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Change Analysis of Atoll Ecosystem and Evaluation of Land Use / Cover in the Selected Island of Lakshadweep Using Geoinformatics

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Abstract:- Classifying land usage and land cover refers to the practice of dividing the surface of the earth into several categories according to its physical and biological characteristics. The use of land by humans, including forestry, mining, agriculture, and urbanization, is referred to as "land use". Land cover is the collective term for the physical and biological characteristics, such as marshes, grasslands, forests, and bodies of water, that cover the surface of the earth. For a number of reasons, including resource management, environmental monitoring, and land-use planning, it is crucial to classify land use and cover. Classifying land use and land cover is a common use of Remote Sensing (RS) technology and Geographic Information Systems (GIS), which analyze satellite images and other spatial data. The purpose of this study is to determine how land use and land cover have changed between 1999 to 2022 on a few chosen islands in the Lakshadweep archipelago in India, namely Kalpeni, Kadamat, Agathi, and Androth. Vectorization and analysis were done using Google Earth Pro and the high-end GIS software named Arc GIS. The investigation's findings support the hypothesis that the aforementioned islands underwent a major transformation. Particularly during that period, the built-up and commercial premises in areas increased.

Keywords*: Land use/cover, Lakshadweep, ArcGIS, GIS, Remote Sensing*.

1. Introduction

Lakshadweep is a tropical archipelago present in the Lakshadweep Sea on the coast of Kerala, India which lies in the Arabian Sea between 8° and 12°30’ N latitude and 71° and 74° E longitude, spread at a distance of 220 to 440 km away from the mainland coast. Lakshadweep archipelago is the smallest Union territory in India. The population of Lakshadweep is 64,473 which consists of various ethnic groups with the majority belonging to Sunni Muslims. The official language of the islands is Malayalam and has a very high literacy rate compared to the national average. The major occupation of the island folk is fishing due to its location in the Arabian Sea, and it is a significant part of their economy and culture. Another major source of income is tourism, due to its rich diversity in its native flora and fauna and picturesque beaches. It is also a treasure trove for bird watchers all over the world. Various species are endemic to Lakshadweep like the Strawberry Hermit Crab (Coenobita perlatus) and Five-Saddle Parrotfish (Scarus scaber) which reside in the islands. All Islands have plenty of coral with live corals and reef surrounding it. The soil is formed by the dead coral weathering. Phosphorus and potash are also found in small quantities (Fosberg 1976)

Urbanization is the process by which large numbers of people become permanently concentrated in relatively small areas, forming cities(Sikdar, Ghosh, and Chowdhury 2023; Antrop 2004). The need for infrastructure development and housing has been raised due to the increase in population leading to urbanization. This has resulted in the expansion of towns and villages, as well as the conversion of natural areas into commercial and

residential zones. Fast urbanization in today's world has become a major worldwide threat due to its harmful effects on the environment (Jaeger *et al.,* 2010). Another geographical influence on the structure and function of ecosystems is human growth brought about by urbanization (Miltner, White, and Yoder 2004). Land Use and Land Cover (LULC) change related to urban development can be harmful since it has the potential to alter natural energy and material cycles of ecosystems and influence mesoscale weather patterns, local climate conditions, biodiversity, and water resources (McDonnell and Pickett 1990; Alberti 2005)

The terms Land Use and Land Cover (LULC) might seem similar but differ. In simple words, land cover is that which covers the earth's surface, and the natural land is land use. Examples of land cover are snow and water. Grassland, deciduous forest, etc. Examples of land use are wildlife management areas, farmland, cities, recreation, area, etc. A stadium and a hospital building are examples of commercial land use. Land Use and Land Cover (LULC) changes have gotten wide attention due to their role in global and local environmental change(Ren *et al.,* 2019) .A society's overall growth depends on its economic development. LULC maps play a crucial role in planning and monitoring various programs at local, regional, and national levels. The generation of planning models by authorities is necessary for achieving sustainable urban development in towns and cities (Rimal *et al.,* 2017)

Monitoring changes in LULC in the Lakshadweep islands is typically done using remote sensing (RS) techniques and Geographic Information Systems (GIS). Satellite imagery is used to conduct studies on land use patterns, vegetation, and coastal feature changes over time. RS and GIS are effective tools for deriving precise and timely information on the spatial distribution of LULC changes (Rawat and Kumar 2015; Reis 2008). Remote sensing data provide valuable multi-temporal data on the processes and patterns of LULC change, and GIS is useful for mapping and analyzing these patterns (Zhang *et al.,* 2002). In addition, a synoptic view from satellites is particularly helpful in rapidly developing areas (Blodget, Taylor, and Roark 1991).Moreover, for assessing historical LULC changes digital archives of remote sensing data are highly useful, and such changes in geographic patterns concerning other environmental and human factors can be analyzed (Dewan and Yamaguchi 2009)

The most useful, economical, and capable of providing satellite data that is outside the range of human eyesight are remote sensing techniques. For precise mapping, remote sensing delivers multispectral and multi-temporal satellite photos. The basic inventory of land resources is provided via LULC mapping. Depending on the goal and requirements of the user, this mapping may be local or regional in scope.

Land Use and Land Cover change (LULC) have been observed to be the world's most emerging issues since this harms climate change, human well-being, and ecosystem services (Parveen, Basheer, and Praveen 2018). Globally, some of the systemic changes like the accumulation of greenhouse gases in the troposphere and ozone layer depletion have occurred as a result of this LULC (Murphy and Ravishankara 2018). Rural areas are engulfed by the rapid expansion of cities leading to changes in land use and land cover. These developmental advances are arising at the expense of natural ecosystems and habitats. A decrease in the world's forest cover and an increase in the agricultural land areas were mentioned in the global scale assessments of the past 40 years' data (Skole *et al.,* 1997)

The existing conditions specify that the rate of exploitation of the land is much higher than that of ancient times. At global, regional, and local levels remarkable changes in the ecosystem and environmental processes have been observed as an after-effect of rapid exploitation of the land. Also, in the mid-1970s the regional climate had an impact due to these land use and land cover changes (Parveen, Basheer, and Praveen 2018). A large proportion of the earth's surface has transformed as an outcome of land cover modification and land use change. Apart from these anthropogenic forces, natural events like floods, ecosystem changes, and climatic fluctuations are contributing to altering the land cover (Parveen, Basheer, and Praveen 2018). Recent studies show that, between 1960 to 2019, an estimation of about 17 % of the earth's land surface has changed. An expansion of global agricultural land areas such as croplands, pasture, and range land has been observed and a net loss of forest area has been identified (Winkler *et al.,* 2021)

Globally, to depict the land cover land use change with enhanced accuracy and more in-depth thematic information, the latest developments in the processing of Landsat data have helped a lot. Due to the recent agricultural expansions in the past two decades, the Brazilian rainforests and the Chaco regions in Argentina,

Paraguay, and Bolivia are now identified as the most endangered forest ecosystems on the map of deforestation hotspots. (Potapov *et al.*, 2022)

At the national level, as a result of the growing population and urbanization, a profound transformation has been noticed in the pattern of land use and land cover. India is a mega-diverse country with a landscape ranging from snow-capped mountains to deserts, plains, hills, water-based ecosystems, and plateaus it is crucial to examine the changes in land use and land cover occurring within the nation. Studies on land use and land cover changes in the Sikkim and Himalayan regions indicate a rise in developed areas and dense forests, alongside a decline in open forests and agricultural land. In the Himalayan states of India, large areas of forest cover are being converted into other land-use forms as a result of population growth and urbanization (Mishra, Rai, and Rai 2020). A declining trend in the major land-use classes such as agriculture areas, forests, water, and glaciers has been observed. Also, an increasing trend has been noticed in the horticulture and built-up areas of the Kashmir region between 1992 and 2015. A recent study in the Doodhganga watershed of the Jhelum basin using spatial analysis methods revealed that, a 2.8% decrease in the cultivated land, a 9.06 % increase in the build-up area, and a 1.05 % decrease in the forest area annually (Ahmed *et al.*, 2021). A sudden spurt in the aquaculture practice during the early 1990s in the Pennar River basin has increased the wetland of the region which was mostly converted from cropland (Roy and Giriraj 2008)

In India, over the past few decades, an extensive landscape change has been observed in major biodiversity hotspots (Skariah and Suriyakala 2022). In Lakshadweep, the natural vegetation belongs to the littoral vegetation type, and within the central domain of the inhabited islands, the natural vegetation is replaced by cultivated plantations. Therefore, the main causative factors for the destruction of natural vegetation are irrational methods of raising plantations and habitation (Reddy *et al.*, 2013). Out of the entire geographical synopsis of Lakshadweep, 4.29% constitutes the littoral vegetation which encompasses an area of 137.2 ha (Reddy *et al.*, 2013). The most extensive area of littoral vegetation of 16.1 ha was in Agatti islands. Recent research shows that there are only limited expansive forest areas with the largest patch index value of 11.73%. Many of the small forest fragments are scattered across the landscape (Reddy *et al.*, 2013). Currently, Lakshadweep islands are exceedingly at risk of global change and are also characterized by low natural habitat cover as the natural vegetation of the area is particularly under human-induced stress (Reddy *et al.*, 2013).

2. Methodology

The present study investigated the LULC changes in the islands from 1999 to 2022. This process required satellite images of various years to be collected from Google Earth. It is a geoportal that represents the earth as a 3D globe. It provides the time series satellite datasets geographic data. The boundaries of the selected Lakshadweep islands of two different time frames (1999 to 2022) were vectorized using Google Earth. With the aid of ArcGIS software spatial relationships among various features were inspected. The vectorized output includes the land use land cover features such as schools, hospitals, resorts, seaports, airports, post offices, etc in the islands.

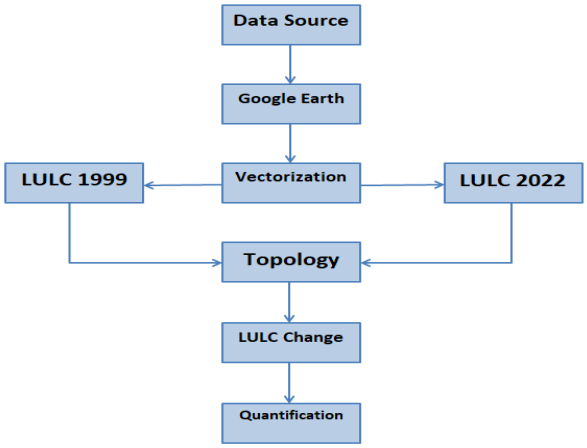

Fig 1. Overall Scheme of the Investigation

2.1 Study area

The Lakshadweep group of islands, dispersed across the Arabian Sea, positioned approximately 200 to 400 km away from the western coastline of Kerala, consists of 36 islands, 12 atolls, 3 reefs, and 5 submerged coral banks. The current study focussed mainly on 4 islands of Lakshadweep namely, Kalpeni, Kadamath, Agathi, and Androth.

2.1.1 Kalpeni

It is one of the most inhabited and beautiful islands which lies between 10° 03′ and 10° 07′ N latitude and 73° 37′ and 73° 39'E longitude, having an area of 2.79 sq. km. The island is situated approximately 287 km away from Kochi positioned to the southeast of Karavatti Island and lies midway between Androtт and Minicoy. In the northern part of Kalpeni island, there is another long and narrow island namely Cheriyam, which is connected from Kalpeni through reefs. The primary soil varieties found on most of the Lakshadweep islands are composed of coral sand. Due to the permeable nature of the soil which facilitates easy penetration of rainfall, as a result, surface runoff is absent in these soils except in specific regions of densely packed soil (Source: CGWB Report, 2009). The total population of Kalpeni Island is 4,418, with 2,336 males and 2,082 females. The literacy rate stands at 95.32% (Source: Census, 2011). Among them most of the individuals are engaged in fishing, thus upholding their unique traditions and culture. For those seeking thrilling aquatic activities, Kalpeni stands out as an excellent option among tourist destinations.

2.1.2 Kadamatt

Kadmatt Island is situated between Amini Island to the south and Chetlat Island to the north with a distance of about 407 km (220 nautical miles from Kochi, Kerala). The shape of the Kadamatt Island is elongated and narrow, only 0.57 km wide at the broadest point and a maximum length of 11 km with an area spread of 3.20 square kilometers. A 200-meter narrow channel separates the southern tip of the island from the uninhabited islet of Kalpitti. A lagoon, measuring about 2 km at the broadest point with a total area of 37. Sq. km is present on the western side. The island is flat, rising 2 to 3 m on the east and 2 to 4 m on the west above the sea level. A prominent sand ridge extends along the western edge of the island. Sand builds up in the southern region, creating undulations, while the northern side remains flat. The lush coconut foliage adds more scenic beauty to the island.

2.1.3 Agatti

Agatti Island is a beautiful island located in the Lakshadweep archipelago of India. It is a heaven for water sports enthusiasts and nature lovers. The coordinates for Agatti Island are approximately 10.8231° N latitude and 72.1762° E longitude. It plays a role in Lakshadweep economic development through its tourist attractions and it is approximately 7.6 km long and 1000 meters wide. The Island is part of the union territory of Lakshadweep in India.

2.1.4 Androtт

Androtт Island is located in the Lakshadweep archipelago of India. The coordinates for Androtт Island in the Lakshadweep archipelago are approximately 10.8481° N latitude and 72.9876° E longitude. The main income sources for the people of this island are traditional fishing methods and coconut cultivation. The island is rich in coconut cultivation and coral reefs. The Jama masjid in Androtт Island reflects the Muslim culture of the inhabitants.

3. Result and Discussion

Analysis of satellite images indicates that the land cover of Kalpeni Island increased by 0.074 km² from 1999 to 2022.By comparing both figures it is evident that a vast area of vegetation has undergone marine transgression which reduced their beach area. In 1999 the island was void of industries, residential areas, and tourism which is their current prime source of income. Whereas now there has been a sudden increase in colonization and tourism activities which in turn flourished the island's overall economy.

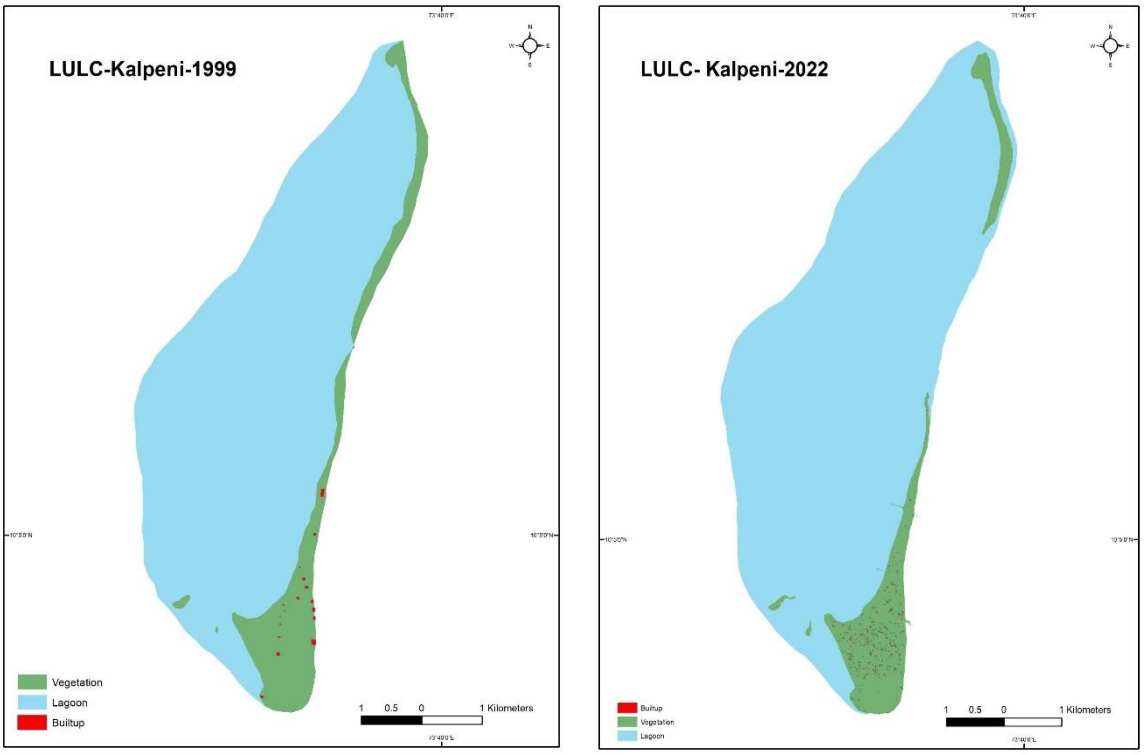

Fig 2. Urbanization Trend in the Kalpeni Island

Similarly, in the case of Androth Island, the area of land cover increased by 0.078 km² in the period of about 23 years from 1999 to 2022. A major event that happened during this period was the population explosion which surged the acceleration of urbanization. This ultimately led to social, economic, and cultural prosperity. A remarkable decline in the sandy shoreline was observed through the satellite image analysis.

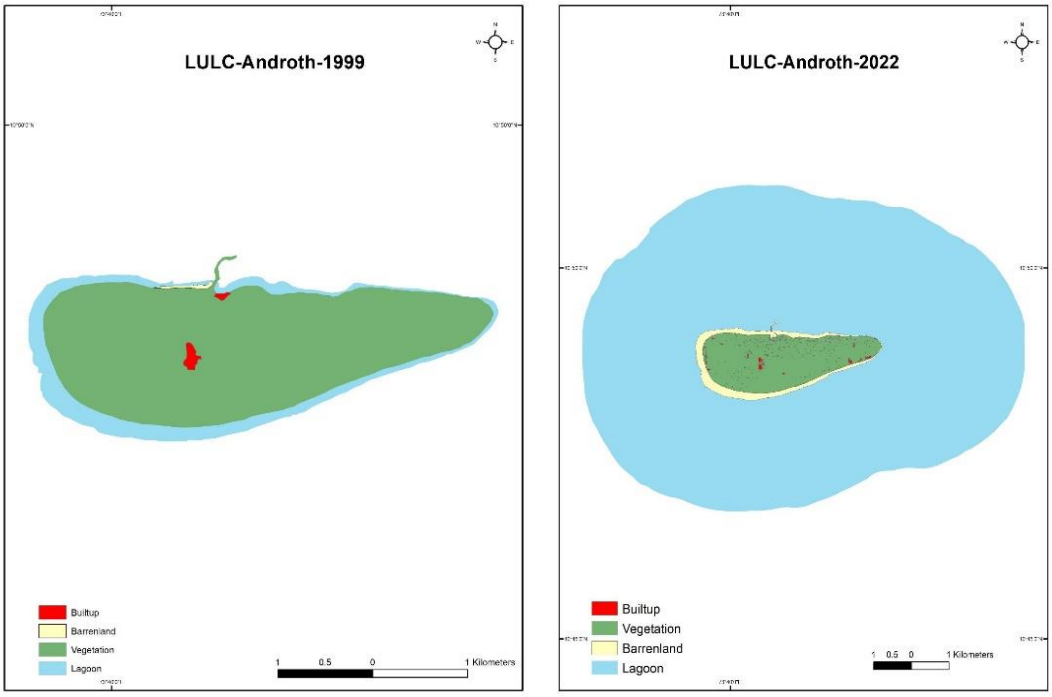

Fig 3. Urbanization Trend in the Androth Island

Based on the investigation of Agatti Island the result indicated that a large scale of urbanization has happened here over the mentioned period. It is approximately 0.107 km² in the above-mentioned time frame. Among these islands, Agatti is the fast-growing urbanized island during this time-lapse.

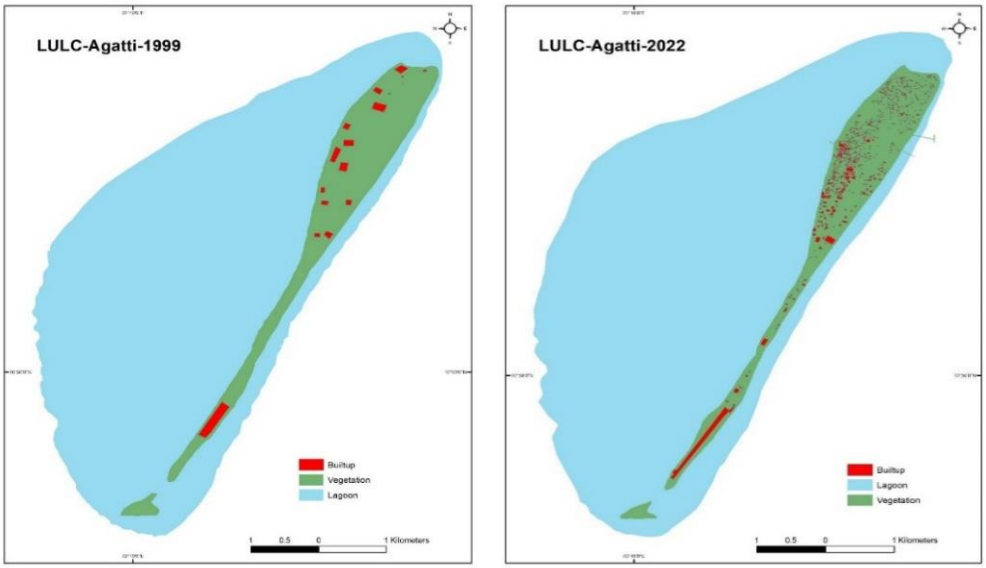

Fig 4. Urbanization Trend in the Agatti Islands

The image clearly shows that Kadamath Island has grown by 0.011 km². In this period of time, urban flourishing was common. There was also evidence of land area transgression.

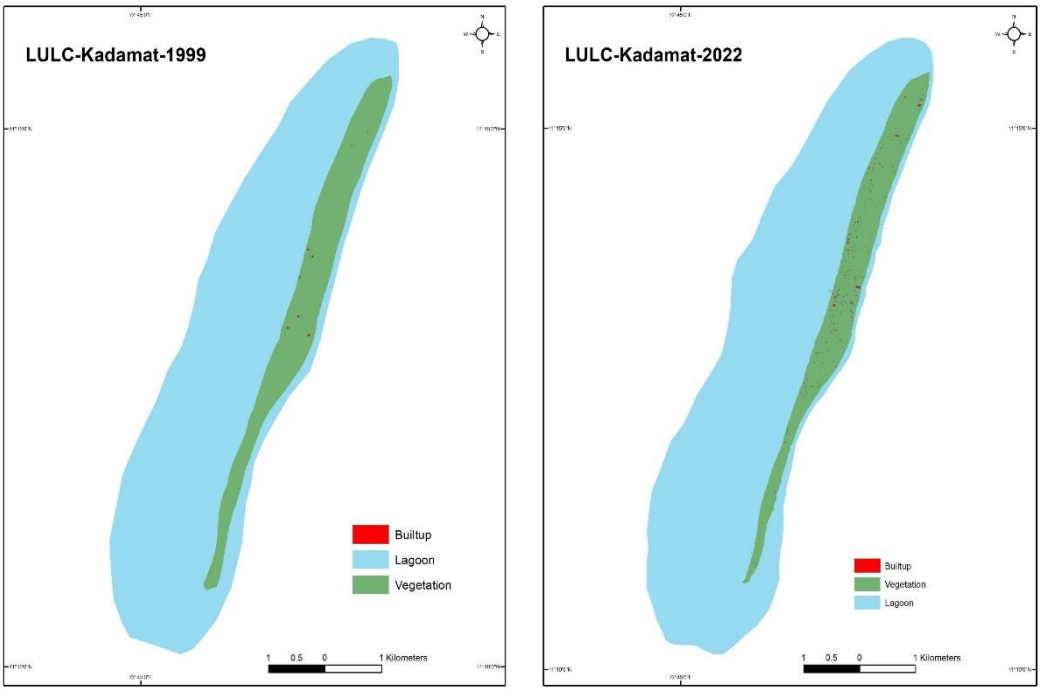

Fig 5. Urbanization Trend in the Kadamat Islands

The general tendency of urbanization in these four islands Agatti demonstrates that a significant number of changes occurred starting in 1999. Second, a similar pattern is displayed by Androth and Kalpeni. Among these islands, Kadamth has undergone the least modification.

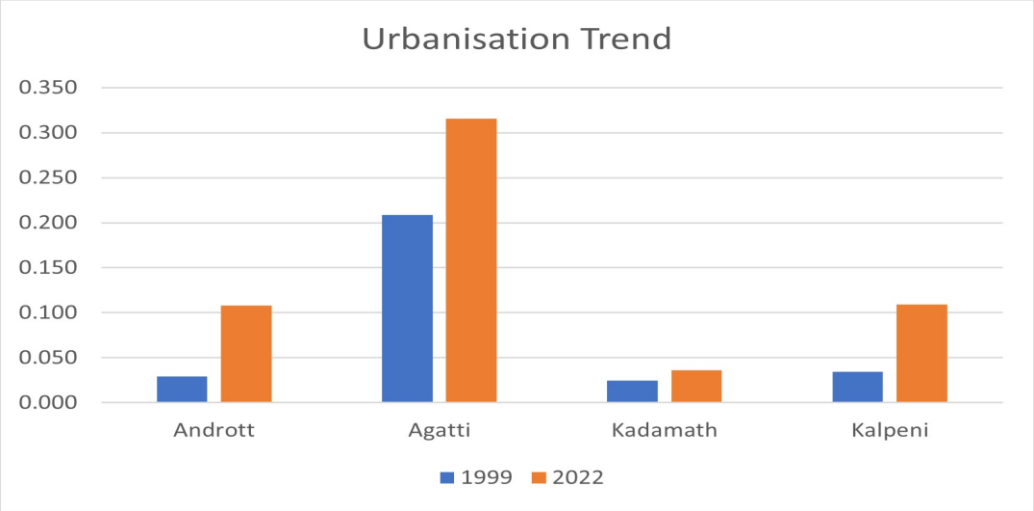

Fig 6. Urbanization Trend from 1999 to 2022

4. Conclusion

This study examined how the primary four islands in the Lakshadweep archipelago changed in terms of land use and cover between 1999 and 2022. The evaluation, mapping, and supervision of the LULC change are significantly aided by GIS and satellite remote sensing. All four of Lakshadweep's islands have had a notable influence from urbanization and other human activity. The island's natural environment, particularly its forests, mangroves, sandy beaches, and coral reefs, has been strained by the development that has occurred there. Space technology has a track record of successfully managing, mapping, and keeping an eye on natural resources, including land use and land cover.

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