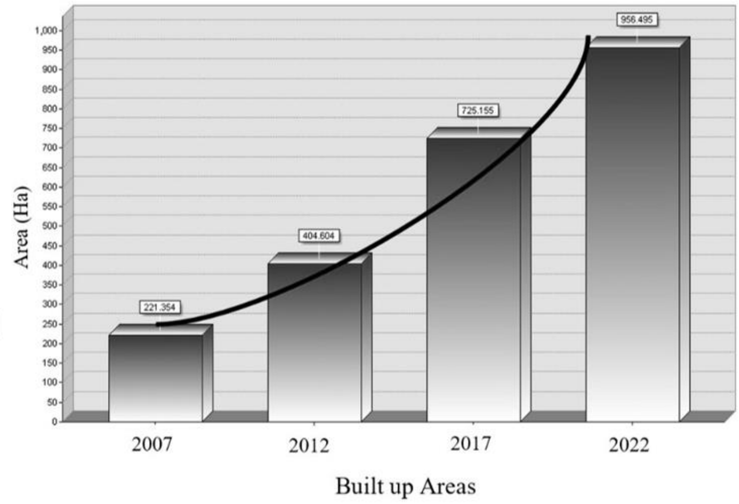


Figure 2: Built up area's changes from 2007 to 2022

Source: Compiled by author, 2022

The above table and graph illustrate mainly the changes in built-up areas from 2007 to 2022. During this time, built-up areas increased by around 735.141 ha. From 2007 to 2022, the rate of increase is over 77%. An exponential trendline was generated to demonstrate the increase of built-up areas over time.

Table 6: Land Classes changes to built-up areas between 2007 to 2022

Land Classes Changes to Built up Areas (2007-2022)	**Area in Hectare (Ha)**
Agricultural Land to Built up Areas	77.473456
Bare Land to Built up Areas	35.364485
Vegetation to Built up Areas	539.20373
Water Bodies to Built up Areas	11.647687

Water Bodies to Built up Areas

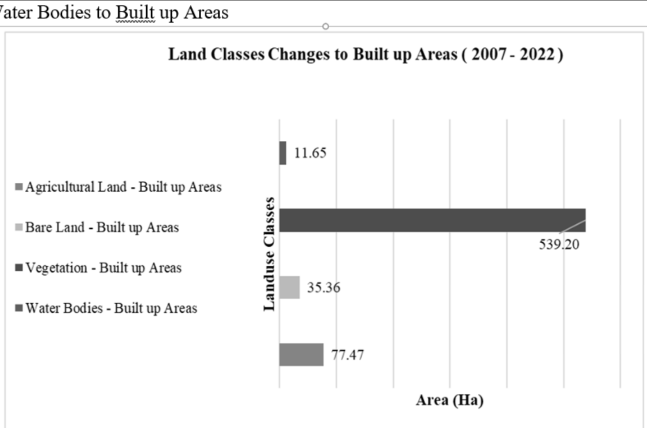
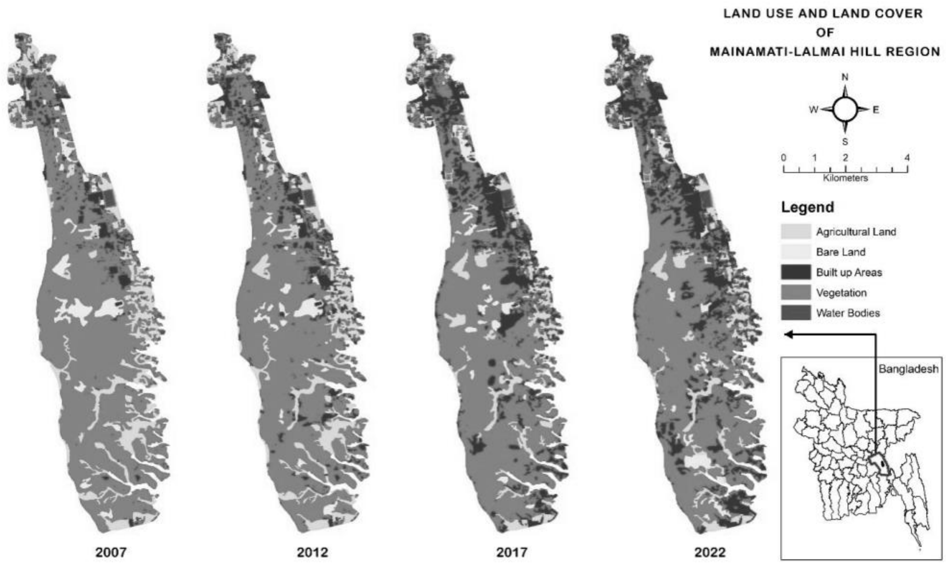


Figure 3: Land Classes changes to built up areas 2007 to 2022 Source: Compiled by author, 2022

The above table and graph mainly show the changes of other classes to built-up areas during the time. As the study aimed to identify the urbanization of the study area, we only focused on built-up area changes. Agricultural land, Bare land, Vegetation, and Water bodies turned into Built-up areas in a considerable number from 2007 to 2022. Almost 539.20 ha of vegetation changed to built-up areas, the highest changing amount among the classes. Besides this, there was 77.47 ha of agricultural land, 35.36 ha of bare land, and 11.65 ha of water bodies changed into built-up areas (Map:3).



Map 3: Land use and land cover of Lalmai-Mainamati (source: compiled by author)

Conclusion

The goal of this work is to emphasize the role that remote sensing and GIS techniques play in the monitoring of archaeological sites and monuments that have considerable historical and aesthetic value but are in threat of urban encroachment. The Lalmai-Mainamati region, chosen as the case study location, has undergone a significant transformation during the past 15 years. Urban growth has indeed expanded by 77% over the past 15 years, as determined using numerous categorization approaches applied to the multitemporal Landsat satellite collection.

Due to significant population shifts in the previously undeveloped areas, the urbanization process in the Lalmai-Mainamati area-town was relatively rapid and sudden. Additionally, this urbanization process has led to large archaeological excavations of preserved characters. Urban pressure can obliterate possible archaeological evidence in this way. Remote sensing techniques have the potential to find these buried archaeological features and can be utilized to safeguard these monuments. Moreover, non-destructive approaches for site examination are advised to be used wherever feasible, as noted by the Valetta Convention of the Council of Europe. In this way, the 11th European Archaeologies Concilium (EAC) Convention documented the importance of remote sensing methodologies in exploring, identifying, documenting, and observing the cultural and geo heritage in the living landscape, particularly when it comes to "a shift of focus from traditional archaeological sites to landscapes and to more broadly-based inventories of monument types" (Girard:2009).

One of the primary challenges to the monuments in this region is urban growth. According to predicted models like the Markov equations, more ancient sites will be at risk from this human danger soon. Archaeological excavations are the longest-running field activities globally in terms of time. Since they must deal with a significant quantity of information and do systematic work in the field and labs, archaeological research and systematic excavations are typically long-term endeavors. Non-destructive remote sensing methods may be used to look for potential archaeological remains using these kinds of prediction models. Such findings might be included in regional urban planning guidelines for preserving ancient sites. Urban pressure may generate a range of specific difficulties for monuments and sites of cultural importance.

This is a significant message of urgency for decision-makers to take quick action to safeguard the ancient sites and the subsoil underneath them. The Cultural Resource Management (CRM) authority can benefit greatly from the suggested procedural method when merged with remote sensing research (satellite, aerial, geophysics, etc.) to manage cultural resources in a consistent and non-destructive manner. Urbanization's impact on the Lalmai-Mainamati region's ancient heritage is a complex problem that must be solved quickly. On the one hand, we don't know very much about the area's architectural historical sites; on the other, they have altered quickly through time.

In order to turn these changes into timely possibilities for assuring the protection of architectural history and the sustainable development of the urban ecosystem through proper management and direction, policymakers should evaluate these changes from a development viewpoint. Using GIS data from 2008 to 2022, this study seeks to examine the trends in urbanization in the 52 Buddhist monasteries' surrounding areas 2008 to 2022. Using open remote sensing data allows for the cost-effective measurement of macro-scale changes.

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[**সার- সংক্ষেপ:** প্রাচীন ভূমিরূপ ও স্থাপত্যিক নিদর্শনসমহ প্রাকৃতিক ও মানবসৃষ্ট বিপত্তির সম্মুখীন হয়ে থাকে। বিশেষ করে জনসংখ্যা বৃদ্ধি, অপরিকল্পিত নগরায়ন ও অবকাঠামোগত উন্নয়ন প্রাচীন ভূমিরূপ ও স্থাপত্যিক নিদর্শনগুলোর উপর সরাসরি প্রভাব ফেলে। এই গবেষণায় লালমাই-ময়নামতি অঞ্চলের ২০০৭ থেকে ২০২২ পর্যন্ত গত পনেরো বছরের নগরায়ন প্রক্রিয়া বিকাশের গতিশীলতা পর্যবেক্ষন করা হয়েছে এবং প্রাচীন ভূমিরূপ ও স্থাপত্যের উপর এর প্রভাব বিশ্লেষণ করা হয়েছে। লালমাই-ময়নামতি অঞ্চলে প্রগৈতিহাসিক ও ঐতিহাসিক বিভিন্ন নিদর্শন পাওয়া গেছে যার মধ্যে অনেকগুলো নিদর্শন বিশ্ব ঐতিহ্যের তালিকাভূক্ত। জি আই এস এবং রিমোট সেন্সিং পদ্ধতি ব্যবহার করে প্রত্নতাত্ত্বিক স্থান গুলোর মানচিত্রায়ন করা হয়েছে এবং ২০০৭ হতে ২০২২ সালের মধ্যে সময়ের সাথে সাথে ভূমি ব্যবহারের পরিবর্তনগুলো পর্যবেক্ষন করা হয়েছে। গবেষণায় দেখা গেছে, গত পনেরো বছরে এই অঞ্চলের নগরায়ন প্রক্রিয়া উল্লেখযোগ্য ভাবে বৃদ্ধি পেয়েছে এবং যার প্রভাব প্রত্যক্ষভাবে আঞ্চলিক প্রাচীন স্থাপত্যিক নিদর্শন ও ভূমিরূপের উপর পড়েছে।]