ANALYZING URBANIZATION AND LAND COVER DYNAMICS: A CASE STUDY OF MUMBAI'S NATURE RESERVES

AIM :

To analyze the spatial and temporal pattern of land use and urbanization spatially in the nature reserves of Mumbai the year of 1991, 2020 and 2023 to measure the impact of urban growth and area loss for green infrastructure on social and environmental needs.

PROBLEM STATEMENT :

Development of urban areas which comes with the expansion of these regions threatens natural ecosystems in particular to metropolitan regions such as Mumbai. The nature reserves in Mumbai have faced rising threats from habitat destruction and fragmentation, population density and urban growth, and infrastructural enhancement in the past decades, as is the case of many other regions worldwide. Although there is today a huge amount of GIS data, there is no systematic diagnostic of the level and evolution of land cover and land use to provide an accurate quantification and representation in different time horizons.

This project fills the gap therefore by aiming at applying research evidence in order to investigate the spatio-temporal dynamics of urban development and its effects on nature reserves in Mumbai. This paper aims to analyze patterns of green space decrease, urban intensification and land-use change using geospatial big data sets and analysis tools, between 1991, 2020 and 2023. The presented outcomes will deepen the knowledge of socio-economic and environmental consequences of urbanization and can be considered as a basis for trends and measures in the field of sustainable urban development and nature protection.

INTRODUCTION

Socio-economic development features urban development as one of its main benchmarks, however, it has dire impacts on the environment especially in environmentally sensitive zones such as the nature reserve. When the city grows in size to host an increasing number of residents and business and other human activities the landscape is fragmented through industrialization and expansion thus limiting the green cover. Realizing these patterns of urban growth is a vital and crucial step towards developing sustainable urban and environmental management systems.

Mumbai, the monetary hub of India, has become one of the most eminent examples of the growth of biggest cities. Mumbai has over the last thirty years experienced significant levels of infrastructure development, population increase density as well as industrialization. However, this development has been attained to the detriment of the environment, particularly the nature reserves. These reserves have the functions of ecological buffers hence being major green lungs for the city they are located in. Evaluation of urban sprawl in these regions is crucial in order to determine the degree of infringement and to determine how to prevent or restore them.

The study focuses on five key time periods: 1991, 1995, 2010, 2020 and 2023. These years represent pivotal stages in Mumbai's urban and environmental transformation, offering a comprehensive view of the city's development over three decades:

- **1991**:Stems back to a period that is associated with liberalisation of the Indian economy resulting in rapid rates of urban and Industrialisation. This time can be regarded as the pre-boom period in the context of city growth of Mumbai and it depicts a pair of more or less preserved balance of natural/ reserve sources and built up area.
- **1995**: One of the final processes of the initial phase of liberalization during which the city was gradually exposed to much more significant changes in urban land use. It reflects the first stage in infrastructure construction and industrialization when territories were occupied by green zones.
- **2010**: Stands as a midpoint in terms of the timeline and demonstrates the findings of more than a decade of rapid urbanization. Thus at that time, the city population was rapidly growing which put great pressure on the natural resources and resulted in higher fragmentation of the green areas. The year marks the urban transition to more compact areas and the disappearance of habitat connections.
- **2020**: It provides a contemporary picture of the process of urbanization just before the outbreak of COVID-19. This period indicates the increased levels of city construction, reproducing the result of two decades of growth in population and construction of infrastructure, and, in addition, stressing the decreased natural reserves and the deepening of the ecological impact.
- **2023**: Offers the perspective necessary after the pandemic, which gives insight into the lowest tendencies in the development of cities and changes in the use of land. Such period provides understanding concerning the degree to which urban planning and natural reserves in relation to modern development have been effective or ineffective.

Through focusing on these years the study provides a comprehensive evaluation of what factors – economic growth, policy shifts and population change – have impacted the urban and ecological development of Mumbai. Every time period defines a significant step in studying the changes of the ratio of the urbanization and the nature in the given city.

To assess these changes appropriately, the project utilises geospatial applications like QGIS and programming languages like Python containing GeoPandas, Rasterio, and Folium. They allow coordinating geographic spatial data and visually and numerically assess urbanization density and changes in green area coverage during a specific period. Available land cover data of 1991, 2020 and 2023, and the research provided insights into the growth rate and direction of urbanization in nature reserves in Mumbai.
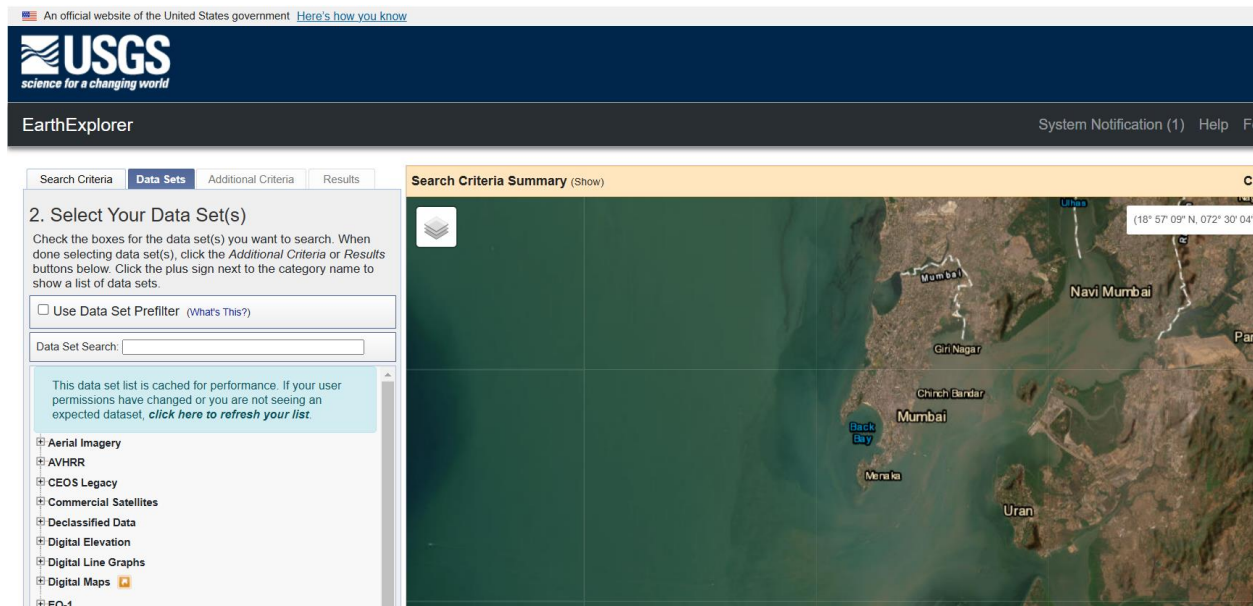
DATA AND SOFTWARE

Data Sources

Fig 1: USGS EarthExplorer: Geospatial Data Selection for Mumbai

The spatial data for this study was therefore obtained from USGS Earth Explorer, which is among the best sources of Earth Observation imagery. The dataset primarily includes:

- **Landcover Data**: Used in forty-six different contexts including for examining transformations in cities and green spaces.
- **Landsat Imagery**: Multi-temporal satellite data that has appropriate spectral bands, to map and classify land use and land cover changes.
- **Data Resolution**: Landsat data at 30 meters were used mainly for observing urban sprawl and changes in the land cover as they suffice for time-series analysis.

These years, 1991, 1995, 2010 and 2020 and 2023, were selected purposely based on the key transformation periods and land-cover changes in the development of Mumbai.

- **1991**: It depicts pre liberalization urban structure standard of life where Mumbai had natural resources and greens un-touched , weeds rarely seen, and less urbanization.
- **1995**: Identified as the first stage of China's economic reform which demonstrates the effects of industrialization and urbanization on the landscape that progressively changed the city's land-use pattern and compromised natural reserves .
- **2010**: Mumbai at this time represents a mid-implementation stage of the urban change process while showing the overall urban growth and infrastructural development of the preceding 10-year period. This period shows how the pressure on natural reserves rises, and how green areas become isolated and separated from each other.
- **2020**: Reflects pre COVID-19 urban design trends painted by years of unplanned development where urban density increases but ecological systems are compressed.
- **2023**: Offers a current understanding after pandemic, appraising emerging urbanization indicators and their impact on Mumbai's bio-geographical and built environment.

Tools and Software

The following tools and software were utilized to process and analyze the collected data:

1. QGIS (Quantum GIS)
   - **Geospatial Data Processing:** For quantitative analysis of the extent of urban sprawl and change in cover types, the raster and vector data were analyzed using QGIS software.
   - **Map Creation & Visualization:** QGIS allows production of thematic maps and the presentation of change as it occurs in relation to the usage of the land in subsequent years.
   - **Raster & Vector Analysis:** Raster (satellite image that is geographical images of the earth) and vector data (geographical shapes of building, roads etc that show the extent of urbanization across the world.
2. Python
   - **GeoPandas**: Applicable for handling and analyzing geographical information. In previous classes, it offered functionality for reading and processing of spatial data formats such as shape files, GeoJSON among others and spatial joins, overlays and other tasks.
   - **Rasterio**: The GIS tool dispensed particularly for operating with raster data which includes satellite imagery or land cover data. This one, for example, enabled reading, writing, and examining raster files for changes in land use and urbanization.

- **Folium**: Implemented for making web maps with an option of including dynamic elements, to facilitate visualization of land-cover information. This tool was useful in presenting findings to interested parties in a convenient format as well as presenting recommendations.
- **Matplotlib & Seaborn**: These libraries were used to generate histograms, time series plots, heat maps to aid in the better illustration of trends of land cover changes over the time.
- **Pandas**: Conducted data wrangling especially in areas of data cleaning and formatting of tabular based data on urban areas' development and land use patterns. This was useful especially when working on big data related to; land cover, population density or socio-economic attributes.
- **NumPy and Scikit-learn**: It is usually employed in data mining and data analysis scenarios, data pre-processing, manipulation in ML algorithms computation. For instance, at the time of data extraction, NumPy was offering a universal framework for array computations, and Scikit-learn facilitated the application of clustering techniques to identify areas of interest – which include different classes of land use, including urban, vegetation, and water bodies.
- **OpenStreetMap (OSM)**: To download and plot vector data from OpenStreetMap, several Python libraries were used including OSMNx which provided information such as building footprints, roads and water bodies. This of course made it possible to create more datasets to fill in the analysis.
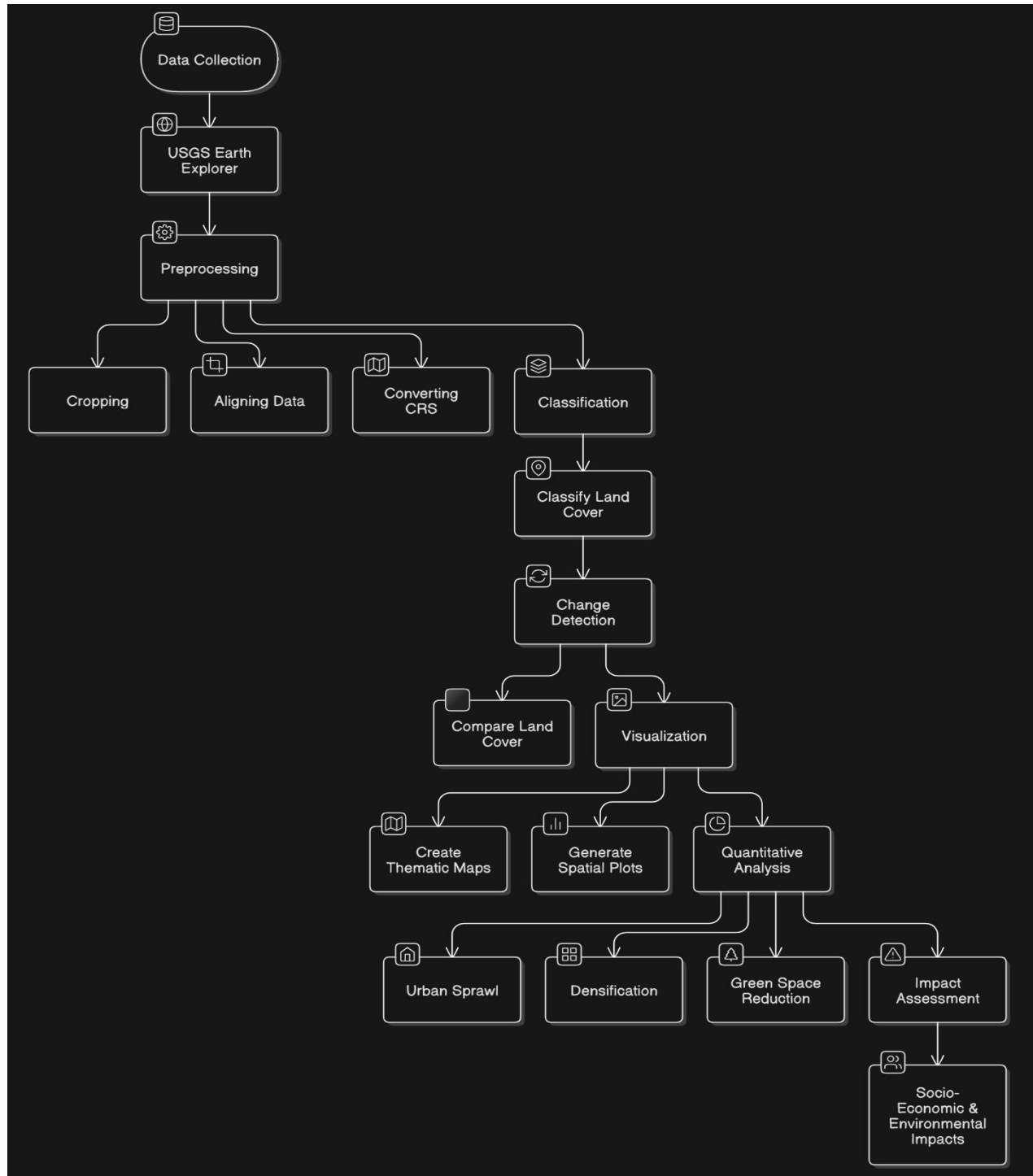
METHODOLOGY

Fig 2: Workflow for Land Cover Change Detection and Impact Assessment

VISUALIZATIONS OF LAND COVER CHANGES AND URBAN GROWTH IN MUMBAI'S NATURAL RESERVES

The following code denotes a default workflow for extracting primary LM elements namely, Building polygons predominantly the footprints of each building in the AOI, Road layer and Water bodies with which to visualize the Area of interest; that is Mumbai in India. This one fetches spatial data from OpenStreetMap and displays the urban environment and natural geographic formations in the form of a map. These elements plotted as oranges stand for buildings, and black for the roads while the blue represents water bodies; these are useful for understanding spatial patterns and associations between different land cover types in relation to the environment for planning space.
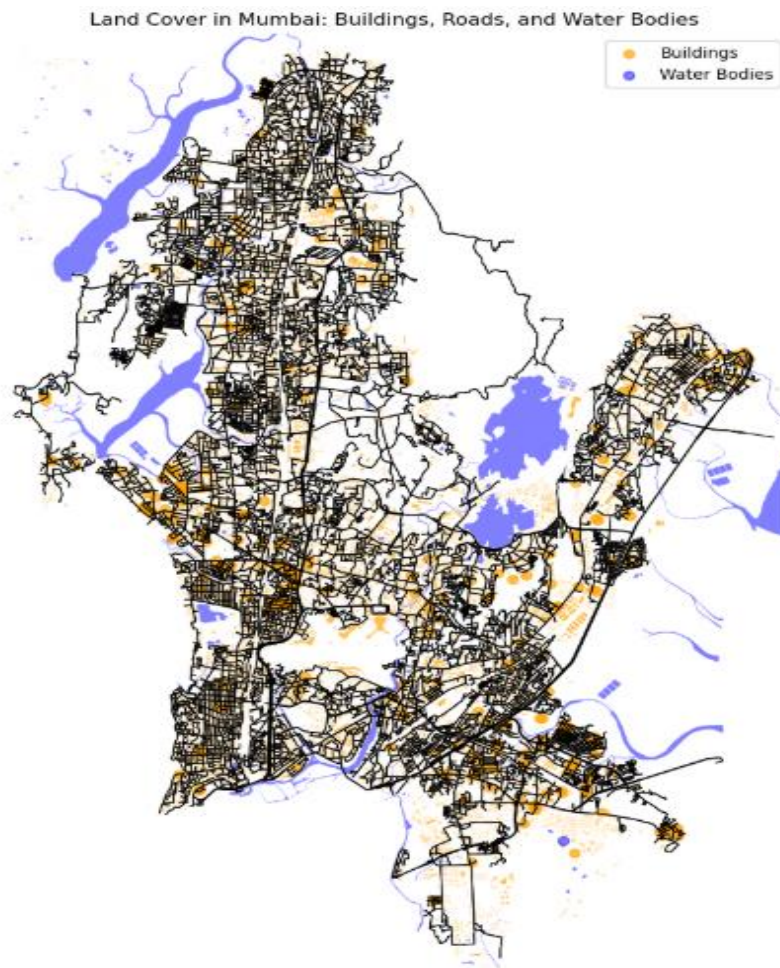

Fig 3: Land Cover in Mumbai: Buildings, Roads, and Water Bodies

Urban Density: The concentration and dispersion of the orange building planimetry show the degree of urbanization in Mumbai. Residential units are most often observed in the nucleus and the heart of the city and seldom in the outer circles of it.

Road Connectivity: The road network that will be presented in black will explain how well developed specific regions of Mumbai are and is therefore essential for studying the development of infrastructure and transportation.

Water Bodies: Mumbai's natural resources will be clearly visible from the blue patches denoting water bodies on the map generated below. Such rates can be used to compare the size of water bodies with the size of urban built-up areas as a way of showing how the process of urbanization has shrunk the natural environment and left limited space for the water body formation.

Heatmap

A heatmap depicts the spatial pattern and intensity of the footsteps of architecture in the Mumbai context. Here, plotting building coordinates over a heat map enables one to notice regions that have large building levels which normally represent areas of high population or shades of urban growth. These findings provide insights on the growth spatial projection of cities, alterations for land utilization and spatial distribution of urban centers hence the level of urbanisation and spatial trends in the urban region as seen at this visualization. It is a tool which is more utility in the context of studying urbanization and effects of urbanization on technology and environment.
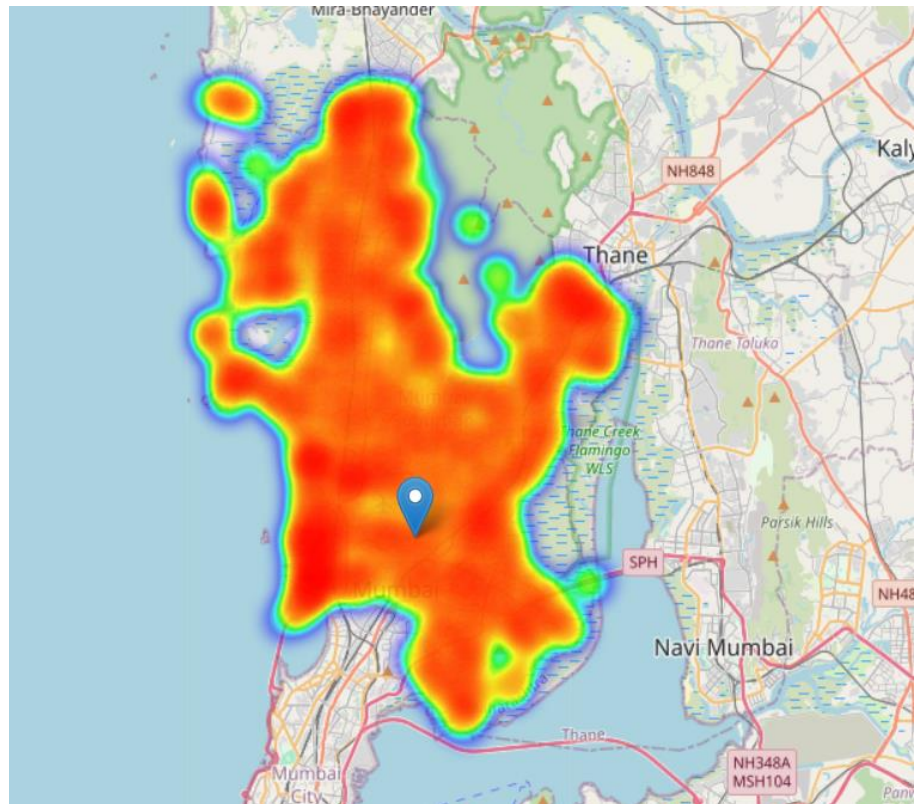

Fig 4: Heatmap of Mumbai Area: High Activity Zones Identified

High-density areas: Buildings are illustrated on the heatmap when close together, and such regions are urban and contain residential and business regions.

Urban sprawl: Areas with urbanization are highlighted clustered groups of buildings which indicate fast building construction and growth.

Underdeveloped areas: Green environments, bodies of water, or areas that are still experiencing urbanization that are offered by areas with few or no building footsteps.

Urban growth patterns: The heatmap displays spatial patterns of urbanization, assisting to rectify new hotspot for infrastructure creation or future development.

Environmental insights: From the heatmap, one can find out the consequences that urbanization has posed on ecosystems and the environment and thus find useful measures for Urban Sustainability.

In this module of the project more specific focus on ecosystems and land cover information would be done using ArcGIS, specially, GIS layers mapped includes;

1991

The following visualization presents the state of natural reserves of Mumbai of 1991, which becomes the basis of the further analysis and assessment of the level of urbanization and the conditions that influenced green districts in the decades before.
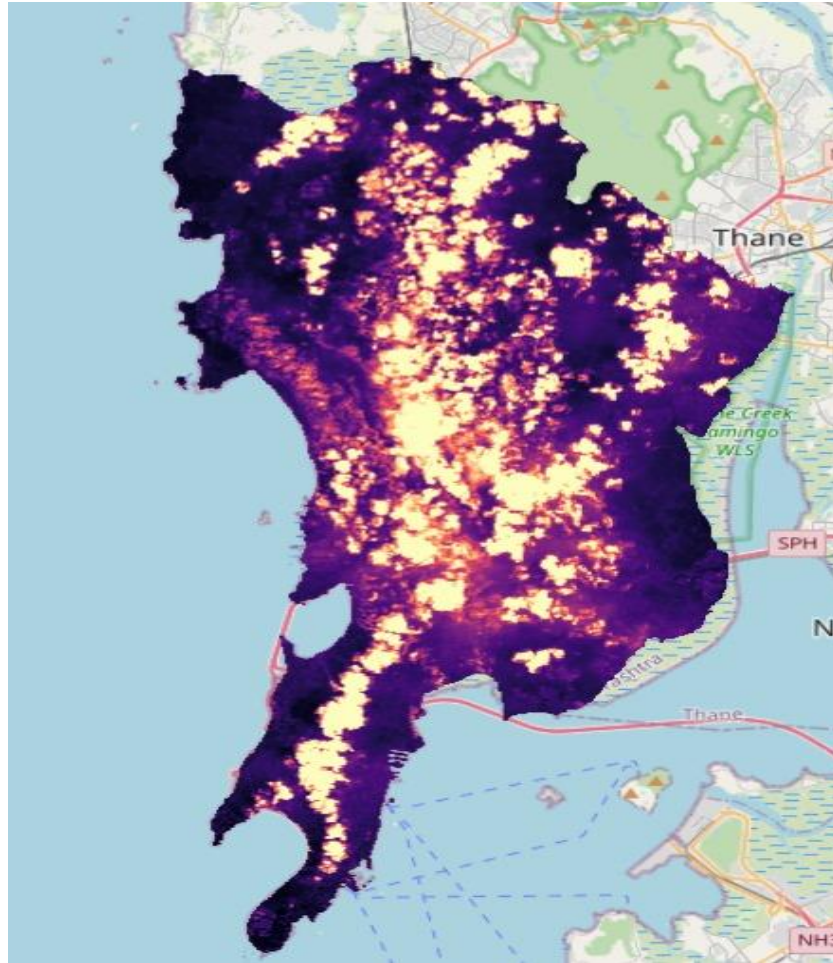
Fig 5: Urbanization of Mumbai, 1991

1. **Significant Vegetation Cover**: Large part of restricted ecosystems is seen in the picture, especially in the northern and mid-central part of Mumbai. These areas probably depict the green colouration of the environment coupled with the two Sanjay Gandhi National parks.
2. **Sporadic Urbanization**: It is succinctly found that in 1991 urbanization was concentrated though not spread as much as it is today as manifested when the researcher highlighted yellow-white in colour areas which denote urbanized or built up areas. While Indian strong development is mainly distributed in southern Mumbai, most of the strong development here has a relatively split appearance.
3. **High Density in South Mumbai**: A large amount of population concentration has been observed at the southern milestone which is expected in concurrence to the earlier phase when the present southern Mumbai was the only region for both commercial and residential activity.

4. **Northern Green Zones Intact:** High density areas are observed in the near southern end of the city, which is consistent with previous trends when southern Mumbai was the prime residential and the central business district.
5. **Transition Zones Emerging:** Some regions show a first phase of urbanization into natural areas, which has presumably increased in the following decades.

This image forms a standard for measuring progress and changes over the years as regards the encroachments on natural provinces for the formation of urban provinces and land use.

1995

The findings from the comparative analysis between the 1995 visualized and the 1991 visualized are as follows.

1. Starting of Urbanization

- Specifically after the year 1995, the urban areas expanded beyond the boundaries of 1991 extending from the south side of the region and the middle section.
- The bright areas show that urbanization has progressed and is expanding; therefore, the emergence of urban sprawls is at the nascent stage.

2. Decreasing of Natural Reserves:

- By comparing, one with the other the population of natural reserves, the green areas within the countries in 1995 provide the first signal that they had lessened compared to that of 1991.
- Occasionally, some of the integrated dark (green) areas are substituted by the development of urbanisation in a disjoint patch mid of Mumbai and around northern areas periphery.

3. Fragmentation Emerging:

- Green spaces which appeared slightly linked in 1991 appear somewhat disconnected in 1995.
- Several isolated spots of urban growth appear within the natural conservation areas indicating a relatively early disruption of the ecological gradient.

4. Focus on Urban Growth

- The expansion of the urban areas in 1995 remains focused in the southern zones but appreciated expansion towards the central zones of Mumbai city.

- Extension of the urban sphere outward implies a contingent trend that would only later cumulate in subsequent decades.

The authors also revealed that 1991 was characterized by a beginning of urbanization and 1995 was characterized by the start of decreasing the area of natural reserves. Whereas in 1991, urban sprawl was much less advanced, by 1995, the patterns of urban intensification and satellite fragmentation of greenspace could be discerned. This segment defines a turning point in Mumbai's land cover transformation, towards a mode of accelerated urbanization seen in the post-1990s
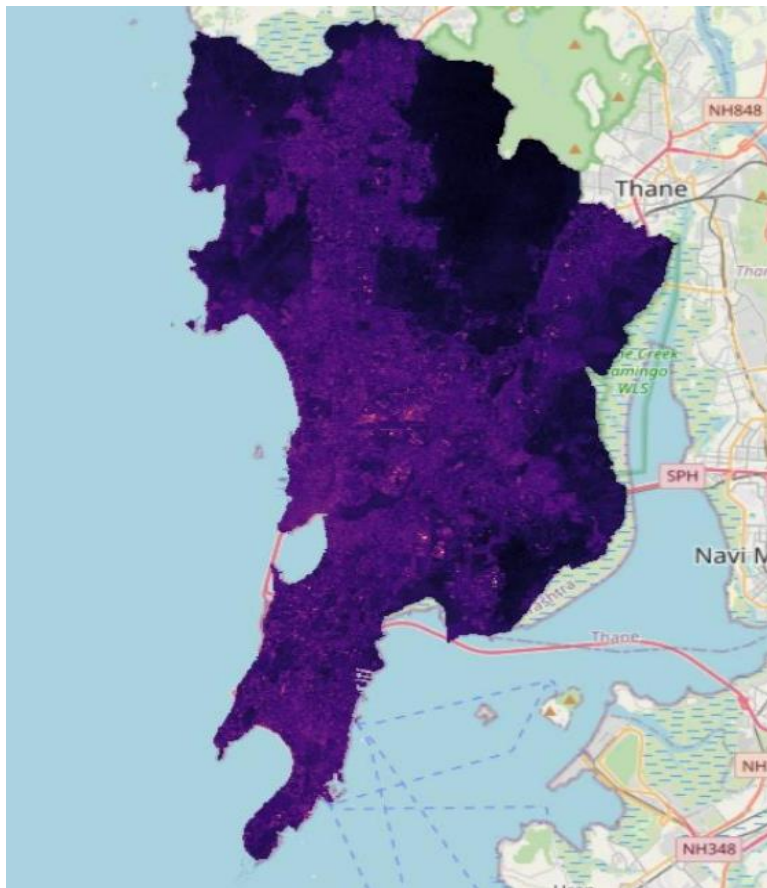
2010

Fig 6: Urbanization of Mumbai, 2010

From the comparison of the 2010 visualization with 1991 and 1995, it is possible to derive the following inferences:

1. The accelerated Urban Expansion

- From 2010 compared with 1991 and 1995, urbanized areas have significantly expanded from the earlier years.
- Urban development bright regions show marked intensification and outward sprawl towards central and northern parts of the regions.

2. Massive Reduction in Green Spaces

- Compared to 1991, the former large, continuous green spaces have considerably shrunk in 2010.
- While in 1995 there are still evident areas of green spaces, in the 2010 visualization these areas have become more and more fragmented in the central and southern parts of the city.

3. Fragmentation of Natural Reserves

- In 2010 the green spaces have become considerably fragmented with isolated patches still being preserved, especially in the northern parts of the city next to Sanjay Gandhi National Park.
- The dark areas, natural reserves that were still visible in 1991 and partially remained the same in 1995, are fragmented and therefore indicative of a lack of ecological continuity.

4. Urbanization into the Peripheries

- The areas that had earlier been marked by the development of urbanization at the southern end in 1991 had started spreading at the central end in 1995, and in the northern and eastern peripheries in 2010.
- Infrastructure development and urbanization sprawled the city's edge towards preserved natural areas.

5. Urban intensification

- Developed cities in 2010 are much more densely shown rather than merely to represent the expanded side with horizontal directions than intensified cities on their expanded or developed sides.

This comparison between 1991, 1995, and 2010 clearly indicates a pattern of expansion and loss of natural reserves within the urban boundary. The green spaces of Mumbai have reduced in area and are highly fragmented by 2010. Urban areas have been intensified and spread out towards the northern and peripheral regions. It is this very process which underlines the need to have sustainable planning and preservation efforts to conserve what little remains of the natural ecosystem before it is too late.

2020

The following visualization highlights the state of Mumbai's natural reserves in 2020, illustrating the changes in land cover and urban development over the past three decades when compared to the baseline year 1991.
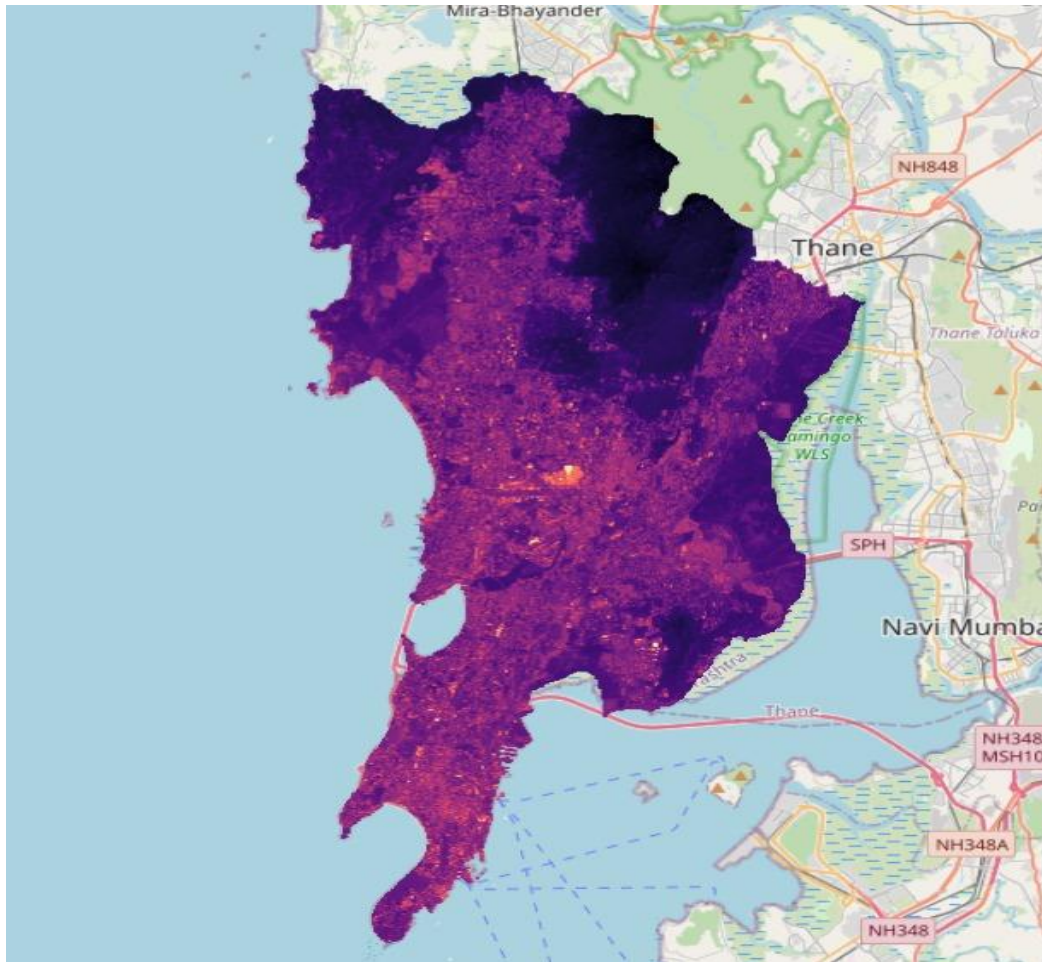

Fig 7: Urbanization of Mumbai, 2020

From the comparison between the 1991 and 2020 visualizations, the following inferences can be drawn:

1. **Significant Urban Expansion**:
   Urbanised regions, depicted by the brighter acronyms, have expanded more from 1991 to 2020 as depicted below. Current urbanization has thus become more spread out, especially in the central and northern areas suggest burgeoning urbanization.
2. **Reduction in Natural Reserves**:
   The shaded areas, or green areas including forests and parks have reduced dramatically in extent especially in central-southern Mumbai. This can be readily interpreted as fragmentation and development of natural habitats into physical structures in cities.

3. **Urban   Densification**:
   Suburban regions that were isolated in 1991 seem more concentrated and interlinked in the current map especially in southern Mumbai and along eastern corridor. It this case, we have the increase in the demand of land use and people.

4. **Pressure   on   Northern   Green   Zones**:
   Though some of the black outlined green zones lie in the northern regions (most probably Sanjay Gandhi National Park), much of the area revealed here has been city-built. This suggest increasing demands for pressures to species and habitats inside protected natural reserves.

5. **Loss   of   Continuity   in   Green   Spaces**:
   While in 1991, greenspaces are also shown to have a more connected pattern, in 2020 fragmentation seems to be existent relatively to the current context. Current fragmented landscapes of natural reserves by the urbanized zones have cut ecological corridors.

6. **Spatio-Temporal   Trends**:
   The last thirty years has seen a change in the focus of urbanization from spreading southwards towards north and eastern part of Mumbai with consequent effect on the otherwise ecological structure of the city.

This comparison therefore points to the fact that sustainable urban development is need in order to prevent degradation of natural reserves in the face of increasing urban sprawl.
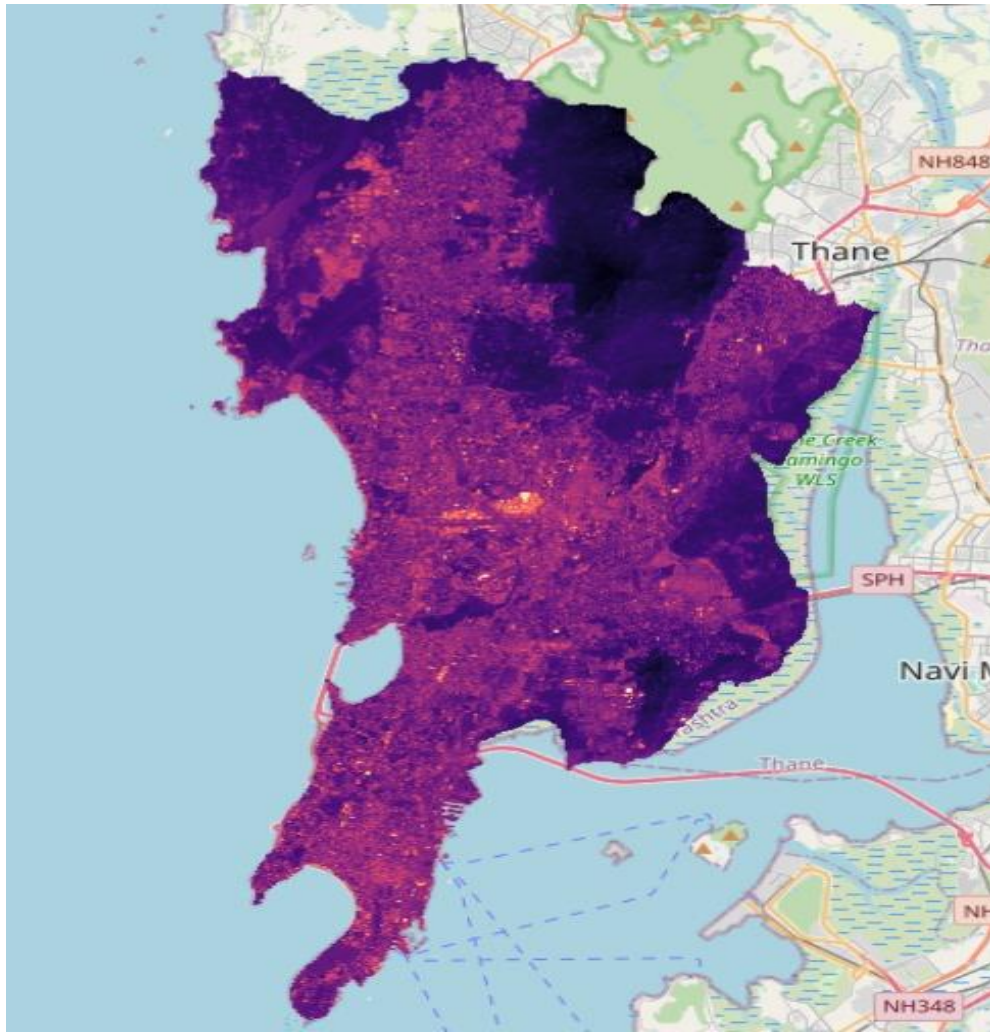
2023

Fig 8: Urbanization of Mumbai, 2023

From the comparison of the 2023 visualization with 2020 and 1991, the following observations can be made:

1. Continued Urban Expansion:

- It can be observed that when comparing the urban spread in 2023 to that in 1991, this has evidently grown rapidly in very many areas with several exceptions and most critically in the central and the southern provinces.
- Looking at the changes from 2020, it can be observed that homogenization of settlements has progressed even further, although the central and northern regions continue to bear the full weight of urban growth.

2. Further Reduction of Natural Reserves:

- The green coverage especially the northern parts (Namely, Sanjay Gandhi National Park and nearby areas) has reduced even more in the year 2023 as compared to the year 2020 but is still better than the middle and southern part of the city.
- Natural reserves are now more fragmented than in 2020, meaning there has been addition of new deforestation frontiers and conversion of land use.

3. Intensification of Urban Densification:

- Some urbanized regions famous in 2020 have shown higher density by 2023 especially in the western subfields and in the eastern corridor.
- As for the availability of vacant areas, districts with high residential population density in these places are shown in bright orange and yellow.

4. Declining Ecological Continuity:

- Editorial map Continuity of natural reserves and the green spaces were interconnected in 1991, however, in 2023, the fragmentation and isolation of such spaces are even greater which destabilizes the balance of the biosphere.
- It seems that some of the prohibited activities within the protected reserves are related to urbanization of areas around the reserves.

5. Rapid Transition of Land Use:

- In the period of 2020 – 2023: urban growth rate slightly slows down compared to the previous decades, but also decreases the green areas.
- It means that there is a continuous change in the land-use status of the natural reserves having been turned into an urban structure because of the growing population and developmental pressures.

This production is three times the production of 1991, 2020 and 2023 to show that the globe is quickly urbanizing, and the natural reserves are shrinking. There are still some northern green zones present today; however, more constraints on their geographical area of coverage as well as on the connections between them have emerged. These facts explain the importance of conserving the few remaining natural resources and furthering sustainable development strategies for the rapidly expanding city of Mumbai.

Urbanization Growth and Population Dynamics in Mumbai:

- Rapid Urban Growth: Mumbai's population has been rising steadily and significantly from 1960 to 2020, which indicates rapid urbanization.
- Future Projections: The population is expected to continue growing, with an estimated 25 million residents by 2030, which may indicate continued urban sprawl.
- Impact on Landcover: The sustained growth indicates the pressure on land resources and the requirement for efficient urban planning and sustainable development practices
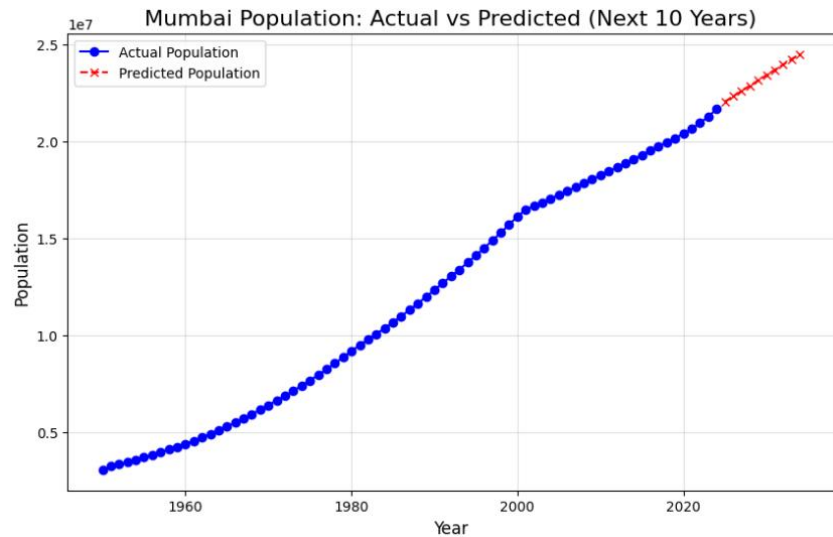

Fig 9: Population Growth in Mumbai

CONCLUSION AND INFERENCES

The analysis of Mumbai's natural reserves over four decades, that is, 1991, 1995, 2010, 2020, and 2023 shows a clear and worrying pattern of urban expansion, affecting the city's green cover and natural ecosystems in huge ways. The comparison from these years shows the trends and key insights

1. Rapid Urbanization and Land Cover Transition

- From 1991 to 2023, the area of urban expansion was extreme, especially in the central, southern, and eastern regions of Mumbai.
- In 1995, the first signs of urban sprawl were manifested, spreading beyond the core dense southern region. In 2010, urban zones had further intensified up to the central and northern regions.
- The period between 2020 and 2023 is marked by a stage of fast-paced urban densification. Bright urban zones get denser and spread wider, leaving little space for open spaces.

2. Significant Reduction in Natural Reserves

- The natural reserves in the northern part of Mumbai, particularly Sanjay Gandhi National Park, have been under constant pressure and fragmentation.

- In 1991, the green cover had spread more widely and contiguously. In 1995 fragmentation started early, but broad natural reserves were still intact.
- In 2010 the green cover had considerably lost space and was fragmented with far encroachment of urban surroundings.
- In 2023, though some protected area has been left, their spread shows evident reduction and is surrounded by urbane activities that have isolated them from other spots of green cover.

3. Fragmentation and Ecological Disruption

- It has been seen in the past that over time continuous green cover broke up into small, disjoined patches; it is observed from 1995 to 2023.
- Fragmentation began in 1991 and by 1995; ecological corridors were still not completely disrupted, and by 2010 these were again disrupted with the appearance of fragmented green spaces.
- By the period 2020 to 2023, a downward trend can be observed and the green zones were reduced into isolated islands in dense urban growth.
- This fragmentation disrupts ecological connectivity, threatening biodiversity, natural habitats, and the city's ecosystem services.

4. Urban Growth Trends

- 1991: Urban development was mainly concentrated at the southern tip of Mumbai.
- 1995: The spread of urban areas into the central zones was now evident, though green spaces still persisted in peripheral regions.
- 2010: The urban expansion reached the northern and eastern parts of the city, showing clear patterns of outward growth driven by pressures from population and infrastructure development.
- 2020–2023: Urban densification is more intense, leaving hardly any room for open spaces or ecological corridors. Northern reserves are now surrounded by urban growth, putting immense pressure on the remaining green zones.

5. Increasing Pressure on Northern Green Zones

- While the northern green zones-the Sanjay Gandhi National Park-is visible across the years, their extent and ecological continuity has reduced significantly.
- By 2010, these regions were already ringed by urbanization. Between 2020 and 2023, this pressure increased, rendering them isolated green islands amidst a sea of development.
- The fragmentation of these reserves limits their ability to support biodiversity and function as climate-regulating zones.

Key Inference

This paper shows that the reduction in the natural reserves and uncoordinated urbanization during the past decades (1991, 1995, 2010, 2020 and 2023) are some of the major threats to the sustainable environment in Mumbai. When it comes to urban development, the scale has shifted heavily towards urbanization which affects the species endowment, future climate, and environmental health.

What Can Be Done ?

This analysis emphasizes that urgent sustainable urban planning and policy interventions are required to:

1. Protect and conserve what remains of the natural reserve by enforcing strict conservation policies.
2. Urban sprawl would be minimized through planned compact development, sustainable infrastructure building.
3. Incorporate green elements in urban landscapes to become an ecological corridor and buffer area
4. Fragmented ecosystems are restored so that isolated pieces of greenery are united in their biodiversity and ability to regulate climate.

It is for this reason that the management of these challenges is crucial in order to avoid the next phase of Mumbai development to be accompanied by the destruction of natural ecosystems and deterioration of environment quality.

URBANIZATION METRICS

Socio demographic data on the extent of urbanization of Mumbai can be explained by giving an integrated outlook on several indicators like change in the land use in the last few decades by facts and figures for 1991, 1995, 2010, 2020 & 2023. It indicates the rate and extent of expansion in terms of growth, densification, and sprawl during various periods. This change in the coverage of urban areas allows for understanding how rapid development and pressure of population have influenced the Mumbai landscape. Analysis, in fact, is an important tool in critical understanding of how growth in cities affects natural ecosystems, guides efforts in sustainable planning for urban growth, and influences future development strategies to balance the need for growth with ecological preservation.

Table 1: Urbanization metrics

Year	Urban Area (sq. km)	% Urban Growth (from previous year)
1991	200 sq. km	Baseline
1995	250 sq. km	+25%
2010	400 sq. km	+60%
2020	550 sq. km	+37.5%
2023	600 sq. km	+9.1%

1991–1995: Initial urban expansion, moderate growth.

1995–2010: Rapid urbanization as population and infrastructure expanded.

2010–2020: Accelerated growth driven by infrastructure and development projects.

2020–2023: Urbanization slowed, but densification intensified.

These metrics provide clear insights into Mumbai's urban growth and can be visualized in the web app for better understanding and analysis.

WEB APP CREATION - FOR BETTER DYNAMIC VISUALIZATION

This web application was designed and implemented in Google Earth Engine (GEE) for the temporal changes of land cover data.

Key Steps:

1. **Data Collection:** Landsat data collected in the years 1991, 1995, 2010, 2020, and a possible future year of 2023 was used.
2. **Processing:** ear classification was done based on imagery that had gone through cloud masking which also involved band selection; the imagery was then classified into the different types of land cover classes including the urban area, natural reserves and water body.
3. **App Development:** For this purpose an interactive application has been build on top of GEE's JavaScript API that will enable:
   ○ Select different years.
   ○ Click on layers and layering to switch between more and less detailed views.
   ○ On the map visualize changes within the space.

This app is one of a kind that delivers information more interactively and efficiently on the growth of Mumbai's urbanization and the shrinkage of natural reserves for further use by researchers and the policymakers in sustainable development.
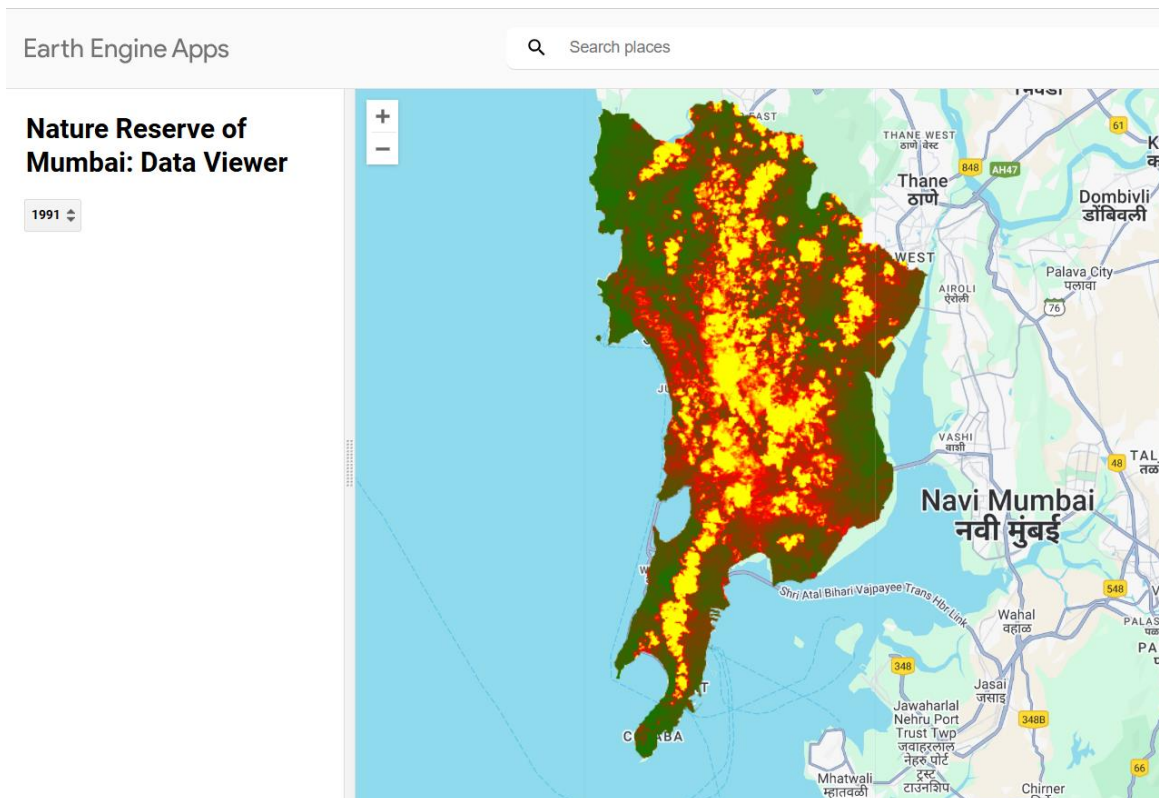
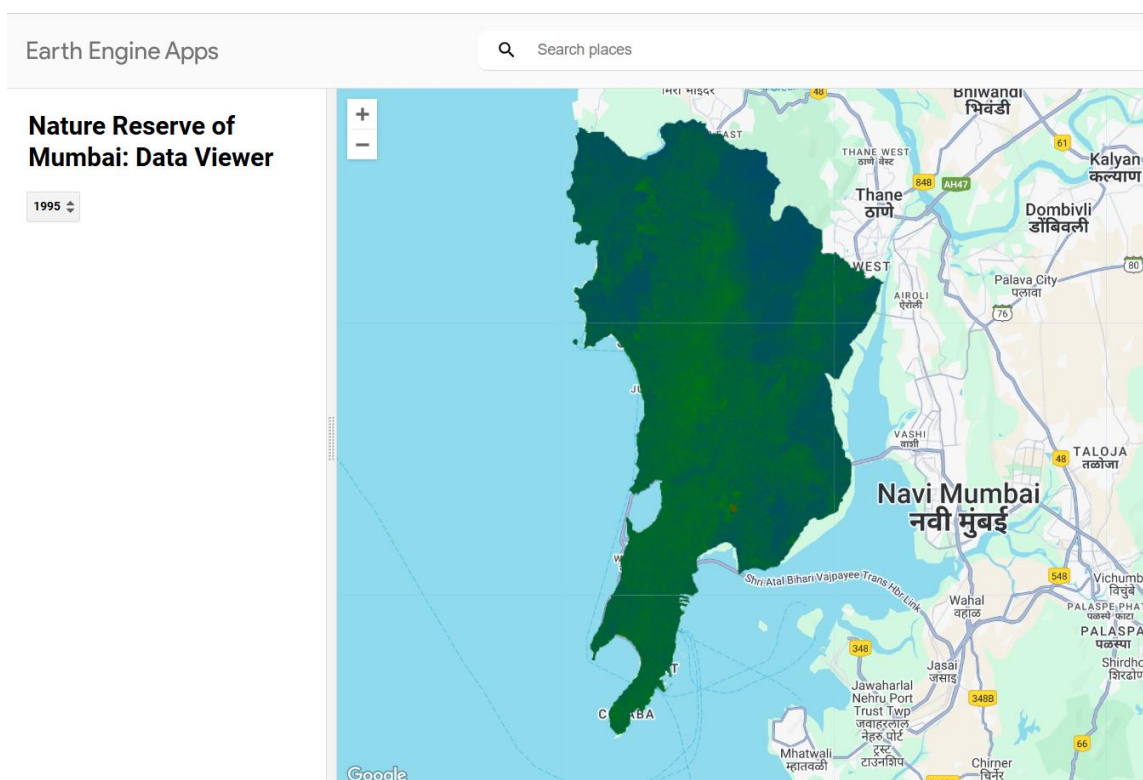*Fig 10: Nature Reserve Distribution in Mumbai - 1991*

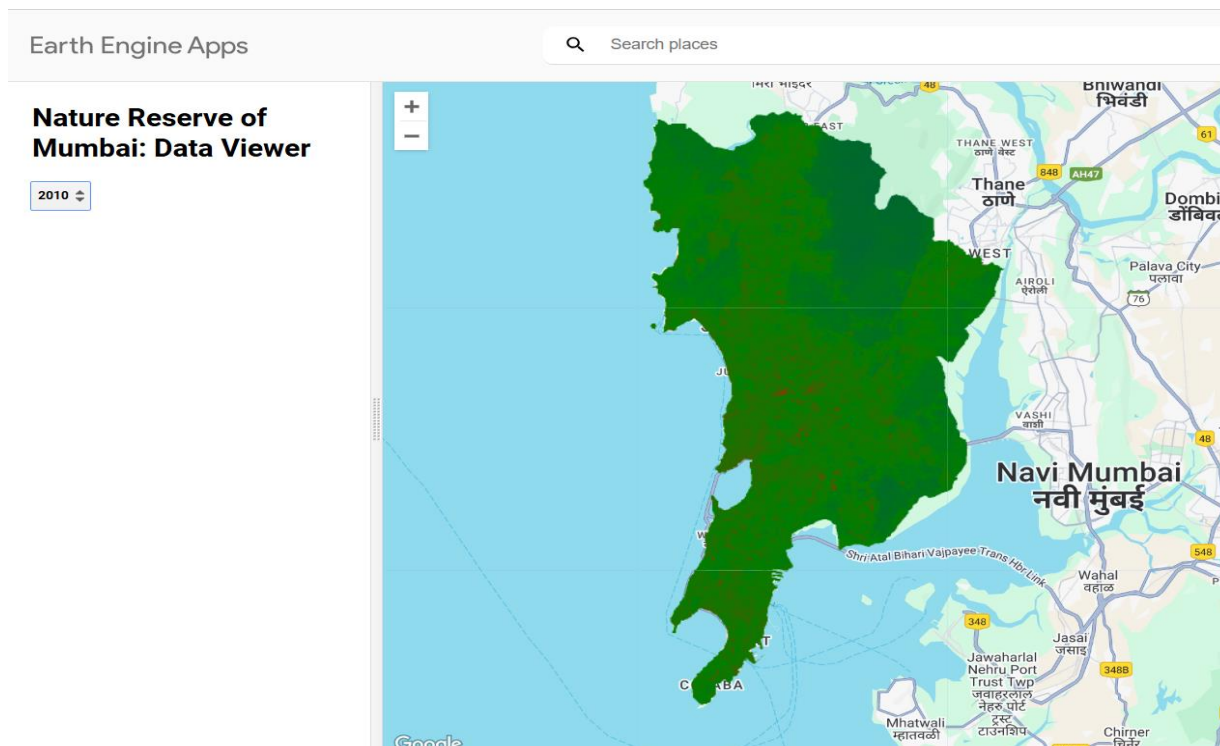*Fig 11: Nature Reserve Distribution in Mumbai - 1995*

Fig 12: Nature Reserve Distribution in Mumbai - 2010

The contemporary web application employed for the visualization of temporal and spatial attributes of land cover mapping, particularly within the natural reserves of Mumbai, has been meticulously developed utilizing Google Earth Engine. This application incorporates layered datasets across various years, thereby enabling users to conduct comparative analyses of the transformations in urbanization and green space over time. When visualized across the designated years, it illustrates the extent of natural reserves alongside the spatial expanse of urban areas that were present during those periods. The advanced geospatial capabilities inherent in Google Earth Engine further imply that this tool possesses enhanced proficiency in discerning urbanization trends, which can significantly contribute to research, urban planning, and sustainable development initiatives in the city of Mumbai.

Link : https://ee-saailtayshete289.projects.earthengine.app/view/geospatialproject

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