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# Assessment Of Land-Use And Land Cover Dynamics Of Loktak Lake (Central Zone) And Its Surrounding Using Geo-Spatial Technology

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***Abstract***
*Loktak Lake, the largest freshwater lake in North-Eastern India and a Ramsar wetland of international importance, has undergone significant land use/land cover (LULC) changes in recent decades due to natural dynamics and human activities. This study analyses spatio-temporal LULC changes in the Central Zone of the Loktak Lake from 2003 to 2023 using multitemporal Landsat data (Landsat-7 ETM+ and Landsat-8 OLI). Supervised maximum likelihood classification was applied in ERDAS, supported by GIS analysis in ArcGIS and QGIS, to classify four LULC categories: water bodies, vegetation, agricultural land, and built-up areas. Classification accuracy was evaluated using confusion matrices and Kappa statistics, with overall accuracies of 84.33%, 85.66%, and 87.00% for 2003, 2013, and 2023 respectively. The results indicate a marked decline in vegetation (−20.74 sq. km) and agricultural land (−6.40 sq. km), alongside a substantial increase in built-up area (+16.62 sq. km) and a net increase in water bodies (+10.51 sq. km). These changes are primarily driven by phumdi clearance, expansion of settlements, and fish farming activities, reflecting growing anthropogenic pressure on the Loktak Lake ecosystem.*
***Keywords:*** *LULC, LULC Change, GIS, LDA, Accuracy assessment, Kappa Coefficient.*

## INTRODUCTION

Wetland, the key ingredient that links water and land, is used as a source of water since ancient times. It is also the biological supermarket that provides a home to a lot of different species of plants and animals. It is collectively referred to as marshes, swamps, bogs, and similar areas(Kiran & Ramachandra, 1999). It is a distinct ecosystem that is flooded by water either permanently or seasonally where oxygen-free processes prevail (Keddy, 2010). It is also an ecosystem that is inundated by water resulting in the production of soil-dominated anaerobic and aerobic plants, which in turn adapts to flooding. Thus, the RAMSAR convention (1971) defines wetlands as "an area of marsh, fern peatland, or water which may be natural, artificial, permanent, and temporary with water that is static on flowing fresh, brackish, or salt including areas of marine water in which the depth is not below 6 meters".

Loktak, the largest freshwater lake in North-Eastern India, is also called the 'floating lake' because of floating 'phumdis' (local name for floating mats) in it. The Loktak Lake hold a significant place as it plays an important role in the economy of the state. Under Ramsar Convention Loktak lake was designated as wetland of International Importance under in 1990 because of its biological abundance, where naturally (floating vegetation) phumdis covers. The lake extensively and is a specialized habitat for many biotas besides being useful to the local people in many ways. The Meitei Community residing near the lake depends on fishing, tourism, etc. (Gupta et al., 2024; Janetius et al., 2022). Many fishermen live on phumsangs which is the floating hut, constructed on the phumdis(Kangabam et al., 2015). So, it is considered as 'lifeline of Manipur' for its ecological richness and economic importance (Bharati et al.,2017: Gupta et al., 2024). It serves as the main source of water for drinking, generation of power and irrigation. Still, Loktak Lake, which acts as a profitable security for the region is under severe stress As a result, governments and communities worldwide have prioritized the conservation and sustainable management of their lakes(Brown et al., 1987).

### Study Area

The present study covers the Central zone of the Loktak Lake which is located between 93° 46′ and 93° 55′ E longitudes and 24° 25′ to 24° 42′ N latitudes. The Loktak Lake is divided into three zones namely the Northern zone, the Central zone and the Southern Zone (Trisal, C. L., & Manihar, T., 2004). The Study is mainly confined to the Central Zone. Geomorphologically, the lake is a floodplain wetland of Manipur River, which is flooded by its lateral flows as well as backflow of water from Sugunu hump (shown in Fig. 1). The lake is oval-shaped with a maximum length and width of 32 km and 13 km respectively. The depth of the lake varies between 0.5 meter and 4.6 meter with an average recorded at 2.7m. The lake covers an area of 287 sq. km which is mainly dictated by the maintenance

of the water level at Ithai at 768.5 m above MSL. There are 14 hills located in the Lake varying in size and elevation and appear as islands in the southern part of the lake. The most prominent among these are Sendra, Ithing, and Thanga islands. The Keibul Lamjao National Park located in the southern part of the lake is a unique floating wildlife reserve and is the refuge of the highly endangered brow antlered deer, locally called Sangai.

According to the 2011 Census of India, the population sizes of the sixteen villages and towns surrounding Loktak Lake vary significantly. With 14,316 residents, Thanga is the most populated of the island and lake-based villages, followed by Karang (1,859) and Ithing (1,832), while Champu Khangpok, a floating (phumdi) village, has a comparatively tiny population of 832. Wangoo (6,134), Laphupat Tera (4,129), Thinungei (4,027), Potsangbam (3,721), and Phoubakchao (3,588) are examples of shoreline and surrounding villages with somewhat high rural populations reliant on agricultural and lake resources. Phubala (2,800), Khoijuman Khunou (2,738), Sunusiphai (1,561), Nongmaikhong (989), Tengkhal Khunou (964), and Khordak (832) are examples of smaller settlements with relatively small populations. Furthermore, Ningthoukhong town had a population of 13,078, and its neighboring villages, Ningthoukhong Awang (1,168) and Ningthoukhong Kha (844), together constitute a significant urban–rural interface on the lake's southwest edge. It is the largest natural freshwater lake in the northeastern region and plays an important role in providing ecological and economic security to the region. A large population living in and around the lake depends upon its resources for their sustenance. The lake has also been the breeding ground of several riverine fishes and continues to be a vital fisheries resource (Gupta et al., 2024). It supports a significant population of migratory and resident waterfowl. Further, the confluence of several rivers, particularly Chakpi, is responsible for the inundation of large areas. The lake earlier used to experience large fluctuations in the water level during the year and several pats with the Loktak were distinct during the low water phase and merged into one sheet of water during high floods.

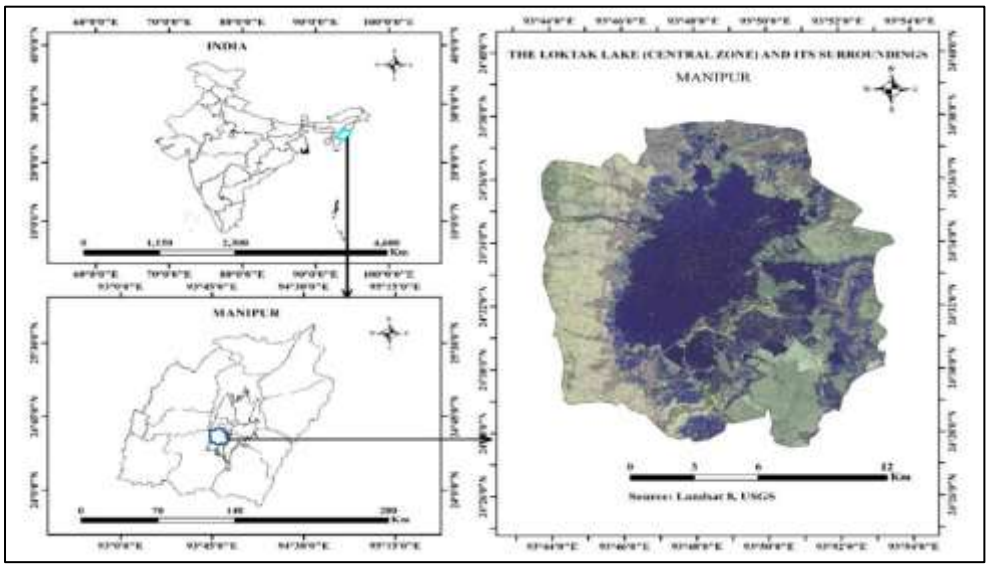


Fig.1: Study Area: Central Zone of Loktak Lake

**Objectives of The Study**

The study is primarily focused on the following objectives.

1. To identify and analyze the Land Use and Land Cover pattern during the period of 2003 to 2023 in the central zone of the Loktak lake.
2. To examine the changes in Land Use and Land Cover during the same period on the study area.

## MATERIALS AND METHODS

**Sources of Data:** The present study is basically based on the secondary data of the satellite images. The satellite images of Satellite Imagery-Landsat 7 (2003), Landsat 8 (2013) and Landsat 8 (2023) obtained from USGS Earth Explorer Dataset and Google Earth Imagery, Survey of India –Toposheet No.83H14 of the study area are used for the based years 2003, 2013 and 2023 with the same vegetative season, lesser cloud cover.

**Methods:** The pre-image processing techniques such as radiometric correction and atmospheric correction are reckoned in the GIS. Maximum Likelihood Supervised Classification has been employed to generate the land use and land cover of the study area using Erdas software. Satellite remote sensing is widely recognized as a valuable tool for providing insights into diverse aspects of lakes, including their physical, chemical, and biological characteristics (Usali & Ismail, 2010). The accuracy of the LULC is assessed using Kappa coefficient technique. User's accuracy and

producer's accuracy are also generated using the same method. The statistical techniques applied are expressed as follow.

$$\text{Kappa Coefficient} = \frac{(\text{Total accuracy} - \text{Random accuracy})}{(1 - \text{Random accuracy})}$$

$$\text{User Accuracy} = \frac{Total\ no.of\ true\ classified\ value\ in\ each\ category}{Total\ no.\ of\ Reference\ value\ in\ the\ category(Row\ Total)} x100$$

$$\text{Producer Accuracy} = \frac{Total\ no.of\ true\ classified\ value\ in\ each\ category}{Total\ no.\ of\ Reference\ value\ in\ the\ category(Column\ Total)} x100$$

$$\text{Over all Accuracy} = \frac{Total\ no.of\ true\ classified\ value}{Total\ no.\ of\ Reference\ value} x100$$

The Kappa Coefficient (κ) ranges from -1 to +1 indicating agreement beyond chance, with 0 meaning agreement is purely random and +1 signifying perfect agreement. Interpretation generally follows: <0 (poor), 0.01-0.20 (slight), 0.21-0.40 (fair), 0.41-0.60 (moderate), 0.61-0.80 (substantial), and 0.81-1.00 (almost perfect) agreement.
The study generated map of LULC of the study area using random accuracy assessment point in ArcGIS 10.8 aided by Google Earth Imagery and acquired Satellite Image. The pattern of LULC and the inter-categorical Land-use/Land Cover change have been analyzed using the QGIS 3.3 software. From the land use and land cover data generated, three intervals i.e. (2003 - 2013), (2013 - 2023) and overall (2003 – 2023) to detect the LULC change are examined on four classes of land use viz. Water bodies, Vegetation, Agricultural Land and Built up.

## RESULT AND DISCUSSION

Land use and land cover pattern in 2003 which is generated from Landsat 7(ETM+) are classified into 4 classes that are water bodies, vegetation, agricultural land and built-up areas shown in the table 1 and in figure 1. The study area is occupied by vegetation with the area of 130.68sq.km. accouting 55.56%, water bodies of 49.04 sq. km. sharing with 49.04%, agricultural land with 45.23 sq. km occupied by 19.23% and built up with 10.27 sq.km. sharing 4.37%. It is found that the largest portion of the study area is occupied by vegetation due to extensive growth of the weed (***Phumdis***) inside the Loktak Lake.
In 2013 Land use/Cover Pattern, vegetation occupied 97.34 sq.km. sharing 41.38 percent and followed by water bodies of 76.69 sq. km.sq. with 32.61 percent, agricultural land of 46.07 sq. km 19.59 percent and built up 15.11 sq.km. with 6.42 percent as the lowest land-use category. It is revealed that there is huge increased in waterbodies coverage due to clearance of the Phumdis inside the Loktak Lake by Loktak Development Authority (LDA). Built up area has also shown an increase of 4.84 sq. km from 2003 to 2013.

Table. 1: LULC Pattern of Central Zone of Loktak Lake, 2003, 2013 and 2023

| Landuse Category | 2003 | | 2013 | | 2023 | |
|---|---|---|---|---|---|---|
| | Area (sq.km) | Area (%) | Area(sq.km) | Area (%) | Area (sq.km) | Area (%) |
| Water bodies | 49.04 | 20.85 | 76.69 | 32.61 | 59.55 | 25.32 |
| Vegetation | 130.68 | 55.56 | 97.34 | 41.38 | 109.95 | 46.74 |
| Agricultural Land | 45.23 | 19.23 | 46.08 | 19.59 | 38.82 | 16.50 |
| Built-up | 10.27 | 4.37 | 15.11 | 6.42 | 26.90 | 11.43 |
| **Total** | **235.22** | | **235.22** | | **235.22** | |

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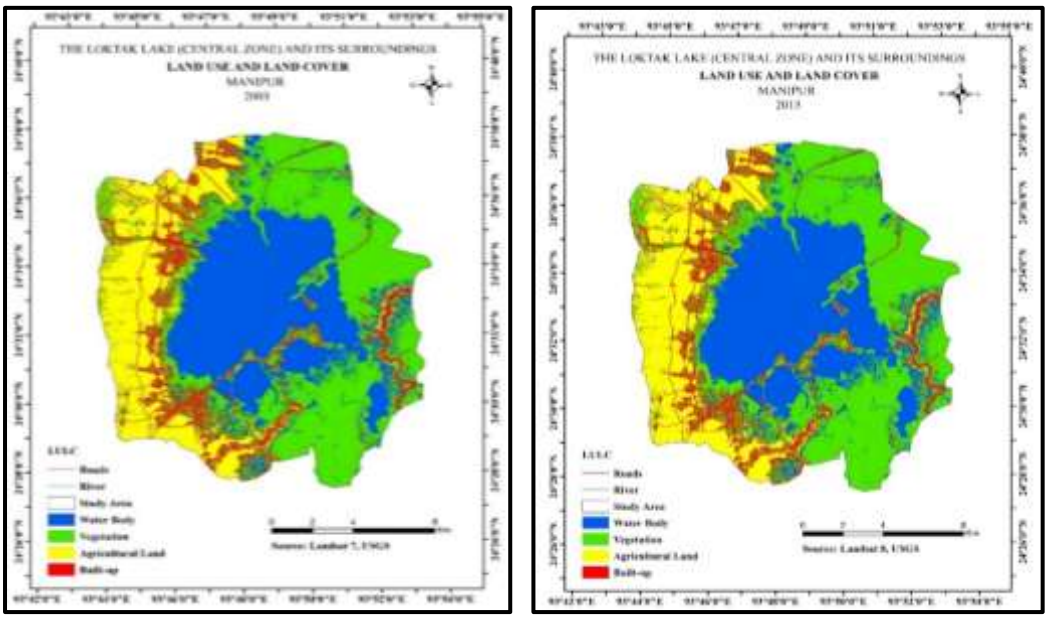


Fig 1. Land Use and Land Cover , Central Zone Loktak Lake, 2003 & 2013

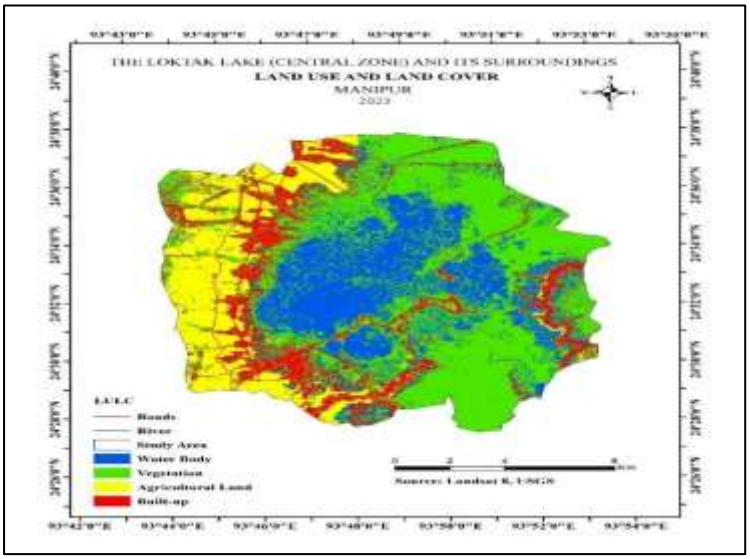


Fig 2. Land Use and Land Cover, Central Zone Loktak Lake, 2023

The Land Use/Cover of the study area drawn from Landsat 8 (2023) shows a land-use change profile of the above categories of land in 2023. Among landuse categories, vegetation is marked as the leading type of use with 109.95 sq.km. accounting 46.74 percent of total and followed by water bodies with area of 59.55 sq.km. sharing 25.32 percent and agricultural land 16.50 percent. The built up area is observed as least land type with 11.43 percent. The study area was largely occupied by Vegetation due to growth of weed and increasing number of Lake Dwellers.

**Accuracy Assessment of Landuse land Cover**

Accuracy assessment is done using Panchromatic enhanced acquired image with spatial resolution (15 Meters) satellite imagery of Landsat 7 (2003) and Landsat 8(2013and 2023). A total 300 random points generated by ArcGIS is used for accuracy Assessment. Due to the lack of availability of clear google earth images, accuracy assessment of 2003 is done only using the Landsat 7 image and for 2013 and 2023 Landsat 8 images as well as google earth Imagery are used for accuracy assessment as shown in table 2.

Table 2: Accuracy Assessment Error Matrix of LULC image 2003, 2013 and 2023

| **Year** | Land Categories | Waterbodies | Vegetation | Agricultural Land | Built-up | Total | User accuracy |
|---|---|---|---|---|---|---|---|
| **2003** | Waterbodies | 55 | 7 | 2 | 3 | 67 | 82.09% |
| | Vegetation | 20 | 132 | 5 | 2 | 159 | 83.02% |
| | Agricultural Land | 0 | 2 | 56 | 1 | 59 | 94.92% |
| | Built-up | 1 | 2 | 2 | 10 | 15 | 66.67% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Producer accuracy | 72.37% | 92.31% | 86.15% | 62.50% | | |
| 2013 | Waterbodies | 91 | 8 | 0 | 0 | 99 | 91.92% |
| | Vegetation | 14 | 103 | 7 | 5 | 129 | 79.84% |
| | Agricultural Land | 0 | 3 | 45 | 2 | 50 | 90.00% |
| | Built-up | 3 | 0 | 1 | 18 | 22 | 81.82% |
| | Producer accuracy | 84.25% | 90.35% | 84.90% | 72.00% | | |
| 2023 | Waterbodies | 75 | 6 | 0 | 0 | 81 | 0.92 |
| | Vegetation | 21 | 111 | 2 | 0 | 134 | 0.83 |
| | Agricultural Land | 0 | 1 | 46 | 1 | 48 | 0.96 |
| | Built-up | 2 | 2 | 4 | 29 | 37 | 0.78 |
| | Producer accuracy | 76.53 | 92.50 | 94.46 | 96.66 | | |

The table 2 presented the overall accuracy of the classified image is computed as 84.33, 85.66 and 87.00 percent for 2003, 2013 and 2023 respectively. From the above table, the Kappa coefficient of the classified Image are 0.75, 0.78 and 0.81 for 2003, 2013 and 2023 respectively. Kappa coefficient of land use and land cover of the area for 2013 is found to be 0.78. The result indicates that the values of kappa coefficient of 2003 and 2013 fall in the substantial category and that of 2023 signifies perfect agreement. In simply, the computed values prove the classification of LULC is significant and reliable.

**Land use/Cover Change**

All three images of Landsat satellite have been compared to examine the changes in LULC during 2003 – 2023 (Table 9). The change detection analysis has been done on the images and the time period is divided into two epochs i.e., 2003-2013 and 2013-2023. The first epoch is characterized by the increase in built up area and water bodies while agricultural land and Vegetation cover is decreasing. Using the classified LULC of 2003-2013 the persistence and change Map and transformation Matrix is generated in QGIS environment. Likewise, the persistence and transformation matrix is generated for 2013-2023. And to analyze the overall change and persistence along the year the persistence and Change map as well as transformation matrix is generated for 2003-2023. The above said changes and transformation matrix is given in the following tables 4,5& 6.

Table 3: Land Use/Cover change (2003-2023)

| LULC classes | 2003-2013 | | 2013-2023 | | 2003-2023 | |
|---|---|---|---|---|---|---|
| | Change | Percent | Change | Percent | Change | Percent |
| Water bodies | 27.66 | 11.76 | -17.14 | -7.29 | 10.51 | 4.47 |
| Vegetation | -33.34 | -14.18 | 12.61 | 5.36 | -20.74 | -8.82 |
| Agricultural Land | 0.85 | 0.36 | -7.25 | -3.08 | -6.40 | -2.72 |
| Built-up | 4.84 | 2.06 | 11.78 | 5.01 | 16.62 | 7.07 |

Table 4: Land Use/Cover Transformation Matrix in sq. km. (2003-2013)

| LULC | **Water bodies** | **Vegetation** | **Agricultural Land** | **Built up** | **Loss (sq.km.)** | **2003** |
|---|---|---|---|---|---|---|
| Water bodies | 32.35 | 15.18 | 0.27 | 1.25 | 16.69 | 49.04 |
| Vegetation | 44.07 | 75.97 | 3.26 | 7.38 | 54.71 | 130.68 |
| Agricultural Land | 0.07 | 3.38 | 39.14 | 2.64 | 6.08 | 45.23 |
| Built-up | 0.20 | 2.82 | 3.41 | 3.84 | 6.44 | 10.27 |
| Gain (sq.km.) | 44.35 | 21.37 | 6.93 | 11.28 | 83.92 | |
| 2013 | 76.69 | 97.34 | 46.07 | 15.11 | | 235.22 |
| Overall Increase/decrease | 27.66 | -33.34 | 0.85 | 4.48 | | |

**LULC Changes 2003 to 2013**

**Water bodies:** The water bodies coverage overall increased by 27.66 sq km, which accounts 11.76% of the change. The significant change in the occupation of water bodies is due to clearance of ***Phumdis*** under a project by the Loktak development authority.

**Vegetation:** The overall vegetation coverage decrease by 33.34 sq.km. which accounts -14.18% of the change. As stated above ***Phumdis*** were cleared by Loktak Development authority, this is the main reason for the decrease in coverage of vegetation while other reason are the expansion of built up and agricultural areas.

**Agricultural Land:** There is an overall increase of 0.85 sq km in agricultural land which accounts 0.36% of the change. This is due to the transformation of vegetation area to agricultural land.
**Built-up:** There is an overall increase of 2.06 sq km in built-up area which accounts 2.06% of the Change. As the population keeps on increasing, there will be an increase in built up areas to meet the basic requirement for residential purposes and establishment of facilities and amenities.

Table 5: Land Use/Cover Transformation Matrix in Sq. Km. (2013-2023)

| LULC | **Water bodies** | **Vegetation** | **Agricultural Land** | **Built up** | **Loss** | **2003** |
|---|---|---|---|---|---|---|
| Water bodies | 46.99 | 28.20 | 0.13 | 1.37 | 29.70 | 76.69 |
| Vegetation | 11.03 | 74.88 | 1.82 | 9.61 | 22.46 | 97.34 |
| Agricultural Land | 1.02 | 5.73 | 36.05 | 3.28 | 10.03 | 46.08 |
| Built-up | 0.51 | 1.14 | 0.82 | 12.64 | 2.47 | 15.11 |
| Gain | 12.56 | 35.07 | 2.78 | 14.25 | 64.66 | |
| 2023 | 59.55 | 109.95 | 38.82 | 26.90 | | 235.22 |
| Overall Increase/decrease | -17.14 | 12.31 | -7.25 | 11.78 | | |

**LULC Change 2013-2023**
**Water bodies:** There is significant decrease in water bodies coverage due to increase in vegetation inside the Loktak Lake. A decrease of 17.14 sq.km. had been observed which accounts 7.29% of the change.

Table 6: Land Use/Cover Transformation Matrix in Sq. Km. (2013-2023)

| LULC | Water bodies | Vegetation | Agricultural Land | Built up | Loss | 2003 |
|---|---|---|---|---|---|---|
| Water bodies | 23.74 | 22.69 | 0.29 | 2.32 | 25.29 | 49.04 |
| Vegetation | 34.32 | 79.28 | 2.45 | 14.63 | 51.40 | 130.68 |
| Agricultural Land | 1.11 | 5.83 | 33.82 | 4.47 | 11.40 | 45.23 |
| Built-up | 0.39 | 2.15 | 2.26 | 5.48 | 4.79 | 10.28 |
| Gain | 35.82 | 30.67 | 5.00 | 21.41 | | |
| 2023 | 59.55 | 109.95 | 38.82 | 26.90 | | 235.22 |
| Overall Increase/decrease | 10.51 | -20.74 | -6.40 | 16.62 | | |

**Vegetation:** The vegetation coverage increase by 12.61 sq.km. which accounts 5.36% of the change. The increase in Vegetation attributes to the growth of ***Phumdis*** inside the Loktak Lake.
**Agricultural Land:** There is a decrease of 7.25 Sq Km in agricultural land which accounts 3.08% of the change. This is due to the transformation of agricultural area to built-up areas.

**Built-up:**Tere is an overall increase of 11.78 Sq km in built-up area which accounts 5.01% of the Change. Maximum transition of vegetation has been observed to built-up.

**LULC Change 2003-2023**
The map showing LULC changes from 2003-2023 is shown in figure 3. The details of transformation are as followed:
**Water bodies:** A dynamic interchange between waterbodies and vegetation has been observed. It solely depends on season of vegetation growth and human intervention. So, Maximum change is observed between water bodies and Vegetation. There is increase in water bodies coverage inside the Loktak Lake. The increase in the number of lake dwellers and fish farming practice are the reason for the increase of built up area inside the Loktak lake. An increase of 10.51 sq.km. had been observed which accounts 4.47% of the change.
**Vegetation:** As stated above there has been a dynamic interchange between vegetation and water bodies. There is a huge decrease in coverage of vegetation over the years. The interchange of vegetation into water solely depends on season of vegetation growth and Human intervention. Other than vegetation to water exchange, the loss of vegetation is due to expansion of built up area and agricultural Land. There is an overall decrease of 20.74 sqkm. of vegetation coverage which accounts 8.82% of the Change.
**Agricultural Land:** Conversion of Agricultural Land into Built-up area is very common phenomena in the study area. There is a decrease of 6.40 Sq.Km. in agricultural land which accounts 2.72% of the change. This is due to the transformation of agricultural area to built-up areas and rejuvenation of forest area in the southern part of the study region which happened to be foothill. Some area which was occupied for shifting cultivation has converted into forest. The cultural habit of fencing the boundary of residential area with bamboos, trees or shrubs may be reason for conversion of agricultural land to vegetation.

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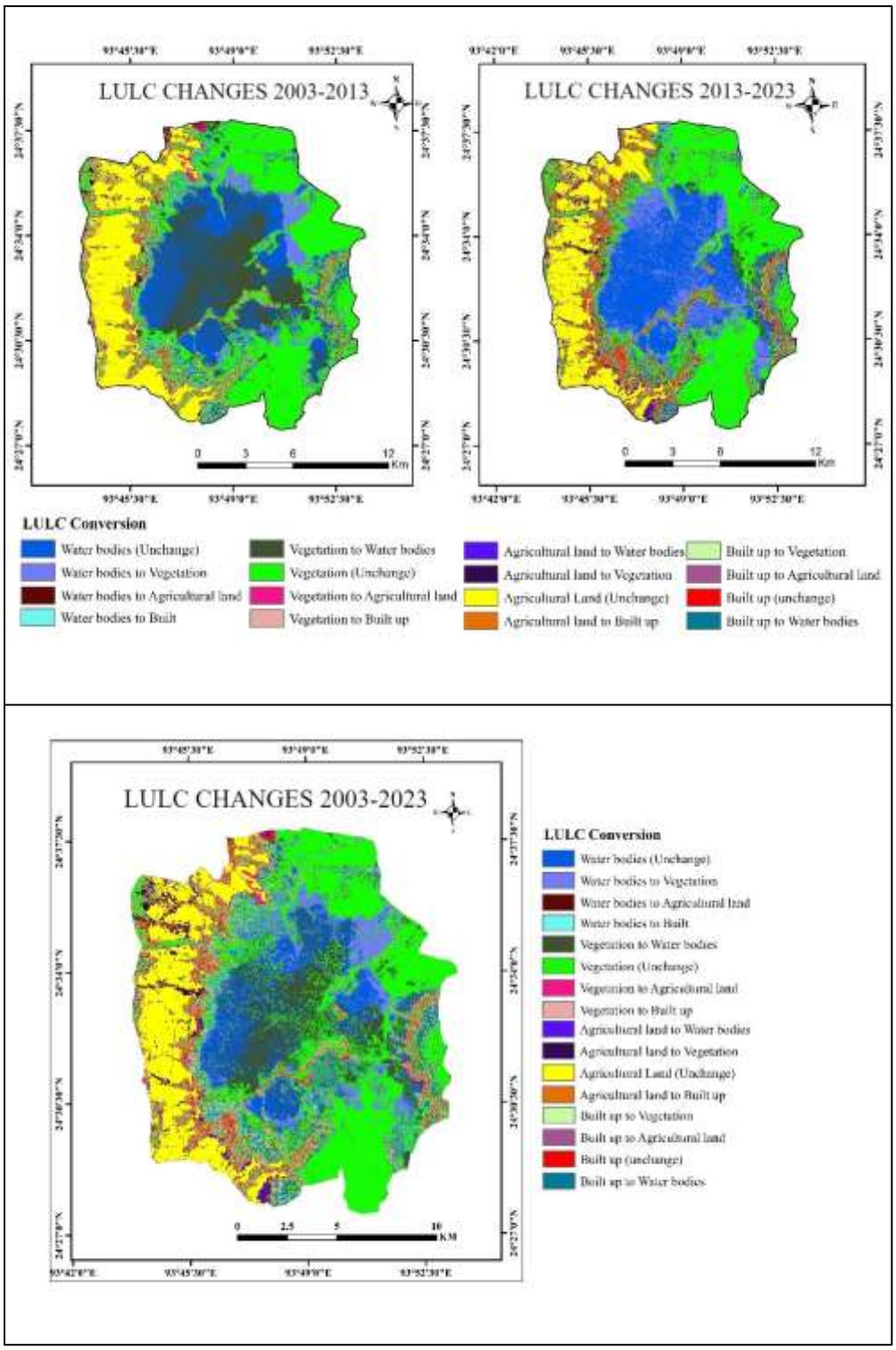


**Fig 3: Land Use/Cover Change (2003-2023)**

**Built-up:** As the population keeps on increasing, there will be an increase in built up areas to meet the basic requirement for residential purposes and establishment of facilities and amenities such as roads, shops, malls, parking areas etc. There is increasing trend of built up area over the years.

Over the 20 years there is an overall increase of 16.62 sq.km in built-up area which accounts 7.07% of the Change. The maximum transition is from vegetation Coverage followed by agricultural area and water bodies respectively. With the increase in population the conversion of agricultural area to built-up area is very common. It is also observed that there is an increase of built up area inside the Loktak Lake. The increase in built-up area is due to increase in the number of Lake dwellers and the practice of ***Athaphum/Phum Namba*** fish farming The increase of built up area inside the Loktak lake can be permanent or temporary.

## CONCLUSION

This study assessed the land use/cover dynamics,LULC of the Loktak lake and its surroundings. To achieve these objectives, the Satellite Images were acquired from the USGS for the Year 2003(Landsat 7), 2013(Landsat 8) and 2023 (Landsat 8). The LULC of the above said year is generated by supervised classification using maximum likelihood classifier. A total loss of 34.34 Sq.km., the maximum loss is experienced in the class of vegetation during the period from 2003 to 2013 due to the clearance of *Phumdis* by the Loktak Development Authority. There is an increase of agricultural land due to transformation of vegetation area for agricultural purposes. A Significant area of Built up is also transformed into water due to clearance of houses of Lake dwellers. During the period of 2013-2023, the practice of *Phum namba* for fish farming inside the Loktak Lake and extensive growth of *Phumdis* lead to increase in coverage of vegetation upto 12.56 sq.km. The built up is also increased by 11.79 sq.km. resulting in the decrease of agricultural land.

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**Authors contributions:** Conceptualisation: Methodology: (Elangbam Karankumar Singh, Prof. Yambem Imo Singh) Cartographic input: (Elangbam Karankumar Singh, Rishikesh Chongtham) Writing-Original draft preparation: (Elangbam Karankumar Singh,O. Amarjit Meitei, Thenggujam Asha Devi,) Review and Moderation: (Leiphrakpam Ajit Singh, Manglembi Ningthoujam).

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