Mapping Land use and Land Cover of Salcete Taluka

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DECLARATION BY STUDENT

I hereby declare that the data presented in the Dissertation report entitled, "Mapping Land use and Land Cover of Salcete Taluka " is based on the results of investigations carried out by me in the Economics Discipline at the Goa Business School, Goa University under the Supervision of Ms Heena Subrai Gaude and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "Mapping Land Use and Land Cover of Salcete Taluka" is a bonafide work carried out by Mr Canviceo N Correia

under the supervision in partial fulfilment of the requirements for the award of the degree of Masters of Arts in the Discipline of Economics at the Goa Business School, Goa University.

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PREFACE

This dissertation examines the land use and land cover (LULC) changes in Salcete taluka, Goa, India, over a 30-year period (1991-2021). Utilizing the power of remote sensing and Geographic Information Systems (GIS) technology, this study delves into the dynamic relationship between human activity and the environment.

Five distinct land cover classes were employed for mapping purposes: tree cover, barren land, built-up area, water bodies, and agricultural land. Supervised classification, with the maximum likelihood algorithm, formed the core methodology for analysing satellite imagery from 1991 and 2021. Ground truth data further validated the classification results.

The integration of economic activity data allowed for a deeper understanding of the driving forces behind observed LULC changes. The analysis revealed a significant shift in land use patterns between 1991 and 2021. While the earlier period showcased a dominance of agriculture, tree cover, and barren land, the latter period witnessed a decline in these categories, accompanied by a substantial expansion of built-up areas.

The case of Madgaon city serves as a microcosm of these broader trends. Over the three decades, Madgaon experienced significant growth in its built-up area, coupled with an increase in tree cover. This expansion came at the expense of barren land, water bodies, and agricultural land.

This research sheds light on the intricate connections between economic activities and environmental sustainability. By mapping LULC changes and integrating economic data, this study offers valuable insights for informed decision-making regarding future urban development and environmental conservation in Salcete taluka

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ABBREVIATIONS USED

Entity	Abbreviation
Land Use Land Cover	LULC
Geographic Information System	GIS
United States Geological Survey	USGS
False Color Composite	FCC

ABSTRACT

This study is done to Map the Land Use Land Cover of Salcete taluka using remote sensing and GIS technology, the time period consist of 30 years, starting from 1991 to 2021.Mapping has been done with the help of five classes namely Tree cover, Barren Land, Builtup Area, Water Bodies and Agriculture Land. The methodology adopted is supervised classification technique and maximum likelihood algorithm further it was validated using ground truth, economic activity data was integrated to detect the economic trend in the study area. It reveal that Land Use Land Cover of Salcete taluka for 1991 has majority share in agriculture, tree cover and barren land, where as Land Use Land Cover of Salcete taluka for 2021 shows loss of agriculture land and tree cover, gain in builtup area. The commercial city Madgaon has gained Builtup area and TreeCover from 1991 to 2021, while Madgon City has lost Barren Land, Water Bodies and Agriculture in that course of time This study shows intricate relationships between economic activities and environmental sustainability.

Keywords: LandUse LandCover, Supervised Classification, maximum likelihood algorith

Chapter 1

Introduction

1.1 Background information

The impact of land use and land cover change (LULCC) on many socioeconomic and ecological processes is crucial to environmental management. This paper focuses on examining the dynamics of LULCC in Salcete Taluka, highlighting its importance in resource management and environmental monitoring. Comprehensive land use/land cover information is crucial for effective planning and sustainable development, according to the study. The purpose of this article is to offer methods for improved land use schemes and to shed light on the changing landscape of Salcete Taluka through an analysis of LULCC patterns and drivers. In order to evaluate the distributions and changes in land use and land cover over time, the methodology makes use of field surveys, GIS analysis, and remote sensing techniques. Significant changes in land use patterns over time are suggested by the findings, which are impacted by variables including urbanization, agricultural expansion, and infrastructure development. In order to tackle new problems and make sure that land resources in Salcete Taluka are used sustainably, the report finishes with suggestions for integrated land management methods. The primary components of the Earth's surface are land use and land cover, which reflect the interactions between humans and their environment. Changes in land use and cover systems have significant ramifications for the environment, the climate, and human health. Sustainable development and the management of natural resources depend on our ability to comprehend these changes. For the purpose of studying LULCC dynamics in a semi-urban context, Salcete Taluka in [specific location] is an appropriate case study. To better educate decision-making and policy-making, this article will examine LULCC in Salcete Taluka, focusing on its patterns, drivers, and ramifications. For a variety of reasons, including urban planning, land use, forestry, conservation, and disaster management, accurate and current information on land use and land cover is crucial. In order to map and monitor LULCC at various spatial and temporal scales, remote sensing technologies in conjunction with geographic information systems (GIS) provide invaluable tools. Trustworthy LULC data is readily available, which allows for evidence-based decision-making and the identification of trends, hotspots, and problem regions. The need for thorough LULC information is especially acute in the context of the Salcete Taluka, where growing urbanization and agricultural intensification are obvious.

The satellite images show that the land cover and land use patterns in Salcete Taluka have changed significantly over time. The tendency of urban expansion is becoming more prominent, and it is defined by the transformation of once-natural habitats and agricultural land into constructed cities. Rapid urbanization and the resulting changes to land cover are shown by the expansion of residential, commercial, and industrial infrastructure. Population increase, changing farming practices, and market needs are driving agricultural intensification in some areas. Environmental degradation and biodiversity loss are costs associated with this intensification, though. Deforestation, encroachment, and the conversion of land to non-forest uses are the main causes of the downward trend in forest cover. Anthropogenic activities, such as pollution, sedimentation, and land reclamation, have an impact on water bodies. Generally, the Salcete Taluka landscape shows signs of constant change due to the interaction between human activities and natural processes. Several factors, including socioeconomic, demographic, institutional, and environmental factors, contribute to LULCC in Salcete Taluka. Population expansion, rural-to-urban migration, and economic development all play a role in propelling urbanization forward. Improvements to accessibility and the ability to transform land have been made possible by the expansion of transportation networks. Developments in technology, shifts in market dynamics, and changes in land tenure systems all play a role in propelling agricultural expansion. The impact of policy interventions, such as zoning restrictions and land use planning, on land cover dynamics varies. Indirect influences on land use patterns are exerted by natural processes like climate change, land degradation, and natural hazards, which worsen vulnerabilities and resilience difficulties. Ecosystems, biodiversity, livelihoods, and socioeconomic development are all significantly impacted by the shifting economic dynamics in Salcete Taluka systems. The loss of natural areas, increasing pollution, and habitat fragmentation are all consequences of urban sprawl that have an impact on both the resilience of cities and the quality of life within them. Food security and rural livelihoods are jeopardized as a result of agricultural expansion's contributions to soil erosion, water depletion, and loss of agro-biodiversity. Deforestation and habitat degradation have a negative influence on ecosystem services, carbon sequestration capability, and climate change impacts. Integrating water resource management techniques is crucial because changes in water quality and hydrological regimes impact ecosystem functioning and human health. Land use planning and management must be approached with an inclusive and collaborative mindset if we are to meet the challenges given by LULCC. Agroforestry, conservation agriculture, and watershed management are all examples of sustainable land management strategies that can increase productivity and resilience while reducing environmental threats. To promote sustainable and equitable land use patterns, it is vital to strengthen land governance mechanisms such spatial planning frameworks, land use regulations, and land tenure rights. The negative impacts of urbanization can be lessened and ecological connectedness can be increased by investing in green infrastructure, urban green areas, and ecological restoration programs. In order to promote responsible land management and adaptive governance, it is essential to raise public knowledge, improve stakeholder collaboration, and increase community engagement. Understanding LULCC dynamics in Salcete Taluka is crucial for informed decision-making and sustainable development, according to the study. Human activities and environmental results are interdependent, and this research shows how by examining the patterns, drivers, and consequences of LULCC. Holistic approaches that balance socioeconomic development with environmental protection and resilience-building are necessary for sustainable land use management. The study offers unique insights into the developing landscape of Salcete Taluka and recommendations for proactive interventions and policy measures by integrating remote sensing technology, GIS analysis, and field observations. Land use systems in Salcete Taluka and elsewhere can be made more resilient and sustainable through the promotion of adaptive governance and the encouragement of stakeholder synergies.

Global environmental and ecological transformations are mostly driven by climate change, which has direct impacts on land use and land cover systems, notably forest ecosystems and the services they provide (Schroter et al., 2005). In order to achieve socioeconomic well-being, land use and land cover represent human activities in a physical landscape (FAO, 2010). The hydrological cycle is impacted by changes in land use and cover brought about by population growth (Baker and Miller, 2013). Modifications to land use and land cover, such as urbanization, ruralization, infrastructure development, and agricultural expansion, can have a substantial impact on local climates by affecting precipitation, temperature, and humidity (Secretariat, 2008; Bernstein et al., 2008). For instance, deforestation increases surface runoff and soil erosion while decreasing evapotranspiration and groundwater infiltration on the surface.

The human-induced changes in land cover, land use, and temperature are influenced by the interconnections among forest ecosystems, land systems, and climate systems (Wu et al., 2017). According to Foley et al. (2005) and Dai et al. (2016), these changes have a significant influence on forest ecology and water availability because they change the Earth's physical features and the composition of the atmosphere. While agricultural operations release greenhouse gases that contribute to environmental degradation, deforestation reduces forests' ability to store carbon dioxide, which accelerates climate change. Agriculture, forestry, and land use changes are expected to contribute significantly to global emissions in the future, according to the Intergovernmental Panel on Climate Change. As a result, land management methods and agricultural practices will need to change in response to climate change. The complex relationship between climate change, land use dynamics, and other natural systems must be understood in order to practice sustainable resource management.

The impacts of climate change on land cover and land use in Salcete Taluka are substantial and complex.

Changes in land use and cover, such as urbanization, deforestation, and agricultural expansion, can alter hydrological processes. More impermeable surfaces mean less water can soak into the ground and more water can run off the surface as rain, which means more flooding and different timing and amount of streamflow as a result of urbanization. Deforestation has a negative impact on evapotranspiration rates and can cause soil erosion, water body sedimentation, and decreased groundwater recharge. Changes to the permeability of the landscape as a result of agricultural activities can influence groundwater levels by changing the rate at which water moves through the soil. Changes in Precipitation Patterns: Precipitation patterns are affected by climate change, which alters the time, intensity, and distribution of rainfall in Salcete and Taluka. Changes in land cover and land use can amplify or lessen the effects of these changes. In contrast to urbanization, which can result in localized increases in precipitation due to the urban heat island effect, deforestation can reduce local precipitation levels by changing atmospheric moisture dynamics.

Changes in Land Cover and Water Availability: Changes in Land Cover and Water Availability might affect the amount of water available in Salcete Taluka. Deforestation and urbanization can limit the capacity of eco systems to store and regulate water, resulting in reduced baseflow in streams and rivers during dry seasons. Water resources may be further depleted if agricultural operations lead to a rise in irrigation water demands. Ecological Consequences: Changes in flow regime volumes can have a substantial impact on the aquatic and riparian ecosystems of the Salcete Taluka. Changes in flow patterns can have an impact on the distribution of aquatic organisms, alter the dynamics of sediment movement, and disturb the availability of habitat. Habitat fragmentation and loss can occur during dry seasons due to reduced flow volumes, which in turn impacts ecosystem resilience and biodiversity. Changes in flow regime quantities may also have an impact on the socioeconomic situation in Salcete Taluka. Damage to property, loss of livelihoods, and interruptions to transportation networks and infrastructure can result from an increased risk of floods caused by changes in land use and cover. There will be repercussions for local economies and way of life as a result of reduced water availability in areas such as agriculture, industry, and household water supplies. Water availability, ecological integrity, socio-economic well-being, and hydrological processes are all affected by the complex and interwoven impacts of climate change and land cover/land use change on flow regime volumes in Salcete Taluka. In order to implement climate adaptation methods and ensure sustainable management of water resources in the region, it is crucial to understand and control these impacts.

The degradation of the environment in the higher catchment areas can have far-reaching effects on local ecosystems and downstream inhabitants. Several facets of the upper catchment's environmental degradation are detailed here:

Deforestation: Deforestation is a major factor in the degradation of the environment in upper catchment areas. The delicate ecological balance of these places is disrupted by the clearing of forests for timber extraction, agricultural expansion, and urbanization. Soil erosion, biodiversity loss, hydrological cycle disruption, and heightened susceptibility to landslides and floods are all effects of deforestation. Soil Erosion: Unsustainable land management practices and deforestation expose the soil to wind and water erosion. Less soil fertility, less agricultural production, and more sedimentation in rivers and reservoirs can result when rainfall washes away topsoil without the stabilizing impact of vegetation. Flooding downstream and deposition on aquatic environments are both caused by soil erosion. Damage to Natural Habitats: Deforestation and other habitat loss in the upper catchment areas leads to a decline in biodiversity. Loss of these ecosystems can cause local extinctions of species and problems with pollination, seed distribution, and nutrient cycling, among other ecological functions. Ecosystem services are vulnerable to the underlying causes of biodiversity loss, which weakens ecosystems' ability to withstand environmental stresses.

Water Pollution Systems: Environmental degradation in the upper catchment areas can lead to water pollution, which can have negative impacts on aquatic ecosystems and human health. Eutrophication, algal blooms, and fish kills are all possible outcomes of agricultural runoff that contaminates rivers and streams with sediment, pesticides, and fertilizers. The discharge of untreated wastewater and runoff from paved surfaces are two additional ways in which industrial operations and urbanization can contaminate water sources. Habitat Fragmentation: Infrastructure development, such as highways, dams, and urban expansion, can fragment natural habitats in the upper catchment areas, isolating wildlife populations and interfering with migration pathways. Habitat fragmentation has a negative impact on genetic diversity, species mobility, and the likelihood that vulnerable species may become extinct. A further consequence is that ecosystems are less able to adjust to new circumstances. Climate Change Impacts: Deforestation, soil erosion, and changes in land use all contribute to environmental degradation in the upper catchment areas, which in turn contributes to climate change. By changing precipitation patterns, increasing the frequency and severity of extreme weather events, and amplifying already-existing environmental stresses like droughts and floods, climate change exacerbates environmental degradation. Ecosystem health, conservation of biodiversity, management of water resources, and sustainable development are all adversely affected by environmental degradation in the upper catchment areas. Promoting sustainable land management techniques, protecting natural habitats, restoring damaged ecosystems, and mitigating the impacts of climate change must be coordinated activities if these concerns are to be addressed.

1.2. Climate Change and its Impacts

Climatic change is the phrase used to describe long-term changes in regional or worldwide climatic patterns that are mostly caused by human activity like burning fossil fuels, cutting down trees, and manufacturing. The enhanced greenhouse effect and global warming are caused by the emission of greenhouse gases into the atmosphere, which are released by these activities. Natural systems, ecosystems, human civilizations, and economies are all impacted by the extensive and complex impacts of climate change. Temperature Rise: The rise in global temperatures is one of the most noticeable impacts of climate change. The polar ice caps and glaciers are melting, changes in precipitation patterns are occurring, and heatwaves are becoming more frequent and extreme as a result of this warming trend. Other climate-related occurrences, like tropical storms, droughts, and wildfires, are also made worse by increasing temperatures. Changes in Precipitation Patterns: Precipitation patterns are altered by climate change, which results in changes in the frequency, intensity, and distribution of precipitation. More rain and flooding in some areas means longer droughts and water shortages in others. The likelihood of catastrophic weather occurrences, the state of water supplies, and agricultural systems can all be negatively impacted by these changes. Sea Level Rise and Temperature: The melting of glaciers and ice sheets, along with the thermal expansion of seawater owing to warming temperatures, are the main causes of sea level rise. Sea level rise endangers coastal communities, infrastructure, and ecological systems by causing erosion, saltwater intrusion into freshwater supplies, and increased vulnerability to storm surges and flooding. Impact on Ecosystems and Biodiversity: Climate change alters habitat conditions, species distributions, and ecological interactions, all of which have a negative impact on biodiversity. Although some species may relocate or adjust to new environments, others may go extinct. Changes in temperature and precipitation regimes can also have an impact on the timing of biological processes like migration, reproduction, and flowering, which can disrupt ecosystem functioning and food webs.

Impacts on Human Health: Climate change threatens human health in a number of ways, including through heat-related diseases, vector-borne diseases, air pollution, and food and water insecurity. Heatstroke, respiratory issues, and injuries are all potentially caused by heatwaves and other severe weather events.

Infectious diseases including malaria, dengue fever, and Lyme disease can spread depending on changes in temperature and precipitation patterns. Climate change worsens social and economic disparities, disproportionately hurting low-income communities, indigenous populations, and other marginalized groups. Extreme weather conditions, displacement brought on by sea level rise or environmental degradation, and economic loss of livelihood brought on by changes in agricultural productivity can result in social discontent, migration, and economic losses. In conclusion, climate change is a global problem with far-reaching impacts on ecosystems, human health, socioeconomic systems, and the environment. Reducing emissions of greenhouse gases, switching to renewable energy, adapting to new climatic circumstances, and strengthening ecosystems and communities that are already at risk are all essential steps in combating climate change. Indeed, a key issue in talks about global warming is attributing climate change to human activities such greenhouse gas emission, deforestation, and changing of land use.

Modern climate change is mainly caused by human activity, according to the scientific consensus, which is backed by a mountain of evidence and research. In detail, these actions cause the climate to change in the following ways:

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are examples of greenhouse gases that are released into the atmosphere via the combustion of fossil fuels for energy production, transportation, industrial activities, and agriculture. The heightened greenhouse effect and global warming are caused by these gases' ability to absorb heat. The observed rise in global temperatures over the past century is closely correlated with the growth in atmospheric concentrations of greenhouse gases, especially CO_2 from burning fossil fuels. Deforestatio: Deforestation, which is mostly caused by urbanization, logging, and agricultural expansion, contributes to climate change by lowering the planet's ability to absorb carbon dioxide from the air. By absorbing carbon dioxide during photosynthesis and subsequently storing it in their biomass and soil, trees play the role of carbon sinks. Clearing or degrading forests releases their stored carbon into the atmosphere, which adds to the problem of rising greenhouse gas concentrations and the overall warming of the planet. In addition to impacting precipitation, temperature, and biodiversity, deforestation also has an impact on regional and local climatic patterns.

Modification of Land Use: Changes in albedo (reflectivity), surface roughness, and evapotranspiration rates result from human activities like agriculture, urbanization, and infrastructure development. These changes impact regional and local climates by changing the Earth's energy balance. One factor that contributes to greater temperatures is the formation of urban heat islands, which occur in cities with a lot of impermeable surfaces. Changes in land use can also have an impact on ecosystems, water supplies, and the carbon cycle, which exacerbates climate change. Several pieces of evidence, such as paleoclimate data, climate models, measurements of greenhouse gas concentrations, and trends in temperature, point to the attribution of climate change to human activity. It is highly likely that human activity has been the primary cause of the observed warming since the middle of the 20th century, according to the Intergovernmental Panel on Climate Change (IPCC) and other scientific organizations. The development of successful methods for adaptation and mitigation of climate change requires an acknowledgment of the role that human activities play in driving this phenomenon. Societies may lessen the impacts of climate change and become more resilient to its effects by cutting down on greenhouse gas emissions, protecting forests, and supporting sustainable land use.

Carbon dioxide emissions come from a variety of sources, with each contributing a different proportion to the total emissions, according to data from the Environmental Protection Agency (EPA) from 2015. Here are some of the sources:

The generation of electricity and heat is a major source of carbon dioxide emissions, making up a large percentage of all emissions worldwide. The combustion of fossil fuels like coal, oil, and natural gas produces carbon dioxide when used to generate electricity and heat. A considerable portion of the world's carbon dioxide emissions come from the transportation sector, which includes automobiles on the road, planes, ships, and trains. A significant portion of the world's greenhouse gas emissions come from the transportation sector, specifically from the burning of fossil fuels in cars and other vehicles. Manufacturing, mining, building, and chemical production are all examples of industrial activities that release carbon dioxide into the atmosphere as a result of their energy-intensive processes and operations. Because it uses fossil fuels and other carbon-intensive inputs, the industrial sector is a major contributor to greenhouse gas emissions. Energy use in commercial and residential buildings, which includes heating, cooling, lighting, and appliances, adds to carbon dioxide emissions. One significant source of emissions is the building sector, which uses fossil fuels to generate energy and heat the structure.

Greenhouse gas emissions are caused by deforestation, soil degradation, enteric fermentation, and other agricultural processes, including the production of animals, the use of fertilizers, and land management. Greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide, are largely emanating from the agricultural sector. Deforestation, land clearing, and changes in land use patterns release carbon dioxide that has been stored in vegetation and soil. Land use change has a significant impact on carbon dioxide emissions, particularly through deforestation and forest degradation, which lowers ecosystems' ability to store carbon.

The hydrologic cycle and regional climatic trends in Salcete Taluka and beyond will be affected by global warming, which is caused by increased atmospheric concentrations of greenhouse gases like carbon dioxide. On the hydrologic cycle, global warming has the following impacts: Changes in Precipitation Patterns: Global warming impacts regional precipitation patterns, resulting in changes in rainfall distribution, intensity, and frequency. Because to this, Salcete Taluka may see more intense rainfall events and more frequent and severe droughts, both of which have an impact on water supply and agricultural output. Temperature Changes: The timing and amount of runoff and streamflow are affected by changes in evaporation rates, soil moisture levels, and snowmelt dynamics, which are brought about by the rising temperatures linked to global warming. As the temperature rises, hydrological processes can change, and evapotranspiration, the loss of water from plants and soil, can increase. Melting of Glaciers and Snowpack in Mountainous Regions is Accelerated by Global Warming, Contributing to Increased Runoff and Changes in River Flow Regimes. Salcete Taluka and other areas that rely on rivers supplied by glaciers may see changes to their ecosystem dynamics, hydroelectric power production, and the amount of water available downstream as a result of this. Sea Level Rise is a result of the thermal expansion of saltwater caused by global warming and the melting of the polar ice caps. Saltwater intrusion into coastal aquifers, flooding of low-lying areas, and degradation of coastal habitats are all consequences of rising sea levels that threaten coastal ecosystems and freshwater supplies in Salcete Taluka. Overall, changes in temperature, precipitation, snowmelt dynamics, and sea levels are some ways in which global warming affects the hydrologic cycle and regional climatic trends in Salcete Taluka. In order to design resilient water resource management practices and adaptive methods to lessen the impact of climate change on local ecosystems and populations, it is crucial to understand these impacts.

1.3 Impact of Land Use and Land Cover Change on the Environment

Like in many other parts of the world, Salcete Taluka is experiencing substantial impacts from land use/land cover change (LULCC) on ecosystems, human societies, and the environment. The LULCC processes and their impacts on Salcete Taluka are briefly explained below: Rapid urbanization in Salcete Taluka has resulted in the transformation of forested regions, natural landscapes, and agricultural fields into man-made residential, commercial, and industrial complexes. Changes to hydrological systems, loss of biodiversity, and rising temperatures (the urban heat island effect) are all outcomes of this development's chopping down of trees and habitats and expansion of impermeable surfaces. Additional socioeconomic changes brought about by urbanization include a rise in the demand for services, infrastructure, and resources. The expansion of agriculture in Salcete Taluka frequently results in deforestation, land degradation, and biodiversity loss, as it is the primary land use in the region. Habitat loss, soil erosion, and diminished ecosystem services are outcomes of converting grasslands and woodlands into agricultural areas for growing crops and grazing cattle. Degradation of soil quality, water resources, and ecosystem health can also be caused by intensive agricultural methods, which involve the use of agrochemicals and automatization.

In Salcete Taluka, ecosystems are disrupted and land use patterns are changed as a result of infrastructure development. This includes the construction of roads, highways, dams, and irrigation canals. Natural habitats are disturbed, wildlife mobility is impeded, and the risk of environmental hazards like landslides and floods is increased as a result of infrastructure developments, which support economic development and improve connectivity. In instance, there are a number of ways in which dam building might influence water quality, downstream ecosystems, and human populations. Deforestati and Forest Degradation in Salcete Taluka are caused by logging, agricultural expansion, urbanization, and infrastructure development. Reduced carbon sequestration, biodiversity loss, and degradation of ecosystem functions like water management, soil stabilization, and climate regulation are all consequences of deforestation. By releasing stored carbon dioxide into the atmosphere, deforestation also contributes to climate change by accelerating global warming and its impacts. Water Resource Management: LULCC changes surface runoff, groundwater recharge, and streamflow patterns in Salcete Taluka, affecting water resources. Changes in land cover, such as deforestation and urbanization, can increase surface runoff and lower groundwater infiltration, resulting in changes in water supply and quality. Water pollution and degradation of aquatic ecosystems can have an effect on human health and biodiversity due to inefficient waste management and agricultural runoff, two examples of poor land use practices.

LULCC in Salcete Taluka has a wide range of related impacts on the environment, ecosystems, and human health. In order to create resilient and healthy communities in Salcete Taluka and reduce the negative effects of LULCC, it is essential to understand these impacts. This knowledge will guide sustainable land use planning, resource management, and conservation initiatives. The availability of water resources is impacted by a number of hydrological processes, and land cover serves as a vital link between the atmosphere and the terrestrial environment. Changes in land cover, especially in catchments, can have big impacts on the amount, frequency, and quality of water flow in Salcete Taluka. A quick explanation of how changes to catchment runoff channels affect water flow is this: Water Flow Quantity: Changes in land cover, like deforestation, urbanization, and agricultural cover expansion, can have an impact on the amount of water that flows through catchments in Salcete Taluka. Greater peak flows and flash floods are the results of rainstorm events when infiltration rates are reduced and surface runoff is increased due to urbanization and impermeable surfaces. Increased runoff and decreased baseflow in streams and rivers are the results of deforestation, which lowers interception and transpiration on plants. Thus, changes in land cover can aggravate hydrological extremes, affecting the amount of water available for ecosystems and human activities. Changes in Land and Cover can also affect the frequency of Water Flow Events in Catchments. Watercourses can become more channelized, drainage patterns can change, and floodplains and wetlands lose some of their natural storage capacity as a result of development and urbanization. Particularly in places vulnerable to urban change and infrastructure expansion, these changes may lead to more frequent flooding. On the flip side, soil degradation and deforestation can reduce water retention capacity, which in turn increases the frequency of droughts and causes rivers and streams to flow at low levels.

Water Flow Quality: Changes to watershed runoff routes may have an effect on the water quality that flows through the streams of Salcete Taluka. A variety of contaminants, including nutrients, heavy metals, pesticides, and sediment, end up in surface runoff as a result of urbanization and agricultural practices. In addition to worsening water quality and endangering aquatic ecosystems and human health, increased runoff from impermeable surfaces can increase the transit of contaminants into water bodies. The oxygen levels, pH, and temperature of bodies of water are all impacted by changes in land cover, which in turn alter ecosystem dynamics and water quality. In conclusion, changes to runoff routes in catchments brought about by changes in land cover can have significant impacts on the amount, frequency, and quality of water flow in Salcete Taluka. Conservation of ecosystems, efficient management of water resources, and reduction of floods all depend on a firm grasp of fundamental hydrological processes. The negative consequences of land cover change on water resources can be lessened by implementing sustainable land use practices and land management measures, which also strengthen watershed ecosystems.

1.4 Contribution of Geospatial Technology

Geospatial technology is crucial to Salcete Taluka on a number of different levels, including agriculture, urban planning, natural resource management, disaster management, and environmental conservation. A quick explanation of how Salcete Taluka makes use of geospatial technologies is as follows: Geospatial technology, such as GIS and remote sensing, aids Salcete Taluka's urban planners in making educated decisions on land use zoning, infrastructure development, and growth management in the city. Use of geographic information systems (GIS) allows for the examination of geographical data pertaining to environmental factors, transportation networks, land cover, and population distribution; this, in turn, aids in the discovery of appropriate sites for commercial, residential, and industrial development. To help with urban monitoring and land use planning, remote sensing data provide useful information on encroachments, changes in land cover, and urban expansion. The sustainable management of natural resources in Salcete Taluka, such as forests, water bodies, and agricultural lands, is supported by geospatial technology. Geographic information system (GIS) mapping and analysis aids in the identification of ecologically sensitive areas, biodiversity hotspots, and essential habitats. Soil erosion, land cover changes, and deforestation rates can all be tracked with the use of remote sensing data, which in turn helps direct restoration initiatives and land management strategies. Through spatial analysis and modeling, geospatial technology also makes it easier to manage watersheds, monitor water quality, and implement sustainable agriculture methods. In agricultural planning, precision farming, and crop management in Salcete Taluka, geospatial technology is essential. Farmers can make better choices about what crops to plant, when to water, and how much fertilizer to apply thanks to GIS-based maps of soil types, terrain, and weather conditions. With the use of remote sensing data, we can learn a lot about crop stress, insect infestations, vegetation indices, and overall crop health, which helps us predict future yields. Geospatial technology also aids in crop insurance schemes, agro-advisory services, and improving agricultural output and resilience. Geospatial technology contributes to disaster preparedness, response, and recovery operations in Salcete Taluka, particularly in reducing the cover of natural hazards like floods, landslides, and cyclones. Risk modeling, vulnerability assessment, and hazard mapping using geographic information systems (GIS) aid in the identification of high-risk locations, evacuation routes, and emergency shelters. The use of remote sensing data allows for the quick evaluation of damage, analysis of the current situation, and preparation for recovery following a disaster. Geospatial technology also makes it easier for disaster management agencies and local authorities to monitor extreme weather events in real-time, implement early warning systems, and enhance decision-making.

By providing spatial data and analysis tools for habitat mapping, biodiversity assessment, and ecological monitoring, geospatial technology aids environmental conservation projects in Salcete Taluka. Geographic information system (GIS) habitat suitability modeling aids in the identification of wildlife corridors, protected areas, and mangrove forests as priority sites for restoration and conservation. To prepare for conservation efforts and implement adaptive management measures, scientists use remote sensing data to track changes in habitat fragmentation, deforestation rates, and land cover. Geospatial technology also makes it easier for the general public to participate in scientific endeavors, citizen science projects, and environmental education programs, which promotes community involvement and responsible resource management. Overall, geospatial technology is incredibly important in Salcete Taluka for a bunch of different reasons, like making decisions based on facts, promoting sustainable development, and being resilient. Salcete Taluka is able to optimize resource allocation, improve the quality of life for its citizens, and protect the environment for the future by using geographic information systems (GIS), remote sensing, and spatial analysis tools.

Indeed, GIS's capacity to combine, analyze, and display spatial data pertaining to water resources makes it an excellent tool for a wide range of hydrological research applications. Some common applications of GIS in hydrological studies are as follows: Using digital elevation models (DEMs) and terrain analysis, GIS enables researchers to demarcate watersheds and sub-basins. In order to facilitate hydrological modeling and watershed management research, GIS tools can be used to study watershed boundaries and features including slope, aspect, and land use. Modeling of Hydrological Processes: GIS-based hydrological models model the routing of streamflows, infiltration, evapotranspiration, and rainfall-runoff as well as other methods of water transport across landscapes. Hydrological models can predict surface runoff, groundwater recharge, and flooding events with the help of GIS-provided spatial data inputs such land cover, soil characteristics, and precipitation data. Floodplain Mapping and Risk Assessment: GIS is used to map floodplains, identify flood-prone locations, and assess flood risks based on variables like topography, land use, soil permeability, and data from previous floods. Flood hazard maps created using GIS are useful for planning land use, being prepared for emergencies, and developing flood mitigation plans. Water Quality Monitoring: GIS integrates monitoring data with geographically referenced land use, land cover, and hydrological feature information to enable the spatial analysis of water quality parameters such as dissolved oxygen, pH, nutrients, and contaminants. Sources of pollution can be located, conservation efforts can be prioritized, and remediation methods can be developed with the use of GIS-based water quality modeling. When it comes to managing groundwater resources, such as aquifer properties, groundwater levels, and recharge zones, GIS plays a crucial role in mapping and evaluating the data. Assessing aquifer susceptibility, calculating rates of groundwater depletion, and developing long-term strategies for groundwater management can all be aided by GIS-based groundwater modeling. Wetland Mapping and Conservation: GIS is used to map wetland extent, vegetation types, and ecological roles, aiding in the conservation and restoration of wetland ecosystems. To better understand habitat quality, track changes in wetland ecosystems through time, and identify priority sites for protection, wetland inventories based on GIS are invaluable. Insights into sediment sources and pathways are provided by GIS-based erosiom modeling, which measures soil erosion rates, sediment transport, and sediment deposition in watersheds. Through the integration of topographical data, land cover information, and erosion parameters, GIS enables sedimentation and erosion studies to pinpoint erosion hotspots and prioritize erosion control strategies. With GIS's spatial analysis tools, data management capabilities, and visualization techniques, hydrological research has come a long way. We now have a better grasp of water resources, and we can make evidence-based decisions about water management and conservation thanks to GIS.

CHAPTER 2:

LITERATURE REVIEW

2.1 Land Use and Land Cover Change Studies

 Summarize key findings from relevant studies on land use and land cover change using remote sensing and GIS. Land use and land cover change (LULCC) studies are crucial for understanding the dynamic relationship between human activities and the environment. Remote sensing and Geographic Information Systems (GIS) have become indispensable tools in monitoring and analyzing LULCC patterns at various spatial and temporal scales. This literature review aims to summarize key findings from relevant studies utilizing remote sensing and GIS techniques in investigating LULCC. Remote Sensing and GIS Methodologies: Remote sensing technologies, including satellite imagery and aerial photography, offer valuable data for mapping and monitoring land cover changes over time. GIS provides a framework for spatial analysis and modeling, enabling researchers to integrate diverse datasets and analyze complex spatial relationships. Urbanization Dynamics: Studies have consistently shown the rapid expansion of urban areas worldwide. Remote sensing data have been instrumental in quantifying urban sprawl, identifying urban growth hotspots, and assessing associated impacts on natural ecosystems. GIS-based analysis has facilitated the identification of factors driving urbanization, such as population growth, economic development, and land-use policies. Deforestation and Forest Degradation: Remote sensing techniques have been extensively employed to monitor deforestation and forest degradation processes, particularly in tropical regions. Studies have highlighted the role of human activities, such as agriculture, logging, and infrastructure development, in driving forest loss. GIS-based spatial modeling has contributed to predicting future deforestation trends and prioritizing areas for conservation efforts. Agricultural Expansion and Intensification: Remote sensing data have been used to track changes in agricultural land use, including expansion into natural habitats and intensification through practices like irrigation and monoculture farming. GIS analysis has facilitated the assessment of land suitability for agriculture, evaluation of crop productivity, and identification of areas vulnerable to soil degradation and water scarcity. Wetland Loss and Degradation: Wetlands are among the most threatened ecosystems globally, facing pressures from urbanization, agriculture, and infrastructure development. Remote sensing techniques have enabled the mapping and monitoring of wetland extent and quality over time. GIS-based hydrological modeling has contributed to understanding the impacts of land use changes on wetland hydrology and ecosystem services. Climate Change Impacts: Remote sensing data have been crucial in studying the impacts of climate change on land cover dynamics, including shifts in vegetation patterns, changes in snow and ice cover, and alterations in coastal landforms due to sea-level rise. GIS-based analysis has facilitated the integration of climate data with land cover datasets, allowing researchers to assess vulnerability and develop adaptation strategies for changing environmental conditions. Remote sensing and GIS technologies have revolutionized the study of land use and land cover change, providing valuable insights into the drivers, patterns, and impacts of LULCC at local, regional, and global scales. Continued advancements in data acquisition, processing techniques, and spatial modeling are essential for addressing emerging challenges related to sustainable land management and conservation efforts.

2.2 DISCUSS STUDIES FOCUSING ON SIMILAR CONTEXTS OR REGIONS.

Studies focusing on similar contexts or regions often provide valuable insights into specific LULCC dynamics and their implications for environmental management and policy. Here are discussions on studies from various regions: Numerous studies have investigated LULCC in the Amazon rainforest due to its significance for global biodiversity and climate regulation. Remote sensing data have revealed extensive deforestation for agricultural expansion, particularly for soybean cultivation and cattle ranching. GIS-based analyses have highlighted the spatial distribution of deforestation hotspots and the associated impacts on biodiversity loss, carbon emissions, and indigenous communities. Efforts to mitigate deforestation have included the implementation of protected areas, land-use planning, and sustainable development initiatives. Southeast Asia has experienced significant land cover changes, primarily driven by palm oil production, logging, and infrastructure development. Remote sensing studies have documented large-scale deforestation in Indonesia and Malaysia, leading to habitat loss for endangered species like orangutans and Sumatran tigers. GIS-based analyses have contributed to identifying priority areas for conservation and sustainable land management, as well as assessing the socio-economic implications of land use transitions on local communities. LULCC in African savannas has been influenced by factors such as population growth, agricultural expansion, and climate variability. Remote sensing techniques have been utilized to monitor changes in land cover types, including shifts between grasslands, woodlands, and croplands. GIS-based studies have examined the drivers of land degradation, such as overgrazing and soil erosion, and their impacts on ecosystem services and rural livelihoods. Integrated approaches combining remote sensing and socio-economic data have supported land-use planning efforts aimed at balancing conservation goals with agricultural productivity and socio-economic development. European agricultural landscapes have undergone transformations due to changes in land management practices, agricultural policies, and urbanization. Remote sensing data have enabled the monitoring of land cover changes, including the conversion of natural habitats to croplands, grasslands, and urban areas. GIS-based analyses have supported agro-environmental assessments, such as evaluating the effectiveness of agri-environmental schemes in promoting biodiversity conservation and sustainable land use practices. Studies have also explored the potential of land use planning and land-use zoning to reconcile competing demands for agricultural production, biodiversity conservation, and ecosystem services provision. In each of these regions, studies utilizing remote sensing and GIS have provided valuable insights into the drivers, patterns, and impacts of LULCC, informing decision-making processes aimed at promoting sustainable land management and conservation strategies. Collaborative efforts involving interdisciplinary research and stakeholder engagement are essential for addressing the complex socio-economic and environmental challenges associated with LULCC in diverse geographical contexts. The dynamics of land use and land cover (LULC) have significant implications for environmental sustainability, resource management, and socio-economic development.

In the context of **Bardez Taluka** in Goa, India, two recent studies have examined these dynamics: "Transition Modelling of Land Use Land Cover Dynamics in Bardez Taluka of Goa-India (1991-2021)" by Gaonkar Venkatesh G. Prabhu et al. (2023) and "Analysis and Prediction of Land Cover Changes using the Land Change Modeler (LCM): A Case Study of Candolim, Bardez-Goa, India" by Farzana Nadaf et al. (2022). Summary of Gaonkar et al. (2023) Gaonkar et al. (2023) conducted a comprehensive analysis of LULC dynamics in Bardez Taluka spanning three decades from 1991 to 2021. Using transition modeling techniques, the study aimed to understand the patterns and drivers of changes in land use and land cover over the specified period. The authors employed remote sensing data and geographic information system (GIS) tools to analyze the transition matrix and quantify changes in different land cover classes. The findings revealed significant transformations in LULC patterns over the study period. Urbanization emerged as a prominent driver of change, leading to the conversion of agricultural and natural land covers into built-up areas. Additionally, the expansion of infrastructure, tourism activities, and population growth exerted considerable pressure on land resources. The study highlighted the importance of effective land management strategies to balance development needs with environmental conservation objectives. Summary of **Nadaf et al. (2022) Nadaf et al. (2022)** focused specifically on the Candolim region within Bardez Taluka to analyze and predict land cover changes using the Land Change Modeler (LCM). By integrating remote sensing data with LCM techniques, the study aimed to assess past trends and forecast future changes in land cover. The authors emphasized the utility of LCM as a predictive tool for land use planning and decision-making processes. The analysis revealed notable shifts in land cover classes within the Candolim area, attributed primarily to urbanization and tourism development. Built-up areas expanded at the expense of vegetation cover, agricultural lands, and water bodies. The study also identified potential future scenarios based on current trends, highlighting the importance of proactive measures to mitigate adverse impacts on ecological integrity and socio-economic well-being.

Comparative Analysis Both studies provide valuable insights into the dynamics of land use and land cover in Bardez Taluka, Goa, India.

While Gaonkar et al. (2023) offer a broader perspective covering the entire Taluka over an extended period, **Nadaf et al. (2022)** zoom in on a specific locality to delve deeper into localized changes and predictive modeling. Together, these studies underscore the multifaceted nature of LULC dynamics, driven by a complex interplay of socio-economic, environmental, and institutional factors. The research on land use and land cover dynamics in Bardez Taluka, Goa, India, contributes significantly to the understanding of environmental change and sustainable development in the region. By employing advanced remote sensing techniques and modeling approaches, the studies offer valuable insights for policymakers, planners, and stakeholders involved in land management and conservation efforts. Moving forward, integrated approaches that consider ecological resilience, socio-economic dynamics, and community engagement will be essential for fostering resilient and sustainable landscapes in Bardez Taluka and similar regions worldwide. Understanding the dynamics of land use and land cover (LULC) is crucial for effective land management, environmental conservation, and sustainable development. Two recent open-access studies have examined LULC dynamics in different regions: "Assessment of Land Use/Land Cover Dynamics of Kaduna Watershed, Using Remote Sensing Data and GIS Techniques" by J. Daramola et al. (2022) and "Driving Forces of Land Use and

Land Cover Changes in the North-eastern Part of Dhaka Conurbation" by Abdul Majed Sajib et al. (2022).

Summary of **Daramola et al. (2022)** Daramola et al. (2022) conducted an assessment of LULC dynamics in the Kaduna watershed utilizing remote sensing data and GIS techniques. The study aimed to analyze temporal changes in land use and land cover over a specified period, providing insights into the drivers and patterns of landscape transformation. Through the integration of satellite imagery and spatial analysis tools, the authors identified key changes in LULC classes, such as urbanization, agricultural expansion, and deforestation. The findings highlighted significant alterations in the Kaduna watershed's landscape, characterized by the conversion of natural habitats into built-up areas and agricultural land. Rapid urbanization, population growth, and infrastructure development emerged as primary drivers of LULC changes, posing challenges to sustainable land management and ecosystem integrity. The study underscored the importance of adopting holistic approaches to address land degradation and promote landscape sustainability in the region.

Summary of **Sajib et al. (2022)** Sajib et al. (2022) focused on the northeastern part of the Dhaka conurbation to investigate the driving forces behind LULC changes in this urbanizing area. Employing a combination of remote sensing techniques and spatial analysis, the study aimed to identify the socio-economic, demographic, and environmental factors influencing land use and land cover dynamics. By analyzing satellite imagery and historical data, the authors delineated patterns of urban expansion, agricultural transformation, and natural resource degradation. The study revealed significant shifts in LULC patterns in the northeastern part of the Dhaka conurbation, attributed primarily to rapid urbanization, industrialization, and population growth. Land fragmentation, loss of green spaces, and encroachment into agricultural areas were identified as key challenges associated with urban expansion. The findings underscored the urgent need for integrated land use planning strategies to mitigate adverse environmental impacts and enhance the resilience of urban ecosystems. Comparative Analysis Both studies offer valuable insights into LULC dynamics in distinct geographical contexts.

While **Daramola et al. (2022)** focus on a watershed area in Kaduna, Nigeria, Sajib et al. (2022) concentrate on the northeastern part of the Dhaka conurbation in Bangladesh. Despite the differences in location and socio-economic context, both studies highlight the common challenges posed by rapid urbanization, population growth, and unsustainable land management practices. The integration of remote sensing data and GIS techniques enables a systematic assessment of LULC dynamics, facilitating evidence-based decision-making and planning processes. The comparative analysis of LULC dynamics in the Kaduna watershed and the northeastern part of the Dhaka conurbation underscores the universal importance of sustainable land management practices in addressing environmental challenges and promoting resilient urban development. By leveraging remote sensing data and GIS techniques, these studies contribute to a deeper understanding of the drivers and impacts of LULC changes, laying the foundation for informed policy interventions and adaptive management strategies in diverse landscapes worldwide. Understanding changes in land use and land cover (LULC) is crucial for urban planning, environmental management, and sustainable development. Two open-access studies have examined LULC dynamics in different regions: "Analysis of Green Land Changes to Building Land Using Geographic Information System (GIS) in Salatiga City from 2013 to 2019" by **Riska Vennithasari et al. (2020)** and "A Study on Land Use and Land Cover Classification Using Microwave Data in Joida Taluk of Uttara Kannada District, Karnataka" by Arjun G. Koppad et al. (2020). Summary of Vennithasari et al. (2020) Vennithasari et al. (2020) conducted an analysis of green land changes to building land in Salatiga City using Geographic Information System (GIS) techniques. The study focused on the period from 2013 to 2019, aiming to assess the conversion of green areas into built-up land. By analyzing satellite imagery and spatial data, the authors quantified changes in land cover types and identified the factors driving urban expansion. The findings revealed a significant decrease in green areas and an increase in built-up land in Salatiga City during the study period. Rapid urbanization, population growth, and infrastructure development were identified as primary drivers of land cover change. The study underscored the importance of sustainable urban planning and green infrastructure initiatives to mitigate environmental degradation and enhance urban resilience.

Summary of Koppad et al. (2020) conducted a study on land use and land cover classification using microwave data in Joida Taluk of Uttara Kannada District, Karnataka. The research aimed to classify different land cover types and assess LULC dynamics in the region. By utilizing microwave remote sensing data and classification algorithms, the authors delineated land cover classes such as forests, agricultural lands, water bodies, and settlements. The study revealed the diverse LULC patterns in Joida Taluk, with forests comprising a significant portion of the landscape. Agricultural activities and settlements were also prominent, indicating human influence on land use dynamics. The findings highlighted the importance of preserving forest ecosystems and implementing sustainable land management practices to ensure ecological integrity and livelihood security in the region. Comparative Analysis Both studies provide valuable insights into LULC dynamics in distinct geographical contexts. While Vennithasari et al. (2020) focus on urban land use changes in Salatiga City, Indonesia, Koppad et al. (2020) concentrate on rural land cover classification in Joida Taluk, India. Despite the differences in location and land use context, both studies underscore the importance of monitoring and managing LULC changes for sustainable development. The comparative analysis of LULC dynamics in Salatiga City and Joida Taluk highlights the diverse challenges and opportunities associated with urban and rural land use. By leveraging GIS and remote sensing technologies, these studies contribute to a deeper understanding of spatial patterns, drivers, and implications of land cover changes. Moving forward, integrated approaches that consider socio-economic, environmental, and cultural factors will be essential for promoting sustainable land use and landscape management in diverse contexts. The extent and rate of changes in land use and land cover (LULC) around industrial facilities are critical for understanding environmental impacts and guiding sustainable development strategies. This article examines the study titled "Extent and Rate of Changes in Land Use/Land Cover Around Kaduna Refining and Petrochemical Company, Chikun Local Government, Kaduna State" by Shehu Zakari Damau et al. (2020), published in the International Journal of Scientific Research in Science and Technology. The study focuses on analyzing LULC changes in the vicinity of the Kaduna Refining and Petrochemical Company (KRPC) located in Chikun Local Government Area, Kaduna State, Nigeria.

Overview of the Study The study by **Damau et al. (2020)** investigates the spatial and temporal dynamics of land use and land cover around the KRPC from an environmental perspective. The authors employ remote sensing techniques and geographic information system (GIS) tools to analyze changes in LULC patterns over a specified period. The primary objective is to assess the extent and rate of land transformation in the vicinity of the industrial complex and identify potential environmental implications. Findings and Analysis Damau et al. (2020) identify significant changes in LULC around the KRPC, characterized by the conversion of natural landscapes into built-up areas and industrial facilities. Urban expansion and infrastructure development emerge as primary drivers of land cover change, with implications for ecosystem integrity and environmental quality. The study highlights the need for effective land management and environmental planning to mitigate adverse impacts and promote sustainable development in the region. The temporal analysis reveals the rapid pace of land transformation, indicating the urgency of implementing proactive measures to address environmental challenges. The authors emphasize the importance of monitoring LULC dynamics and integrating environmental considerations into industrial planning processes to ensure long-term sustainability and resilience. Implications and Recommendations The study's findings have important implications for environmental management and policy formulation in industrialized regions like Chikun Local Government Area. By quantifying LULC changes and assessing their environmental consequences, the study provides valuable insights for stakeholders, including government agencies, industry regulators, and local communities. The findings underscore the need for collaborative efforts to balance industrial development with environmental conservation objectives. Based on their analysis, Damau et al. (2020) recommend several measures to address the challenges posed by land use change around the KRPC. These include:

• Implementing land use planning regulations to control urban sprawl and protect natural habitats.

• Introducing sustainable land management practices to minimize soil erosion and habitat degradation.

• Enhancing environmental monitoring and assessment mechanisms to track changes in LULC and their impacts over time.

• Promoting community engagement and participation in decision-making processes to ensure inclusive and sustainable development. In conclusion, the study by Damau et al. (2020) sheds light on the extent and rate of changes in land use and land cover around the KRPC in Chikun Local Government Area, Kaduna State. By employing remote sensing and GIS techniques, the authors provide valuable insights into the spatial and temporal dynamics of LULC patterns, highlighting the environmental implications of rapid urbanization and industrial expansion. The study underscores the importance of integrating environmental considerations into industrial planning and management processes to achieve sustainable development goals in the region.

Chapter 3:

Methodology

The methodology section of any research serves as a roadmap detailing the steps undertaken to investigate a particular phenomenon or answer a research question. In this context, the methodology revolves around analyzing land cover change using remote sensing techniques. Land cover change, a crucial aspect of environmental monitoring and urban planning, is often studied to understand the dynamics of landscape transformation and its implications for ecosystems and human activities

In this study, the methodology encompasses several key stages: data collection, preprocessing, image classification, change detection analysis, validation, statistical analysis, and limitations. Each stage plays a vital role in unraveling the complexities of land cover change and extracting meaningful insights from satellite imagery.

The primary approach employed in this study is remote sensing, a powerful tool for monitoring and assessing changes in land cover over time. Remote sensing involves capturing, analyzing, and interpreting information about the Earth's surface without direct physical contact. Satellite imagery, acquired from platforms like Landsat and Google Earth Engine, serves as the primary data source for this analysis.

The first step in the methodology involves collecting satellite imagery covering the study area across different time periods. Landsat and Google Earth Engine provide multi-temporal and multi-spectral imagery, offering insights into land cover dynamics over several decades. The choice of imagery depends on factors such as spatial resolution, temporal coverage, and spectral bands suited to the study objectives. Once the satellite imagery is acquired, preprocessing steps are applied to ensure data quality and consistency. This includes radiometric and geometric corrections to remove atmospheric and geometric distortions, respectively. Additionally, image compositing or mosaicking may be performed to create seamless representations of the study area, facilitating subsequent analysis.

Image classification is a critical stage where land cover types are identified and delineated from satellite imagery. Supervised classification techniques, such as Maximum Likelihood and Random Forest algorithms, are employed to classify pixels into predefined land cover classes. Training data, consisting of spectral signatures representing each land cover type, are used to train the classification algorithm.

Change detection involves comparing classified images from different time periods to identify and quantify changes in land cover. By analyzing pixel-level differences between consecutive images, areas experiencing land cover transitions, such as urban expansion or deforestation, are detected. Change detection metrics, such as area change and percentage change, provide quantitative measures of land cover dynamics.

Validation is crucial to assess the accuracy of the classification results and the reliability of the change detection analysis. Ground truth data or validation samples are collected to compare against the classified imagery, allowing for accuracy assessment through error matrices or other validation metrics. Validation ensures the robustness of the methodology and enhances the credibility of the study findings. Statistical analysis complements the qualitative insights derived from remote sensing data by quantifying the relationships between land cover change and various socio-economic or environmental factors. Descriptive statistics, correlation analysis, and regression modeling may be employed to explore patterns and trends in land cover dynamics and their drivers.

Despite its utility, remote sensing-based analysis has limitations and uncertainties that must be acknowledged. Factors such as sensor resolution, classification errors, and cloud cover can influence the accuracy and reliability of the results. Additionally, the interpretation of land cover classes may be subjective, leading to potential biases in the analysis. In conclusion, the methodology section outlines a systematic approach to analyzing land cover change using remote sensing techniques. Through data collection, preprocessing, classification, change detection, validation, and statistical analysis, this study aims to unravel the dynamics of landscape transformation and its implications for environmental management and sustainable development. By addressing limitations and uncertainties, the methodology ensures the rigor and credibility of the research findings, contributing to our understanding of land cover change dynamics and informing evidence-based decision-making.

3.1 Data Collection

In this study, remote sensing data serves as the primary source of information for analyzing land cover change. The selection of satellite data sources, timeframe, resolution, and data acquisition process is crucial for ensuring the quality and suitability of the imagery for the study objectives.

3.2 Satellite Data Sources:

Two main satellite data sources are utilized in this study: Landsat and Google Earth Engine.

Landsat: Landsat satellites, operated by the United States Geological Survey (USGS) and NASA, provide a rich archive of multispectral imagery dating back to the early 1970s. Landsat satellites capture data in multiple spectral bands, including visible, near-infrared, and thermal bands, enabling the analysis of various land cover types and changes over time.

Google Earth Engine: Google Earth Engine is a cloud-based platform that hosts a vast repository of satellite imagery and geospatial datasets. It offers access to petabytes of Landsat, Sentinel, and other satellite data, along with powerful computational capabilities for analyzing large-scale environmental changes.

3.3 Timeframe and Resolution of the Imagery:

The timeframe and resolution of the imagery play a crucial role in capturing temporal dynamics and spatial details of land cover change.

Timeframe: The study spans multiple decades, aiming to analyze land cover change over a time period, from 1991 to 2021. Landsat imagery dating back to the early 1970s provides a long-term perspective on landscape dynamics, allowing researchers to track changes over time and assess trends in land cover transformation.

Resolution: The spatial resolution of the imagery determines the level of detail captured in the images. Landsat satellites typically offer spatial resolutions ranging from 30 meters (for visible and near-infrared bands) to 100 meters (for thermal bands). This moderate resolution is well-suited for capturing landscape-scale changes, including urban expansion, deforestation, and agricultural encroachment.

3.4 Data Acquisition Process:

The acquisition of satellite data involves accessing, downloading, and processing imagery from reliable sources.

USGS Earth Explorer: Landsat imagery can be obtained from the USGS Earth Explorer platform, which provides free access to a vast archive of satellite data. Researchers can specify the study area, time range, and satellite sensor to retrieve relevant imagery for analysis. USGS Earth Explorer offers options for downloading both raw and preprocessed Landsat data, depending on the specific requirements of the study.

Google Earth Engine: Alternatively, researchers may leverage the capabilities of Google Earth Engine to access and analyze satellite imagery directly within the platform. Google Earth Engine offers a streamlined workflow for querying, filtering, and visualizing satellite data, eliminating the need for manual data download and preprocessing. This cloud-based approach enables scalable analysis of large datasets and facilitates collaboration among researchers. Overall, the selection of remote sensing data sources, timeframe, resolution, and data acquisition process is critical for conducting robust analysis of land cover change. By leveraging Landsat and Google Earth Engine data, researchers can gain valuable insights into the dynamics of landscape transformation and inform evidence-based decision-making for environmental management and sustainable development initiatives.

3.5 Preprocessing

Preprocessing of raw satellite imagery is essential to enhance data quality, correct for distortions, and prepare the imagery for subsequent analysis. In this study, several preprocessing steps are undertaken to ensure the accuracy and reliability of the land cover change analysis:

3.5.1 Radiometric Correction:

Radiometric correction adjusts the pixel values of satellite imagery to remove atmospheric effects and sensor-induced variations. This correction ensures consistency in brightness and color across the image, facilitating accurate interpretation and classification of land cover features. Common radiometric correction techniques include histogram matching, dark object subtraction, and atmospheric correction algorithms.

3.5.2 Geometric Correction:

Geometric correction, also known as orthorectification, rectifies the satellite imagery to a standardized map projection and geometrically accurate representation of the Earth's surface. This correction compensates for terrain distortions, sensor viewing geometry, and Earth's curvature, ensuring that features are portrayed in their true geographic locations. Geometric correction typically involves referencing the imagery to ground control points (GCPs) or digital elevation models (DEMs) and applying transformation algorithms to minimize geometric errors.

3.5.3 Image Enhancement Techniques:

Image enhancement techniques are employed to improve the visual interpretation and analysis of satellite imagery by enhancing certain features or highlighting specific spectral characteristics. Common image enhancement techniques include:

- Contrast Stretching: Adjusts the contrast of the image to improve visual clarity and distinguish subtle variations in brightness.
- Histogram Equalization: Balances the distribution of pixel values across the image to enhance overall contrast and reveal hidden details.
- Sharpening Filters: Enhances spatial resolution by emphasizing edges and fine-scale features in the imagery, enhancing the interpretability of land cover patterns.

These image enhancement techniques help enhance the visual interpretability of satellite imagery and improve the effectiveness of subsequent classification and change detection analysis.

3.5.4 Image Compositing or Mosaicking:

In cases where multiple satellite images are acquired for the study area over different time periods or from different sensors, image compositing or mosaicking may be performed to create a seamless and temporally continuous representation of the landscape. Compositing involves combining multiple images to create a single composite image that represents the best available data for each pixel. Mosaicking involves stitching together adjacent image tiles to create a complete and continuous coverage of the study area. These processes help overcome limitations such as cloud cover, sensor gaps, and seasonal variations, ensuring a comprehensive analysis of land cover change.

By undertaking these preprocessing steps, the raw satellite imagery is refined and standardized, laying the foundation for accurate and reliable analysis of land cover change. The resulting preprocessed imagery is ready for classification, change detection, and further analysis to extract meaningful insights into landscape dynamics and environmental trends.

3.6 Classification

In this study, classification techniques are employed to categorize pixels within the satellite imagery into distinct land cover classes. The primary classification approach utilized is supervised classification, which involves training a classification algorithm using labeled training data to classify pixels based on their spectral characteristics. Two commonly used supervised classification techniques are Maximum Likelihood and Random Forest.

3.6.1 Supervised Classification Techniques:

a. Maximum Likelihood Classification:

Maximum Likelihood Classification (MLC) is a widely used parametric classification method that assigns each pixel in the image to the class that has the highest probability of generating the observed spectral values. MLC assumes that the spectral values for each class follow a Gaussian distribution and calculates the likelihood of each pixel belonging to each class based on its spectral signature. The class with the highest likelihood is assigned to the pixel.

b. Random Forest Classification:

Random Forest is a machine learning-based classification algorithm that constructs an ensemble of decision trees and combines their predictions to produce a final classification result. Each decision tree is trained independently using a subset of the training data and a random selection of input features. During classification, each tree "votes" on the class label for each pixel, and the most frequent class label among all trees is assigned to the pixel.

3.6.2 Description of Training Data and Reference Points:

In supervised classification, the accuracy and reliability of the classification result depend on the quality and representativeness of the training data used to train the classification algorithm. Training data consist of labeled samples of known land cover classes, typically derived from ground truth data, existing land cover maps, or expert knowledge.

a. Training Data:

Training data are selected from within the study area to cover a representative range of land cover classes present in the imagery 10 training samples were taken per class. For example, if the study area includes urban, agricultural, and forested areas, training samples for each class would be selected to capture the spectral variability within those classes. Training data should be spatially distributed across the study area to ensure adequate coverage and representation of land cover variability.

b. Reference Points:

Reference points are specific locations within the imagery where ground truth data or expert knowledge is used to assign class labels. These reference points serve as the basis for generating training data and calibrating the classification algorithm. Reference points may be selected using field surveys, high-resolution aerial imagery, or existing land cover maps, and they should be georeferenced to ensure accurate spatial alignment with the satellite imagery. By utilizing supervised classification techniques such as Maximum Likelihood and Random Forest, and by employing high-quality training data and reference points, the classification algorithm can accurately distinguish between different land cover classes within the satellite imagery. This enables the generation of detailed land cover maps that provide valuable information for analyzing land cover change dynamics and informing environmental management decisions.

3.7 Land Cover Categories

In this study, several land cover categories are identified and classified within the satellite imagery to characterize the landscape and analyze land cover change dynamics. These categories include built-up areas, vegetation, agricultural land, water bodies, barren land, and potentially other land cover types specific to the study area. Each land cover category is defined based on its distinct spectral and spatial characteristics, allowing for differentiation and classification within the imagery. Below is a detailed description of each land cover category and how they are defined and distinguished in the analysis:

1. Built-up Areas:

Built-up areas represent urban and developed land characterized by human-made structures such as buildings, roads, and infrastructure. In the satellite imagery, built-up areas typically exhibit high reflectance in visible and near-infrared bands, with regular patterns and spectral signatures associated with artificial surfaces. These areas are distinguished by their spatial arrangement, density of structures, and lack of vegetation cover.

2. Tree cover:

Tree cover encompasses areas covered by natural or cultivated vegetation, including forests, grasslands, crops, and shrublands. In satellite imagery, treecover appears as areas with high reflectance in the near-infrared portion of the electromagnetic spectrum, due to the strong absorption of visible light by chlorophyll. treecover is characterized by its green coloration, texture, and spatial distribution, which vary depending on factors such as species composition, canopy structure, and phenological changes.

3. Agricultural Land:

Agricultural land comprises areas used for cultivation, farming, and agricultural activities, including croplands, orchards, and pastures. In the satellite imagery, agricultural land exhibits varying spectral characteristics depending on crop type, stage of growth, and management practices. Different crops may have distinct spectral signatures in visible and near-infrared bands, allowing for their identification and classification within the imagery.

4. Water Bodies:

Water bodies include natural and artificial bodies of water such as lakes, rivers, reservoirs, and ponds. In satellite imagery, water bodies appear dark or black in visible bands due to their low reflectance, while they exhibit high reflectance in near-infrared bands. Water bodies are distinguished by their smooth or reflective surfaces, which contrast with surrounding land cover types, as well as their spatial connectivity and hydrological features.

5. Barren Land:

Barren land comprises areas devoid of significant vegetation or soil cover, such as deserts, sand dunes, and rocky terrain. In satellite imagery, barren land appears as areas with low reflectance in both visible and near-infrared bands, often exhibiting a uniform or featureless appearance. Barren land is characterized by its lack of vegetation, sparse vegetation cover, and distinct spectral signature compared to other land cover categories.

6. Other Land Cover Types:

Depending on the study area and research objectives, additional land cover categories may be defined and classified within the imagery. These may include wetlands, forests, wetlands, snow and ice, and other specialized land cover types specific to the local environment and land use practices.

In the analysis, each land cover category is defined based on its unique spectral, spatial, and temporal characteristics, which are extracted and classified from the satellite imagery using supervised or unsupervised classification techniques. By accurately delineating and distinguishing between these land cover categories, researchers can generate detailed land cover maps and quantify changes in land cover over time, providing valuable insights into landscape dynamics and environmental change processes.

3.8 Change Detection Analysis:

The methodology employed for detecting changes in land cover over time involves comparing classified images from different time periods and calculating change detection metrics. The process typically includes the following steps:

Image Acquisition and Classification: Satellite imagery covering multiple time periods is acquired and classified using supervised or unsupervised classification techniques to generate land cover maps for each time period.

Image Registration: The classified images from different time periods are geometrically registered to ensure spatial alignment and pixel-to-pixel correspondence between the images.

Change Detection Algorithm: A change detection algorithm is applied to compare the classified images and identify areas where land cover has changed between the time periods. Common change detection algorithms include image differencing, post-classification comparison, and image rationing.

Calculation of Change Detection Metrics: Change detection metrics are calculated to quantify the extent and magnitude of land cover changes. These metrics may include:

Area Change: Total area of land cover change (e.g., increase or decrease in built-up areas).

Percentage Change: Percentage of land cover change relative to the total area of interest.

Change Magnitude: Magnitude or intensity of change for each land cover class (e.g., change in vegetation cover).

Visualization of Change: The detected changes are visualized using change detection maps, which highlight areas of significant land cover change and provide insights into spatial patterns and trends over time.

3.9 Validation:

Validation is conducted to assess the accuracy of the classification results and the reliability of the change detection analysis. The validation process involves the following steps:

Ground Truth Data Collection: Ground truth data or validation samples are collected from the study area to serve as reference points for validating the classification results. These validation samples may include field surveys, high-resolution aerial imagery, or existing land cover maps.

Random Sampling: Random sampling is used to select validation points within the study area, ensuring spatial representativeness and minimizing bias in the validation process.

Validation Protocol: A validation protocol is established to compare the classified land cover maps with the ground truth data. This protocol specifies the evaluation metrics and procedures for assessing classification accuracy.

Accuracy Assessment: Classification accuracy is assessed using various evaluation metrics, such as overall accuracy, producer's accuracy, user's accuracy, and kappa coefficient. These metrics measure the agreement between the classified land cover maps and the ground truth data.

Confusion Matrix: A confusion matrix is generated to summarize the classification results and quantify errors of omission and commission for each land cover class. The confusion matrix provides insights into the accuracy and reliability of the classification algorithm.

By conducting validation, researchers can evaluate the reliability of the classification results and the effectiveness of the change detection analysis in accurately identifying and quantifying land cover changes over time. Validated results enhance the credibility of the study findings and support evidence-based decision-making for environmental management and land use planning initiatives.

3.10 Statistical Analysis:

In the study, various statistical techniques are employed to analyze the data and extract meaningful insights:

Descriptive Statistics of Land Cover Changes:

Descriptive statistics, such as mean, median, standard deviation, and range, are computed to summarize the magnitude and spatial distribution of land cover changes over time. These statistics provide quantitative measures of the extent, variability, and trends in land cover dynamics within the study area.

3.11 Limitations:

The methodology employed in the study is subject to several limitations and constraints:

Data Limitations:

The accuracy and reliability of the analysis may be influenced by limitations in the satellite imagery, such as cloud cover, sensor noise, and spatial or spectral resolution. Additionally, data availability and quality may vary across different time periods or study areas, potentially affecting the consistency and comprehensiveness of the analysis.

Classification Errors:

Errors in land cover classification, such as misclassification of land cover types or spectral confusion between classes, can introduce uncertainties into the analysis. Classification errors may arise due to inherent variability in spectral signatures, mixed pixels, or limitations of the classification algorithm used.

Spatial and Temporal Scale:

The spatial and temporal scale of the analysis may impact the detection and interpretation of land cover changes. Fine-scale changes may be overlooked at coarse spatial resolutions, while long-term trends may be obscured by short-term fluctuations. Choosing an appropriate scale for analysis is essential to capture meaningful patterns and trends in land cover dynamics.

Areas for Future Research or Improvement:

To address the limitations and enhance the robustness of the methodology, several areas for future research or improvement are identified:

Integration of Multi-Source Data:

Incorporating additional data sources, such as high-resolution imagery, LiDAR data, or socio-economic datasets, can improve the accuracy and comprehensiveness of the analysis. Integration of multi-source data enables a more holistic understanding of land cover dynamics and their drivers.

Advanced Classification Techniques:

Exploring advanced classification techniques, such as machine learning algorithms or object-based image analysis, may enhance the accuracy and efficiency of land cover classification. These techniques can better capture complex spatial patterns and spectral variability in the imagery, improving the detection of subtle land cover changes.

Longitudinal Studies:

Conducting longitudinal studies over extended time periods allows for a more comprehensive analysis of land cover changes and their drivers. Longitudinal studies provide insights into the trajectories of landscape transformation and the effectiveness of land management interventions over time.

By addressing these areas for future research or improvement, researchers can enhance the reliability, accuracy, and applicability of land cover change analysis, contributing to a deeper understanding of environmental dynamics and supporting informed decision-making for sustainable land use planning and management.

3.12 Summary of the Methodology Section:

- The methodology begins with the acquisition of satellite imagery from reliable sources such as Landsat and Google Earth Engine, covering multiple time periods.
- Preprocessing steps including radiometric and geometric correction are applied to enhance data quality and prepare the imagery for analysis.
- Supervised classification techniques such as Maximum Likelihood and Random Forest are utilized to classify land cover categories within the imagery.
- Change detection analysis involves comparing classified images from different time periods to identify and quantify land cover changes.
- Validation is conducted to assess the accuracy of classification results, using ground truth data and evaluation metrics such as accuracy assessment and confusion matrix.
- Statistical analysis, including descriptive statistics and correlation analysis, is employed to extract meaningful insights into land cover dynamics and their relationships with socio-economic factors.

Key Findings and Insights:

- The methodology facilitates the identification and characterization of various land cover categories, including built-up areas, vegetation, agricultural land, water bodies, and barren land.
- Change detection analysis reveals significant patterns of land cover change over time, such as urban expansion, deforestation, and agricultural intensification.
- Validation confirms the accuracy and reliability of the classification results, enhancing confidence in the study findings.
- Statistical analysis uncovers correlations between land cover change and socio-economic factors, providing insights into the drivers and impacts of landscape transformation.

Overall, the methodology section serves as a robust framework for analyzing land cover change and extracting valuable insights into environmental dynamics. By combining remote sensing techniques with rigorous validation and statistical analysis, the study contributes to our understanding of land cover dynamics and supports evidence-based decision-making for sustainable land use planning and management initiatives.

Chapter 4

Analysis

In this chapter, we utilize the data and methodology outlined in the previous section to conduct a comprehensive analysis of the impact of economic activities on land use/land cover in Salcete Taluka. The analysis is structured as follows:

4.1 Preprocessing of Satellite Imagery:

Radiometric correction adjusts pixel values to remove atmospheric effects and sensor-induced variations, ensuring consistent brightness and color across the image.

Radiometric correction addresses variations in pixel values caused by atmospheric conditions and sensor characteristics. By removing these effects, the imagery becomes more consistent and reliable, providing clearer representations of the Earth's surface. This improvement in accuracy is crucial for distinguishing subtle differences in land cover types and detecting changes over time. Additionally, radiometric correction ensures that quantitative analysis, such as vegetation indices or land cover classification, produces more accurate results.

Geometric correction corrects spatial distortions in the imagery, ensuring that features are accurately represented and aligned with geographic coordinates. This correction is essential for spatial analysis, as it enables precise measurement and comparison of features across different images and time periods. Without geometric correction, spatial inaccuracies could lead to misinterpretation of land cover changes and erroneous conclusions about their causes or impacts.

Overall, these preprocessing steps significantly enhance the quality and interpretability of the satellite imagery. They provide a solid foundation for subsequent analysis, enabling researchers to accurately characterize land cover dynamics and their relationship with economic activities in the study area. With clearer, more reliable imagery, researchers can identify patterns, trends, and spatial relationships with greater confidence, leading to more informed decision-making and sustainable land management practices.

Standard False Colour Composite (FCC) combines different spectral bands to create a false-color image, enhancing visual interpretation by emphasizing features like vegetation, water bodies, and urban areas.

The Standard False Colour Composite (FCC) is a visualization technique that combines different spectral bands from satellite imagery to create a false-color representation of the landscape. Unlike true-color images, which mimic the colors visible to the human eye, false-color composites assign different bands to specific colors to highlight distinct features and phenomena.

In the case of land cover analysis, the FCC typically assigns the near-infrared (NIR) band to red, the red band to green, and the green band to blue. This color scheme enhances the visual interpretation of land cover types by emphasizing specific features:

Vegetation: Vegetation appears in shades of red or pink in the FCC, as healthy vegetation reflects a high amount of near-infrared radiation. This allows for easy identification and differentiation of vegetated areas from other land cover types.

Water Bodies: Water bodies, such as rivers, lakes, and reservoirs, appear in shades of blue or dark blue. The FCC enhances the contrast between water bodies and surrounding land cover, making them easily distinguishable.

Urban Areas: Urban areas, characterized by impervious surfaces like buildings, roads, and pavement, typically appear in shades of gray or white. The FCC helps delineate urbanized regions from natural landscapes, facilitating the identification of built-up areas.

By employing the Standard False Colour Composite, analysts can visually interpret satellite imagery more effectively, identifying and delineating land cover features with greater clarity and precision. This enhances the understanding of landscape characteristics and supports various applications, including land use planning, environmental monitoring, and natural resource management.

4.2 land cover classification process:

Supervised Classification with Maximum Likelihood Algorithm:

Supervised classification involves training a classification algorithm, such as the Maximum Likelihood algorithm, to assign each pixel in the satellite imagery to predefined land cover categories.

The Maximum Likelihood algorithm calculates the probability of each pixel belonging to a specific land cover class based on its spectral signature, using statistical principles to determine the most likely class assignment.

QGIS, a geographic information system (GIS) software, provides tools and plugins for implementing supervised classification algorithms, making it a popular choice for land cover analysis.

Use of Ground Truth Data as Training Samples:

Ground truth data collected from the study area serve as reference points or training samples for the classification algorithm.

Ground truth data typically consist of field observations, high-resolution imagery, or existing land cover maps that provide accurate information about the land cover types present in the study area.

These training samples are used to train the classification algorithm by associating spectral signatures with specific land cover classes, enabling the algorithm to accurately classify pixels in the satellite imagery.

Generation of Land Cover Maps:

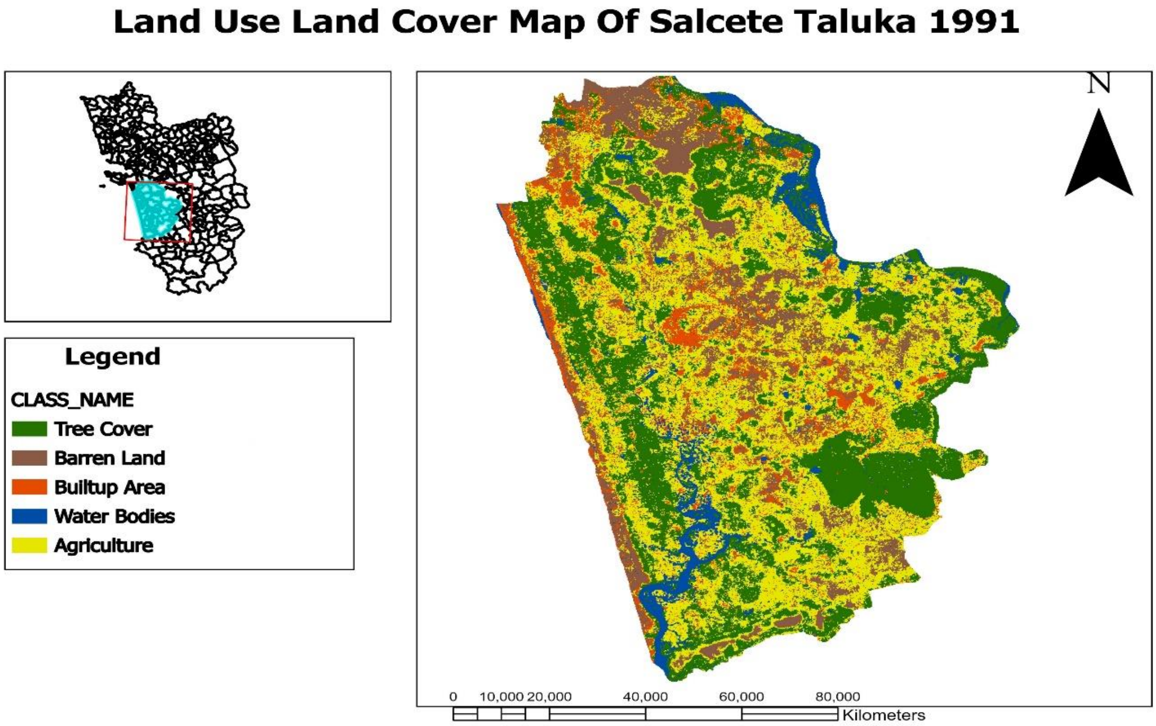
Once the classification algorithm is trained, it is applied to the entire Landsat 8 imagery of Salcete Taluka to classify each pixel into one of the predefined land cover categories.

The output of the classification process is a land cover map that depicts the spatial distribution of different land cover types within the study area.

Land cover maps provide valuable information about the composition and arrangement of land cover features, facilitating the understanding of landscape patterns and processes.

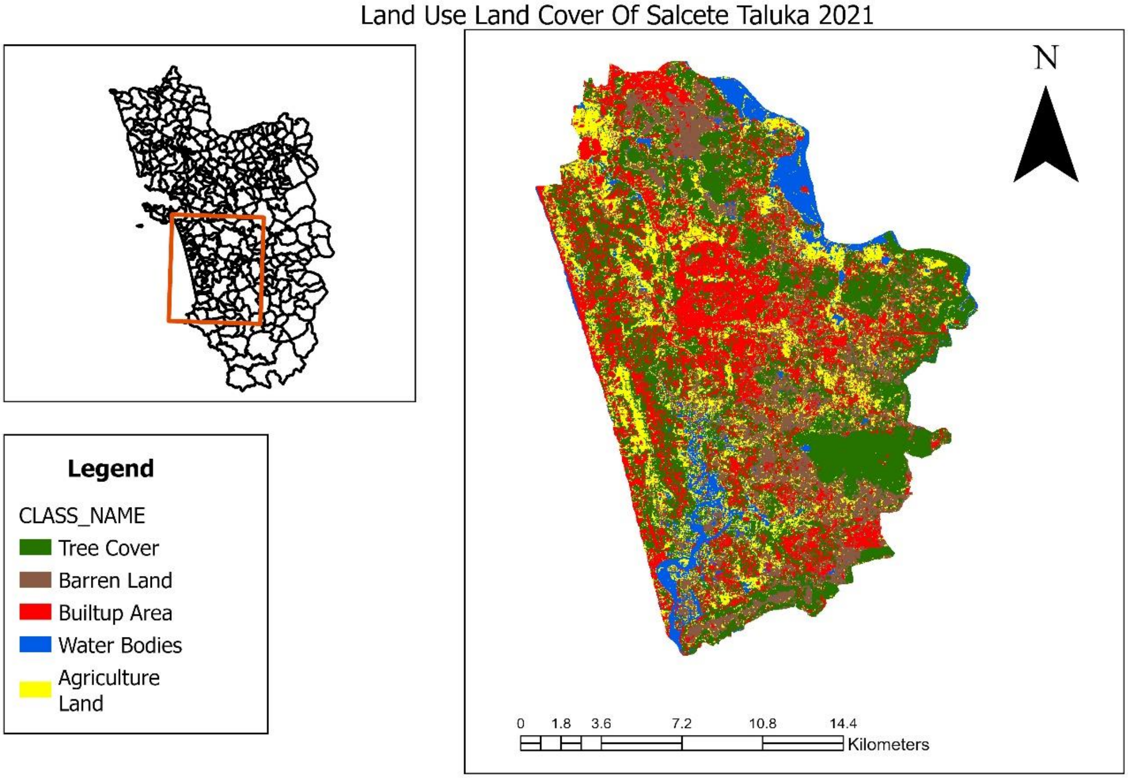
By utilizing supervised classification with the Maximum Likelihood algorithm and incorporating ground truth data, researchers can generate accurate land cover maps for Salcete Taluka. These maps help in understanding the spatial distribution of different land cover types and provide essential information for various environmental management and land use planning applications.

Fig 4.2.1



Land Use Land Cover Map Of Salcete Taluka 1991
N
Legend
CLASS_NAME
Tree Cover
Barren Land
Builtup Area
Water Bodies
Agriculture
0
10,000
20,000
40,000
60,000
80,000
Kilometers

Fig No: 4.2.2



Accuracy Assessment:

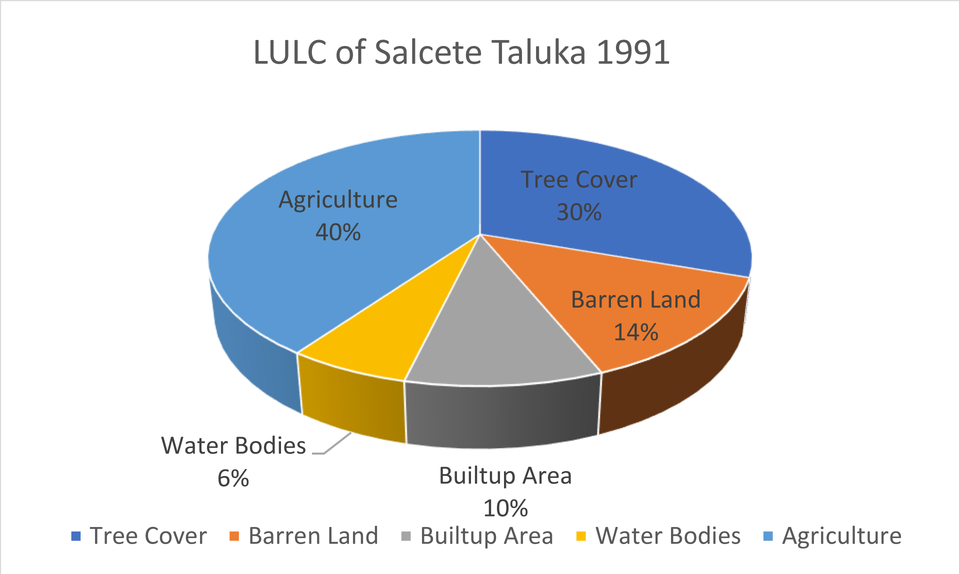
The Kappa Coefficient was found to be 94% and 95.87% for the LULC map 1991 and LULC map 2021 respectively, it signifies highly successful classification process

4.3 Change Detection Analysis:

In the change detection analysis:

Fig No: 4.3.1

Graphical depiction of Land Use Land Cover Of Salcete Taluka 1991

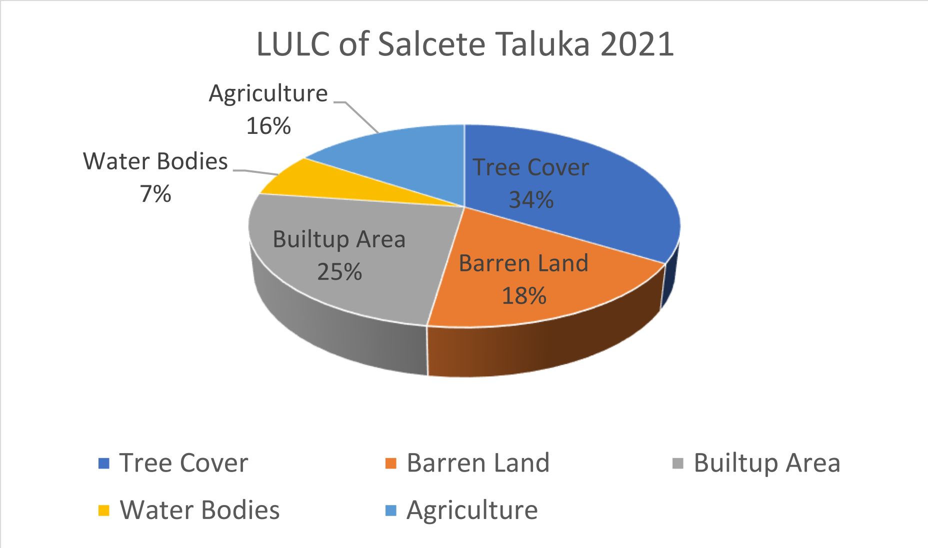


Source: Secondary Data

LULC of salcete taluka in 1991, majority consist of Agriculture comprising of 40%,while the least consist of water bodies i.e 6%

Fig No 4.3.2

Graphical representation of Land Use Land Cover Of Salcete Taluka 2021



source: secondary data

LULC of salcete taluka for the year 2021, the majority share of landcover consist of builtup area(25%) and least water bodies(7%)

Comparison of Classified:

The classified from different time periods are compared to identify changes in land use/land cover over time.

Visual inspection and analysis of the classified images enable the identification of temporal trends, such as urban expansion, agricultural changes, and alterations in tree cover.

Changes in the spatial extent and distribution of land cover classes are assessed to understand the dynamics of landscape transformation.

Tabulated Area For Village Level Analysis

Table:4.3.1

Tabulated Area For Salcete Taluka 1991

	Village	Tree Cover (m²)	Barren Land (m²)	Builtup Area (m²)	Water Bodies (m²)	Agriculture (m²)
1	GORKOMARAD	3793500	770400	290700	693900	3311100
2	ASSOLNA	4296600	551700	454500	353700	5940000
3	KAVLESI	1354500	1777500	919800	2302200	1968300
4	VERODA	3238200	2675700	590400	196200	8266500
5	KARMANE	2524500	18900	255600	1122300	1956600
6	TALEWADA	4149900	702900	319500	70200	3069900
7	CHINCHINIM	2528100	306900	580500	1068300	4522500
8	PARODA	2930400	27000	135000	64800	712800
9	URLI	1673100	7200	63000	195300	681300
10	DEVSUA	990900	89100	336600	1196100	1991700
11	SARZORA	2652300	1202400	857700	207000	4165200
12	MULEM	4836600	142200	576900	83700	2160900
13	FATRADE	2875500	948600	931500	163800	2961000
14	DRAMAPUR	862200	763200	549900	51300	3106800
15	TALAVLI	463500	486900	737100	643500	2541600
16	KAVORIN	2009700	290700	393300	156600	2329200
17	DIKARPAL	194400	374400	196200	66600	1114200
18	AKE	34200	602100	479700	9900	629100
19	SAO_JOSE_DE_AREAL	776700	1971000	2135700	136800	5600700
20	NAVELI	1076400	539100	484200	243000	3124800
21	SAO JOSE DE AREAL(E)	8100	45900	80100	4500	236700
22	ADSULI	89100	12600	53100	9900	98100
23	KANA	230400	2700	19800	7200	126900
24	MUGAL	0	894600	121500	7200	723600

25	**DAVARLIM**	**112500**	**1114200**	**462600**	**14400**	**1580400**
26	**GIRDOLIN**	**3534300**	**1009800**	**405900**	**295200**	**3825900**
27	**SERNABATIM**	**812700**	**164700**	**291600**	**42300**	**321300**
28	**BANAVALI**	**3798000**	**809100**	**1075500**	**259200**	**4143600**
29	**VANELI**	**667800**	**900**	**51300**	**3600**	**273600**
30	**GANDAVLI**	**317700**	**0**	**10800**	**1800**	**36000**
31	**KOLVE**	**1247400**	**133200**	**633600**	**136800**	**802800**
32	**MAKAZAN**	**2234700**	**258300**	**149400**	**412200**	**1772100**
33	**MUNGUL**	**496800**	**262800**	**367200**	**55800**	**1607400**
34	**MADGAON**	**1224900**	**3732300**	**3679200**	**276300**	**6924600**
35	**DHUNKALI**	**495000**	**1800**	**106200**	**11700**	**524700**
36	**BTALBHATI**	**1995300**	**144000**	**836100**	**162900**	**1298700**
37	**GANSUA**	**162900**	**27000**	**159300**	**18000**	**156600**
38	**GIRIM**	**969300**	**14400**	**153900**	**4500**	**503100**
39	**SHELVAN**	**6154200**	**1797300**	**837000**	**2519100**	**8199900**
40	**SANTEMOL**	**3121200**	**3105900**	**768600**	**755100**	**7326000**
41	**MAJORDA**	**1553400**	**89100**	**979200**	**84600**	**1760400**
42	**NUVE**	**3253500**	**1515600**	**768600**	**369000**	**5145300**
43	**KAMARLIM**	**1288800**	**156600**	**134100**	**743400**	**1364400**
44	**UTARDA**	**1135800**	**226800**	**938700**	**99900**	**674100**
45	**LOTLI**	**4180500**	**4730400**	**1474200**	**325800**	**4221000**
46	**RASAAIN**	**6478200**	**3125700**	**2070900**	**2263500**	**3679200**
47	**NAGVE**	**747900**	**2267100**	**1135800**	**114300**	**1064700**

source: secondary data

Table:4.3.2

Tabulated Area For Salcete Taluka 2021

	Village	**Tree Cover (m²)**	**Barren Land (m²)**	**Builtup Area (m²)**	**Water Bodies (m²)**	**Agriculture (m²)**
1	**GORKOMARAD**	**2673900**	**2561400**	**1433700**	**1053000**	**1137600**

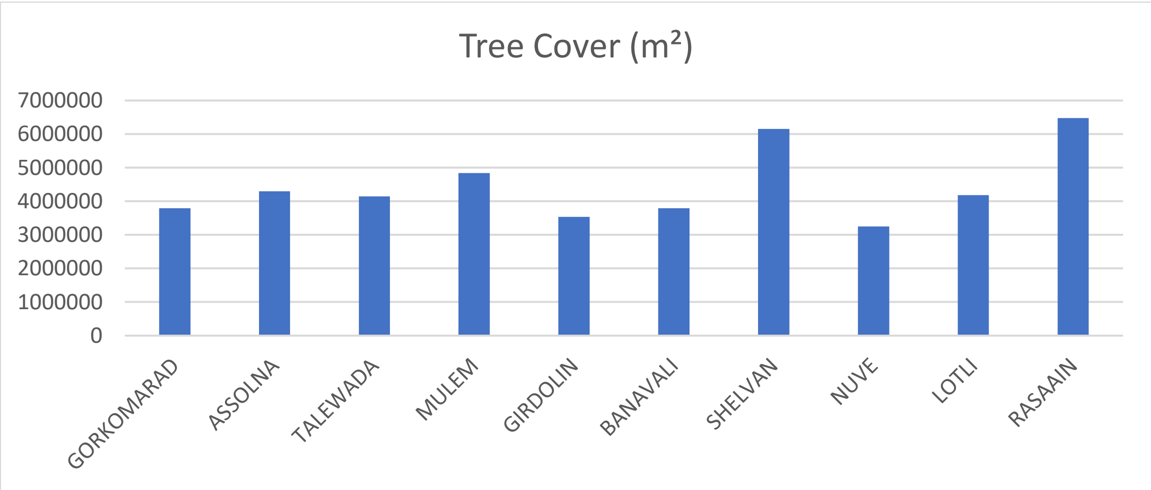
2	ASSOLNA	3969900	2843100	2332800	684900	1765800
3	KAVLESI	1837800	736200	2172600	2273400	1302300
4	VERODA	4498200	4799700	4395600	158400	1115100
5	KARMANE	2218500	497700	948600	1108800	1104300
6	TALEWADA	4378500	2970900	450900	900	511200
7	CHINCHINIM	2185200	1994400	1796400	1358100	1672200
8	PARODA	3093300	383400	316800	11700	64800
9	URLI	1260900	102600	554400	207900	494100
10	DEVSUA	1260900	646200	629100	1226700	841500
11	SARZORA	2835000	4081500	1158300	139500	870300
12	MULEM	4867200	1453500	589500	68400	821700
13	FATRADE	2943900	153000	2618100	91800	2073600
14	DRAMAPUR	1584900	1699200	1426500	31500	591300
15	TALAVLI	1403100	855000	935100	417600	1261800
16	KAVORIN	2292300	1755000	464400	66600	601200
17	DIKARPAL	595800	493200	516600	55800	284400
18	AKE	34200	602100	479700	9900	629100
19	SAO_JOSE_DE_AREAL	2125800	3718800	2666700	71100	2038500
20	NAVELI	1962000	588600	2223900	60300	632700
21	SAO JOSE DE AREAL(E)	21600	72900	70200	11700	198900
22	ADSULI	83700	3600	117000	0	58500
23	KANA	212400	31500	68400	900	73800
24	MUGAL	126000	567000	884700	3600	165600
25	DAVARLIM	407700	549900	1712700	9900	603900
26	GIRDOLIN	4641300	1654200	1692900	257400	825300
27	SERNABATIM	549900	27000	719100	25200	311400
28	BANAVALI	3823200	383400	3511800	136800	2230200
29	VANELI	457200	27000	448200	900	63900
30	GANDAVLI	207000	16200	128700	0	14400
31	KOLVE	860400	118800	1413000	183600	378000
32	MAKAZAN	2774700	610200	480600	225900	735300

33	**MUNGUL**	**717300**	**381600**	**836100**	**87300**	**767700**
34	**MADGAON**	**2956500**	**846000**	**10381500**	**81900**	**1571400**
35	**DHUNKALI**	**356400**	**23400**	**281700**	**10800**	**467100**
36	**BTALBHATI**	**1609200**	**201600**	**1503000**	**206100**	**917100**
37	**GANSUA**	**126900**	**2700**	**166500**	**27900**	**199800**
38	**GIRIM**	**795600**	**216900**	**455400**	**2700**	**174600**
39	**SHELVAN**	**6941700**	**2565900**	**3138300**	**3387600**	**3474000**
40	**SANTEMOL**	**5248800**	**2992500**	**2925000**	**1381500**	**2529000**
41	**MAJORDA**	**1317600**	**344700**	**1435500**	**138600**	**1230300**
42	**NUVE**	**4329000**	**1052100**	**2880900**	**226800**	**2563200**
43	**KAMARLIM**	**1069200**	**436500**	**706500**	**1043100**	**432000**
44	**UTARDA**	**935100**	**177300**	**1116000**	**72900**	**774000**
45	**LOTLI**	**4296600**	**4367700**	**3728700**	**539100**	**1999800**
46	**RASAAIN**	**5885100**	**3702600**	**2545200**	**3604500**	**1880100**
47	**NAGVE**	**880200**	**396900**	**2075400**	**162000**	**1815300**

source: secondary data

Fig No 4.3.3

Top 10 Villages With Tree Cover For the Year 1991

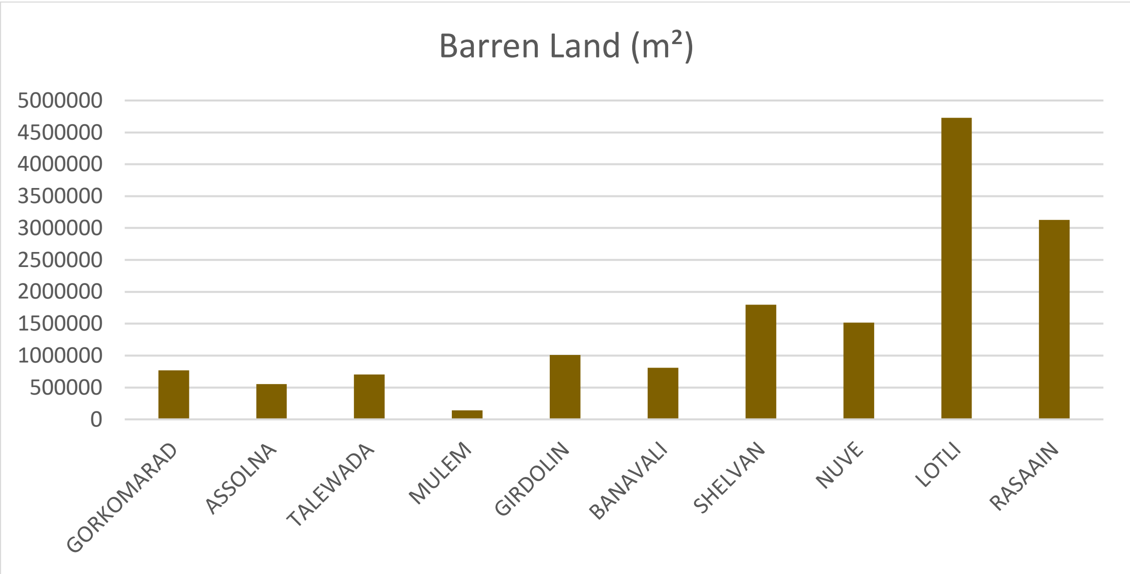


source: secondary data

Villages like Rasaain, Shelvan and Mulem have the most treecover while the others are Assolna, Gorkomarad and Talewada

Fig No 4.3.4

Top 10 Villages With Barren Land For the Year 1991

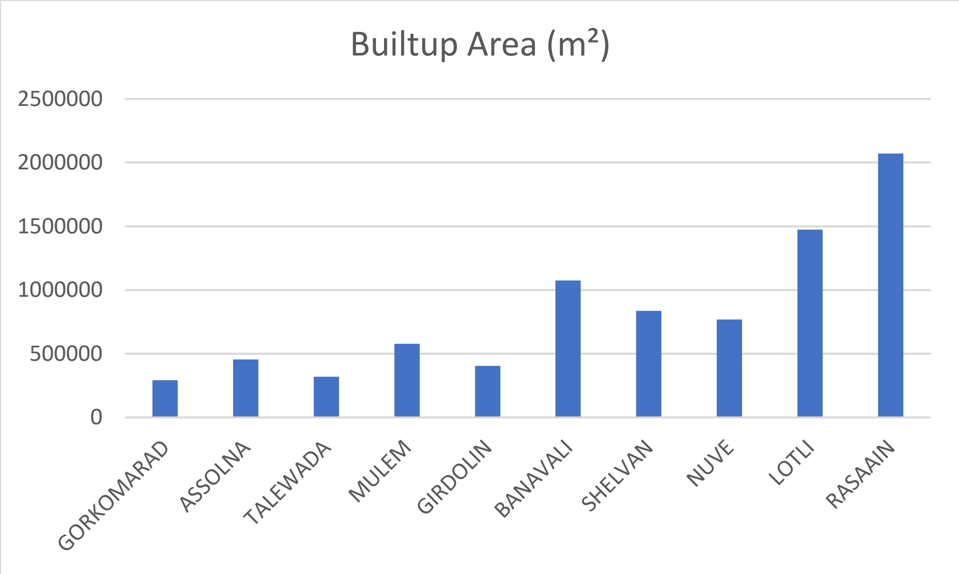


source: secondary data

Village with most barren land in 1991 are Rasaain, Lotli and Shelvan, the others have the least like Mulem and Banavlim

Fig No 4.3.5

Top 10 Villages With Builtup Area For the Year 1991

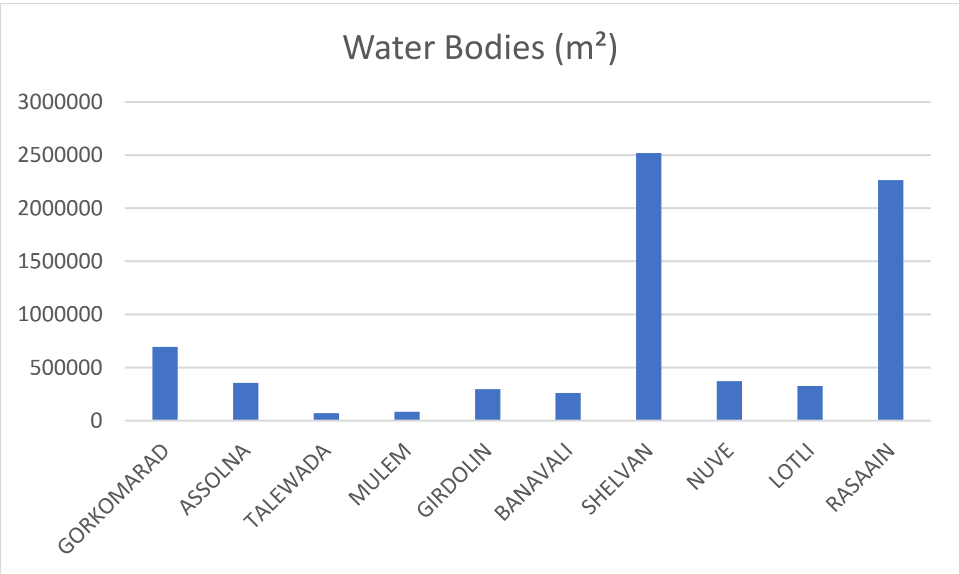


source: secondary data

Builtup area largely consist of Village like Rasaain, Lotli and Banavali, while the least are Gorkormarrad and Talewada

Fig No 4.3.6

Top 10 Villages With Water Bodies For the Year 1991

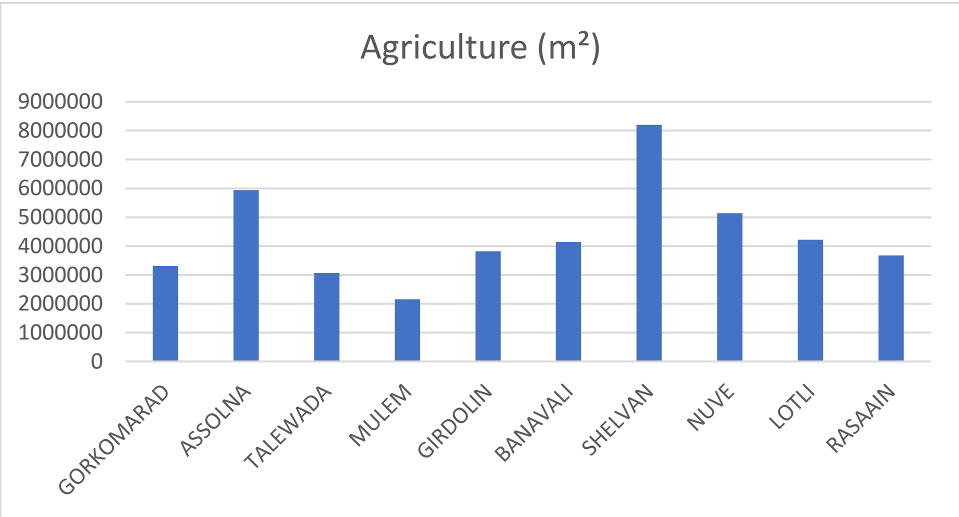


source: secondary data

The year 1991 water bodies were present in Village like Shelvan, Rasaain, Gorkormarad and Assolna

Fig No 4.3.7

Top 10 Villages With Agriculture Land For the Year 1991

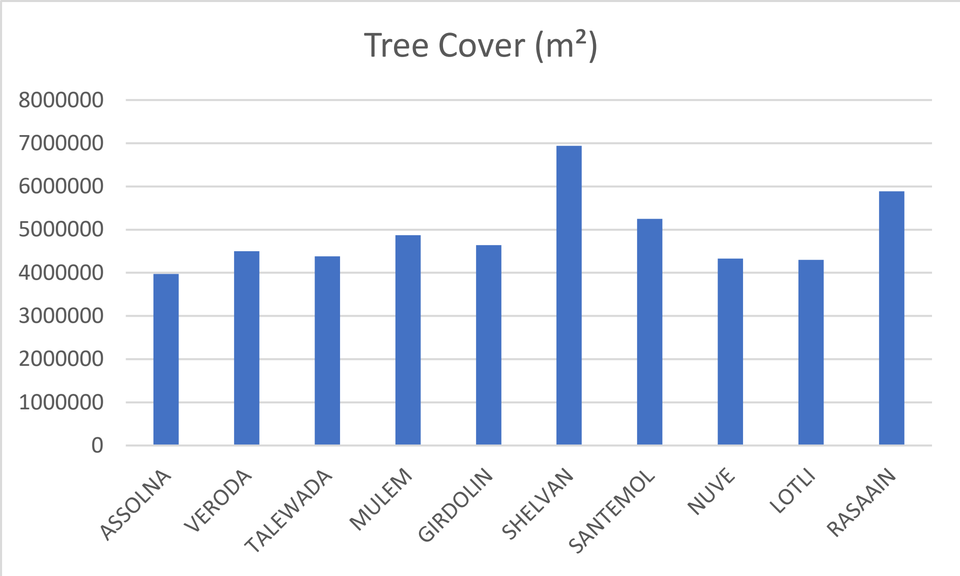


source: secondary data

The graph 4.3.7 indicates that in the year 1991, Agriculture consist of Village like Raasain, Shelvan, Assolna and Banavalim

Fig No 4.3.8

Top 10 Villages With Tree Cover For the Year 2021

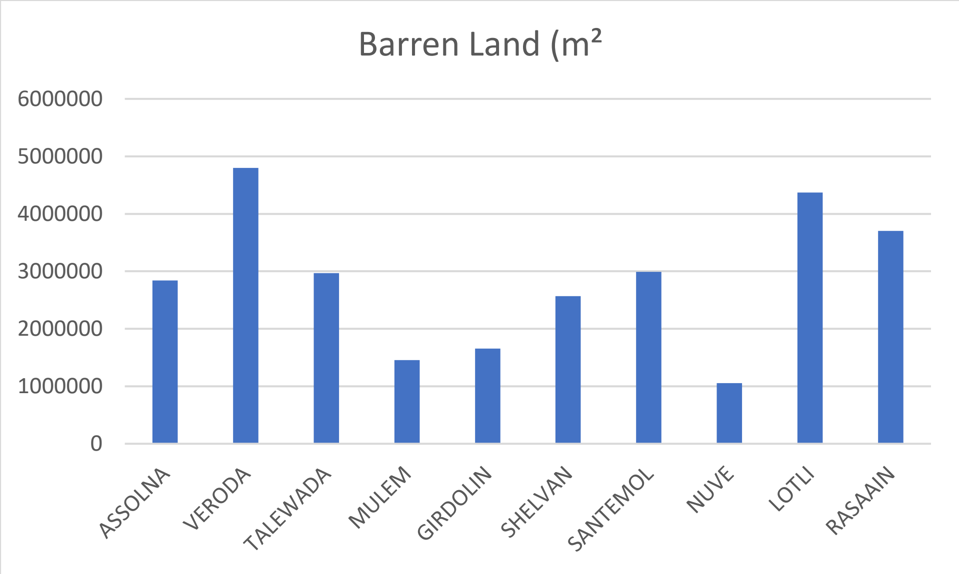


source: secondary data

Fig No 4.3.8-dipicits that treecover for the year 2021 was mostly in villages like Rasaain, Shelvan, Santemol and Assolna while the least was in Nuve, Lotli and Talewada

Fig No 4.3.9

Top 10 Villages With Barren Land For the Year 2021

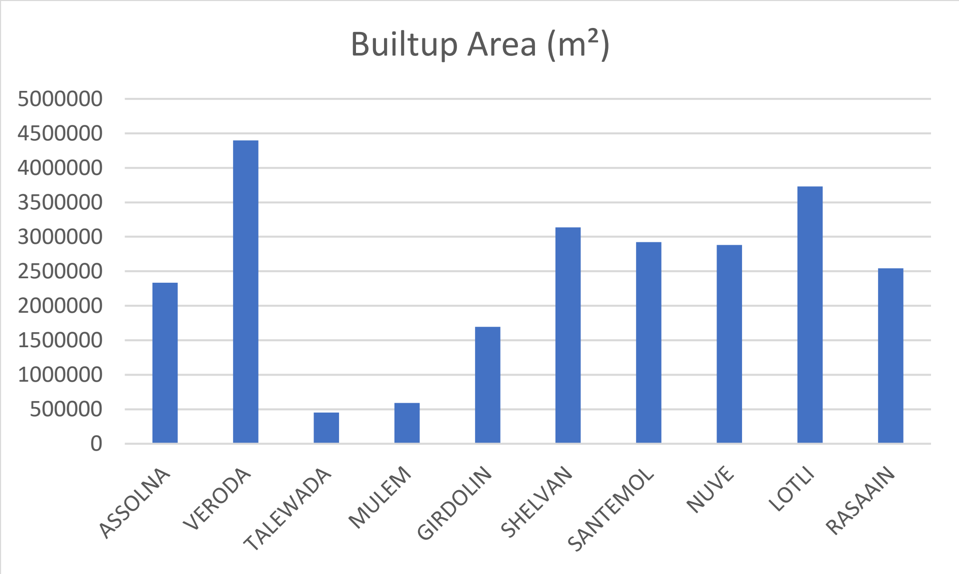


source: secondary data

Fig No 4.3.9- discloses Barren Land Cover for 2021, Veroda, Lotli and Rasaain had the most Barren Land while Mulem, Girdolim and Nuve had the least

Fig No 4.3.10

Top 10 Villages With Builtup Area For the Year 2021

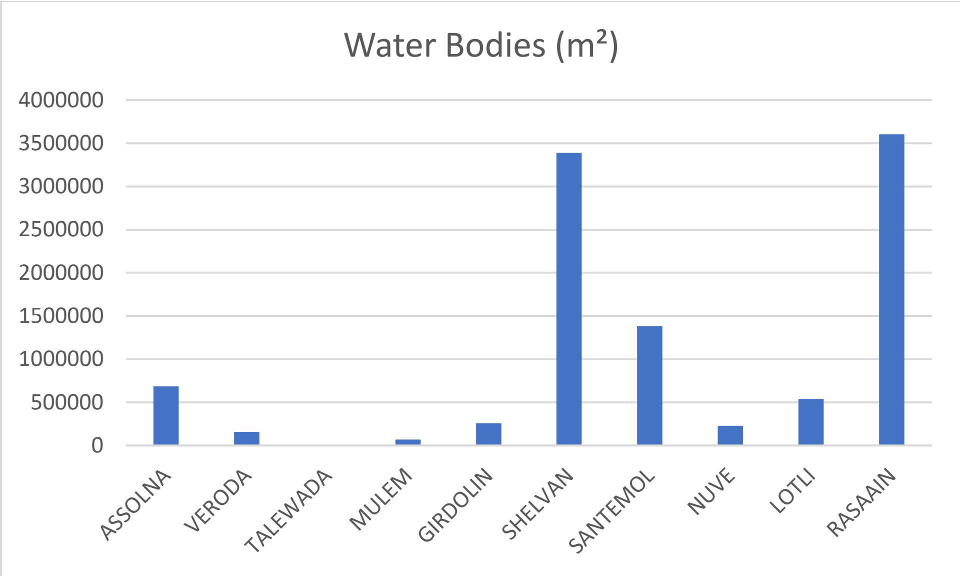


source: secondary data

Fig No 4.3.10-exihibits Villages with Builtup Area For The Year 2021, Veroda, Rasaain and Loti have the most Builup area and the least are Talewada and Mulem

Fig No 4.3.11

Top 10 Villages With Water Bodies For the Year 2021

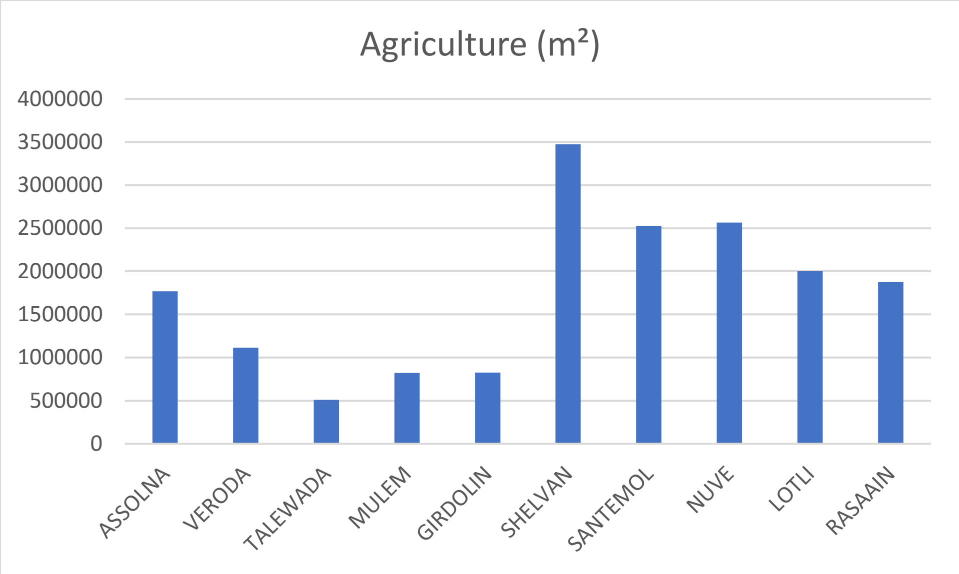


source: secondary data

Fig No 4.3.11-reveals that Villages Like Shelvan, Santemol and Rasaain have most water bodies and Assolna, Mulem and Talewadda have least water bodies in 1991

Fig No 4.3.12

Top 10 Villages With Agriculture Land For the Year 2021



source: secondary data

Fig No 4.3.12-shows that in the year 2021, Agriculture was prominent in Village like Shelvan, Santemol and Nuve while Talewada, Mulem and Girdolin had least Agriculture Land Cover

Calculation of Change Detection Metrics:

Table:4.3.3

LULC Change Detection For Madgaon City

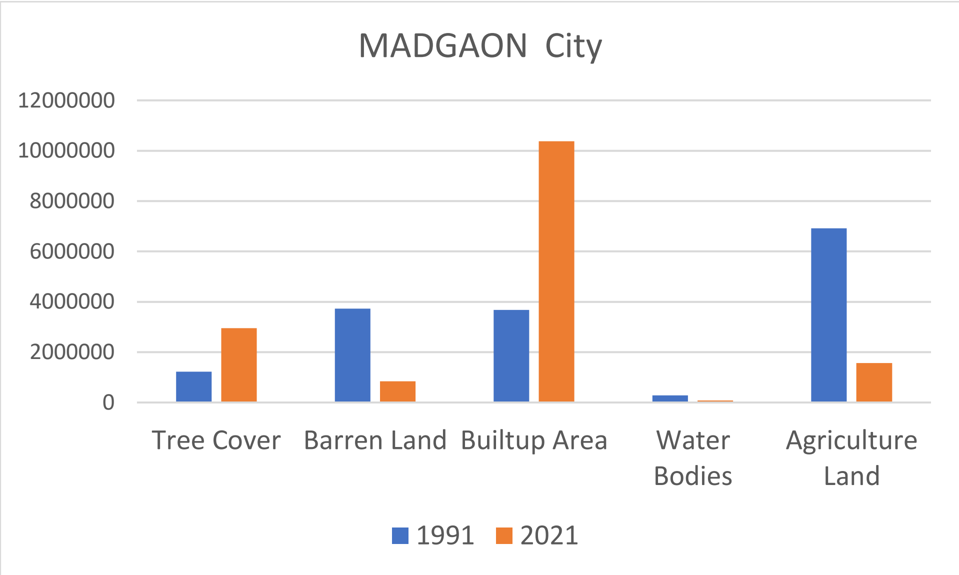
Classes	1991	2021	percentage change(%)
Tree Cover	1224900	2956500	141.3666
Barren Land	3732300	846000	-77.333
Builtup Area	3679200	10381500	182.1673

Water Bodies	**276300**	**81900**	**-70.3583**
Agriculture Land	**6924600**	**1571400**	**-77.307**

source: secondary data

Fig No 4.3.13

Graphical Representation of Change Detection for Madgaon City



source: secondary data

Fig No 4.3.13-reveals that Madgaon City has gained Builtup area and TreeCover from 1991 to 2021, while Madgon City has lost Barren Land, Water Bodies and Agriculture in that couse of time.

Change detection metrics, such as area change and percentage change, are calculated to quantify the impact of economic activities on land cover dynamics.

Area change represents the total change in the spatial extent of specific land cover classes between different time periods.

Percentage change expresses the magnitude of change relative to the total area of interest, providing insights into the rate and intensity of land cover changes.

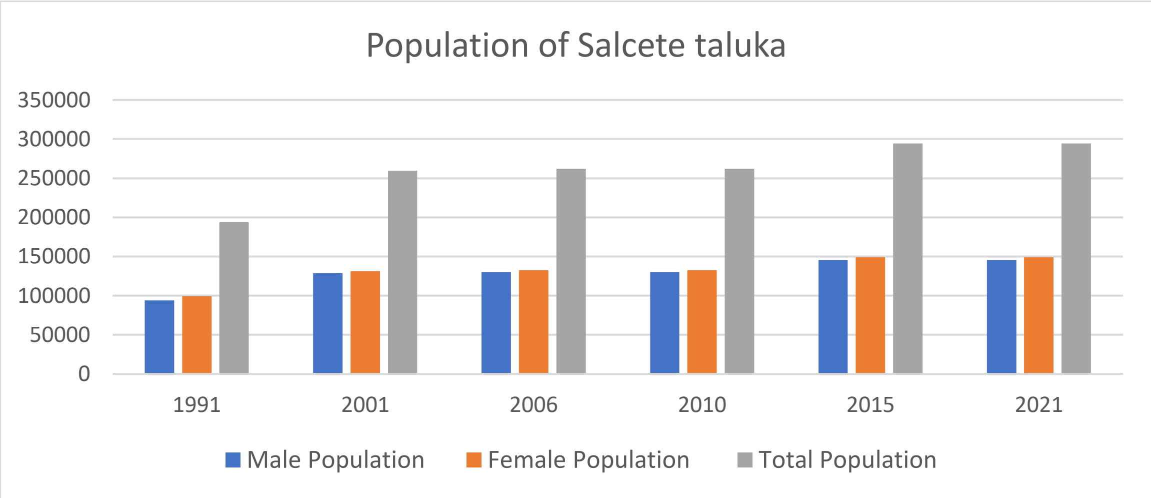
These metrics help assess the extent to which economic activities, such as urbanization, industrialization, and agricultural expansion, have influenced land use/land cover dynamics over time.

Overall, the change detection analysis provides valuable insights into the temporal trends and spatial patterns of land cover change, enabling researchers to understand the impact of economic activities on landscape transformation in the study area. By quantifying changes in land cover dynamics, policymakers and land managers can make informed decisions to promote sustainable land use practices and mitigate environmental impacts.

4. Integration of Socio-Economic Data:

Fig No 4.4.1

Population Trend of Salcete Taluka

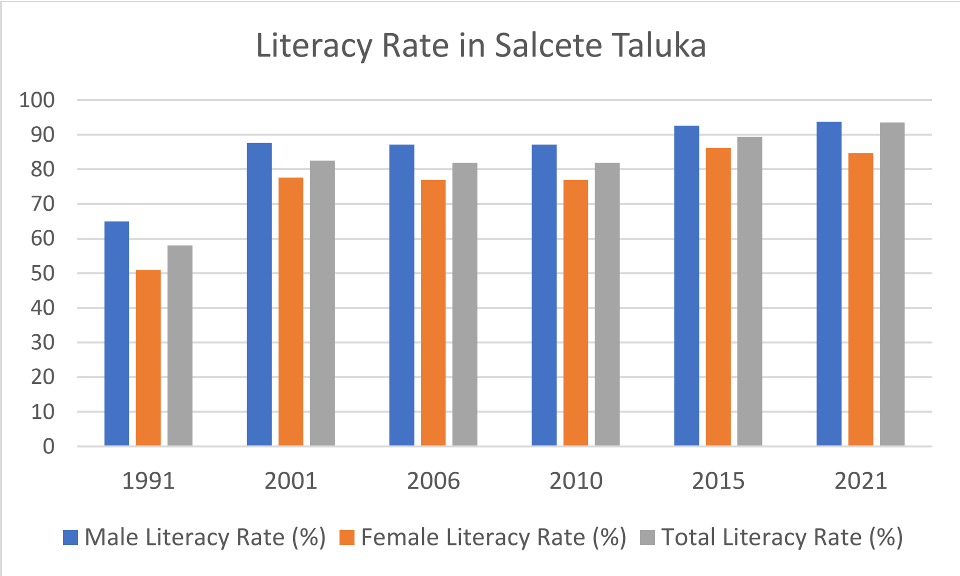


source: secondary data

Fig No 4.4.1-shows that over the period of 30years there is increase in total population from 193777 to 294464, female population has increased from 99148 to 149016, while the male population has increased from 93841 to 145448.

Fig No 4.4.2

Male And Female Literacy Rate In Salcete Taluka

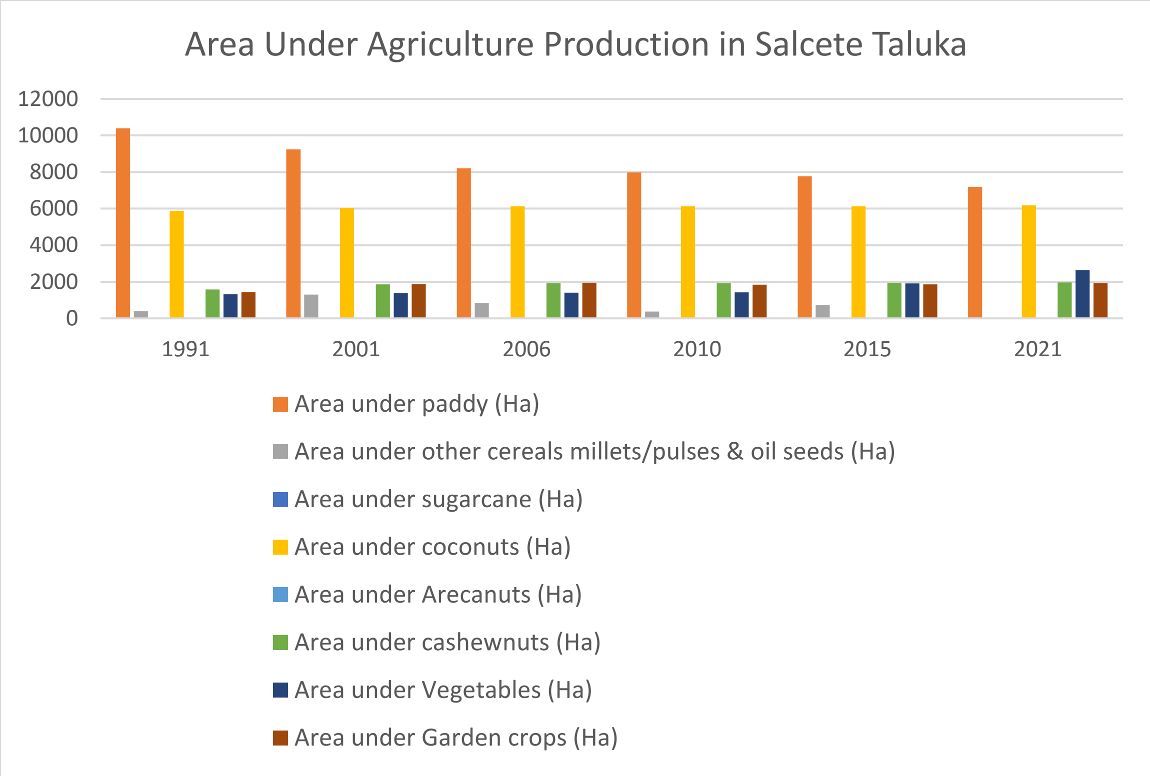


source: secondary data

Fig No 4.4.2-reveals that total literacy rate in salcete taluka has increased from 58% to 93.56, Female literacy rate increase from 51% to 84.62%, while the male literacy rate increase from 65% to 93.69%

Fig No 4.4.3

Area Under Agriculture Production In Salcete Taluka

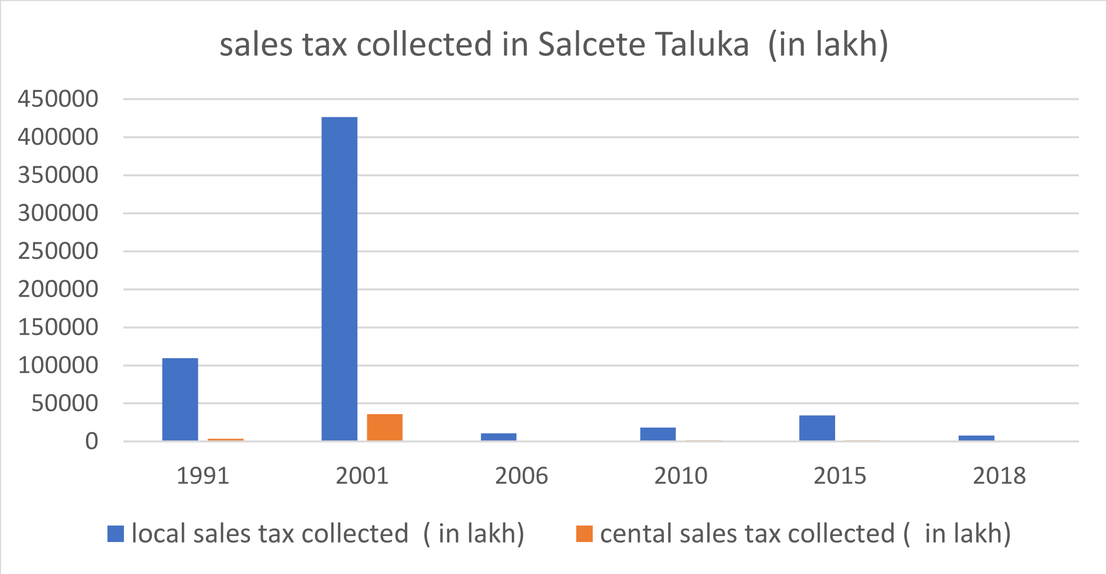


source: secondary data

Fig No 4.4.3-indicates That there is fall in the area under agriculture production, crops like sugarcane and arecanut have the least of area under production. Paddy, millets and oil seeds have significantly lost area under production, while coconuts, cashewnuts, vegetable and gardern crops have gained area under production

Fig No 4.4.4

Sales Tax Collected in Salcete Taluka

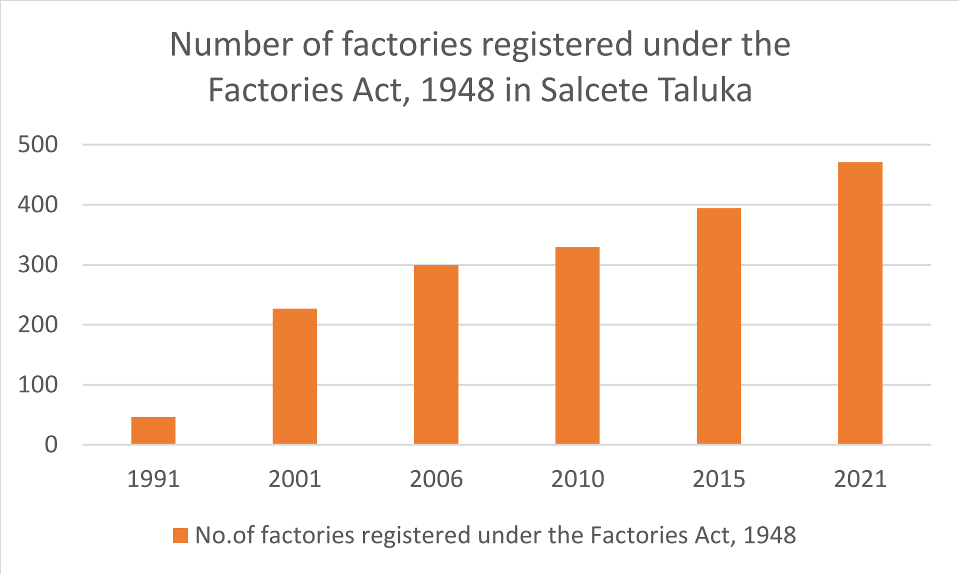


source: secondary data

Fig No 4.4.4-discloses that sales tax collection has decreased since 2001.The higest sales tax recorded was 426406 lakhs at local level and 35804 lakhs at central level

Fig No 4.4.5

Number Of Factories Registered Under The Factories Act, 1948 In Salcete Taluka

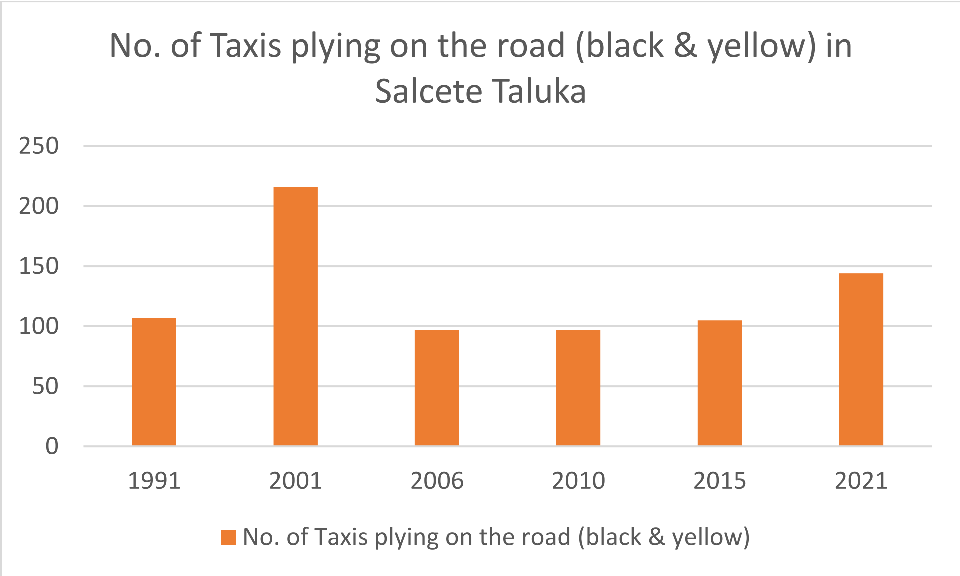


source: secondary data

Fig No 4.4.5-indicates that the number of factories registered under the factories act, 1948 in salcete taluka have increased from 46 to 471

Fig No 4.4.6

Number Of Taxis Used As Means Of Transport

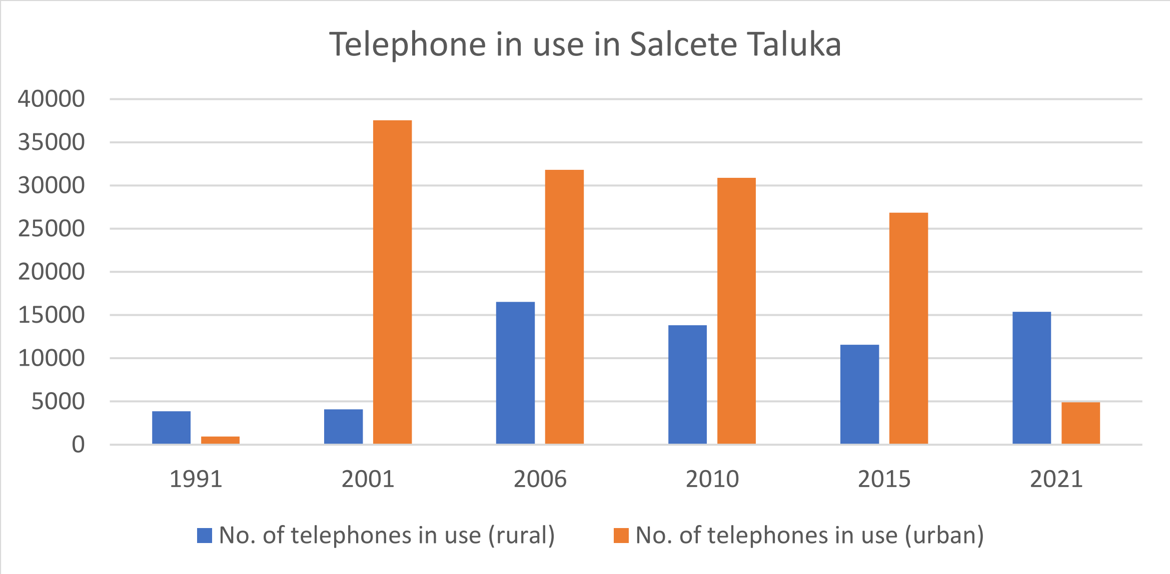


source: secondary data

It is clear from Fig No 4.4.6 that the number of taxies plying on road in salcete taluka, the highest was in 2001 with 216 taxis and 144 taxis in the year 2021

Fig No 4.4.7

Telephones In Use In Salcete Taluka

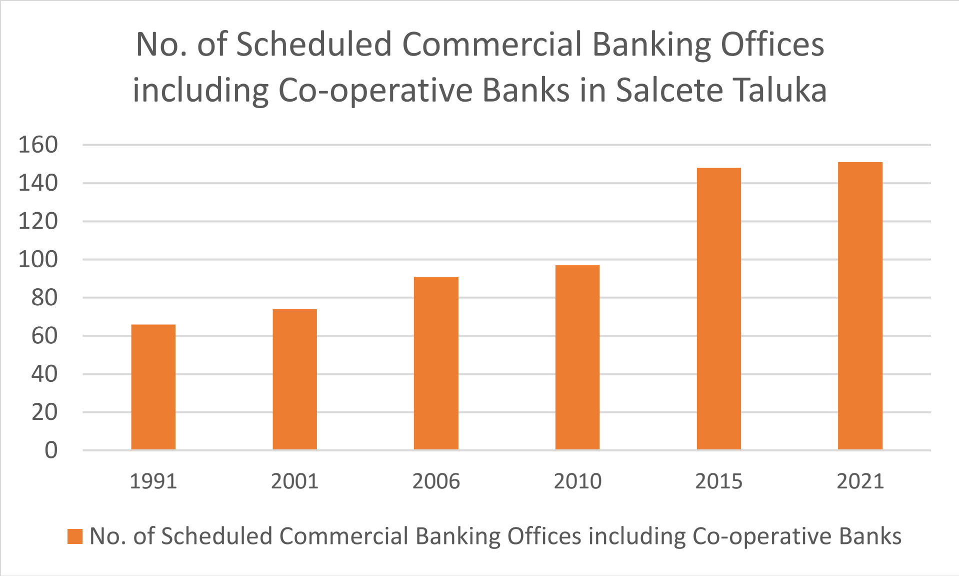


source: secondary data

Fig No 4.4.7-indicate that there is decrease in the use of telephones in urban area and increase use of telephone in rural area in salcete taluka

Fig No 4.4.8

Trends In Banking System In Salcete Taluka

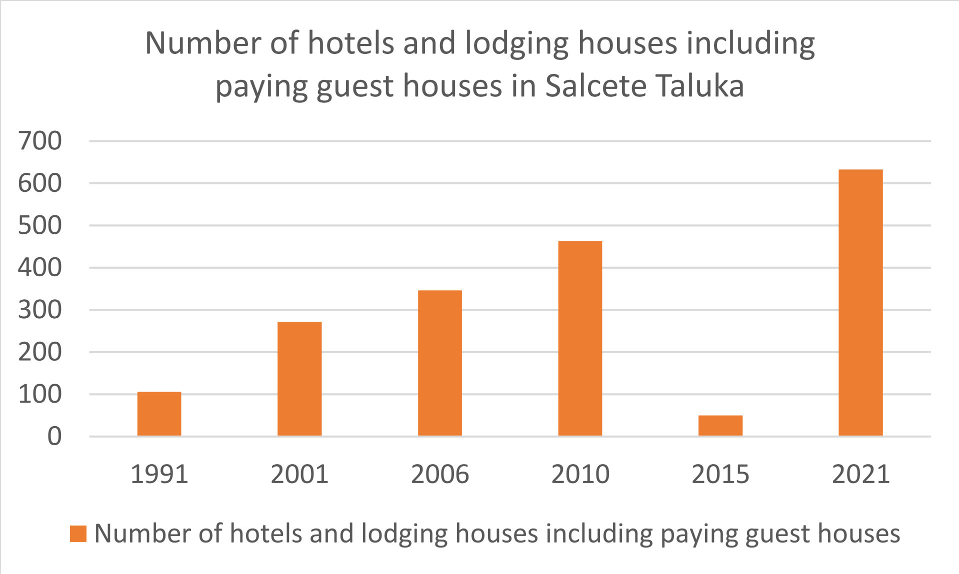


source: secondary data

Fig No 4.4.8-indicates that there has been significant growth in in the number of bank offices in salcete taluka, 66 banks in 1991 and 151 banks in 2021

Fig No 4.4.9

Number Of Hotels And Guest Houses In Salcete Taluka



source: secondary data

Fig No 4.4.9-discloses the number of hotels and guest houses in Salcete Taluka. 106 in 1991 and 633 in 2021, only 50 guest house and hotels were recorded in 2015

Integration of Socio-Economic Data:

Socio-economic data related to various economic activities in Salcete Taluka, such as population growth, urbanization rates, industrial development, and tourism activities, are collected and compiled.

These data may be obtained from government sources, census reports, research studies, or local authorities, providing insights into the demographic, economic, and social characteristics of the study area.

Socio-economic indicators serve as proxies for understanding the drivers and impacts of land cover change, as economic activities often influence land use patterns and landscape dynamics.

4.5 Patterns and Trends in Land Cover Change:

Analysis reveals significant patterns of land cover change, including urban expansion, agricultural intensification, and alterations in vegetation cover.

Urban areas have expanded rapidly, encroaching on natural landscapes and agricultural land.

Agricultural intensification is observed, characterized by the conversion of natural habitats into croplands or intensified agricultural practices.

Changes in vegetation cover indicate shifts in ecosystem health and biodiversity, with implications for ecosystem services and habitat fragmentation.

4.6 Implications of Land Cover Changes:

Urban Expansion: Rapid urban growth leads to increased demand for land, infrastructure development, and habitat loss. This poses challenges for biodiversity conservation, water resource management, and ecosystem services provision.

Agricultural Intensification: Intensified agricultural practices may enhance food production but also contribute to soil degradation, water pollution, and loss of biodiversity. Sustainable agricultural practices are essential to mitigate negative environmental impacts.

Changes in Vegetation Cover: Alterations in vegetation cover affect ecosystem resilience, carbon sequestration, and habitat quality. Loss of natural vegetation can result in increased vulnerability to natural hazards, reduced water retention, and diminished biodiversity.

4.7 Limitations and Future Research Directions:

Limitations:

Data Constraints: Limited availability of high-resolution imagery or socio-economic data may constrain the accuracy and scope of analysis.

Classification Errors: Errors in land cover classification or uncertainties in image interpretation may introduce biases or inaccuracies in the results.

Uncertainties in Socio-economic Data: Incomplete or outdated socio-economic data may hinder the assessment of economic activities' impact on land cover dynamics.

Future Research Directions:

Improved Data Acquisition: Explore opportunities to acquire higher-resolution satellite imagery or socio-economic datasets to enhance the accuracy and resolution of analysis.

Refinement of Classification Techniques: Investigate advanced classification techniques or machine learning algorithms to improve the accuracy and efficiency of land cover classification.

Longitudinal Studies: Conduct longitudinal studies over extended time periods to assess temporal trends in land cover change and evaluate the effectiveness of land management interventions.

Integration of Stakeholder Engagement: Engage local communities, policymakers, and stakeholders in participatory research processes to incorporate local knowledge and priorities into land use planning and management strategies. By addressing these limitations and pursuing future research directions, we can enhance our understanding of the dynamics of land use/land cover change in Salcete Taluka and support evidence-based decision-making for sustainable land management and development initiatives.

Chapter 5

Conclusion

In conclusion, the analysis of land use/land cover dynamics in Salcete Taluka provides valuable insights into the impact of economic activities on the environment and underscores the need for sustainable land management practices. Through the integration of satellite imagery, socio-economic data, and advanced analysis techniques, we have identified significant patterns and trends in land cover change, highlighting the complex interactions between human activities and environmental dynamics. The analysis of land use and land cover dynamics in Salcete Taluka offers valuable insights into the intricate relationship between economic activities and environmental sustainability. By integrating satellite imagery, socio-economic data, and advanced analysis techniques, we've discerned significant trends and patterns in land cover change, shedding light on the complex interplay between human actions and ecological processes.

Economic activities, notably urban expansion, agricultural intensification, and shifts in vegetation cover, emerge as key drivers of land use transformations in the region. The rapid urbanization and industrial growth witnessed in Salcete Taluka have resulted in the encroachment of urban areas onto natural habitats and agricultural land. This phenomenon poses considerable challenges for biodiversity conservation and the provision of ecosystem services, highlighting the need for sustainable urban planning strategies that prioritize green infrastructure and habitat preservation.

Similarly, the intensification of agricultural practices has led to increased food production but has also exacerbated issues such as soil degradation and biodiversity loss. It underscores the importance of adopting sustainable agricultural techniques that promote soil health, water conservation, and biodiversity conservation.

economic indicators such as population and literacy show positive trends of growth. The loss of Agriculture land and Water Bodies, with gain in Builtup area underscore the need for integrated land management approaches that balance economic development with environmental preservation. This calls for concerted efforts to promote sustainable land use practices, conserve natural ecosystems, and enhance resilience to environmental change.

However, it's essential to acknowledge the limitations inherent in our analysis, including data constraints, classification errors, and uncertainties in socio-economic data. These factors may have influenced the accuracy and robustness of our findings, emphasizing the need for ongoing research and data refinement.

Looking ahead, future research should focus on addressing these limitations and exploring new avenues for understanding land use dynamics in Salcete Taluka. Improved data acquisition, advanced classification techniques, and longitudinal studies can provide a more comprehensive understanding of the complex interactions between economic activities and environmental dynamics. In conclusion, our analysis underscores the importance of holistic and integrated approaches to land management that consider the intricate relationships between economic activities, environmental sustainability, and societal well-being. By promoting sustainable land use practices and fostering stakeholder engagement, we can strive towards achieving a balance between economic growth and environmental conservation, ensuring the long-term resilience and prosperity of Salcete Taluka and its inhabitants.

For future recommendations, several avenues can be explored to enhance our understanding of land use/land cover dynamics in Salcete Taluka and inform more sustainable land management practices:

- Improved Data Acquisition: Invest in acquiring higher-resolution satellite imagery and socio-economic datasets to improve the accuracy and resolution of analysis. Utilize emerging technologies such as drones and remote sensing platforms to capture real-time data and monitor land cover changes more effectively.
- Advanced Analysis Techniques: Explore the application of advanced machine learning algorithms, such as convolutional

neural networks (CNNs) and random forests, for land cover classification and change detection. These techniques can improve the accuracy and efficiency of analysis and provide deeper insights into landscape dynamics.

- Longitudinal Studies: Conduct longitudinal studies over extended time periods to assess temporal trends in land cover change and evaluate the effectiveness of land management interventions. Long-term monitoring initiatives can provide valuable information on the resilience of ecosystems to environmental change and human disturbances.
- Integrated Land Management Strategies: Develop integrated land management strategies that consider the complex interactions between economic activities, environmental dynamics, and societal needs. Incorporate principles of ecosystem-based management, sustainable development, and participatory governance to promote resilience and sustainability in land use planning and decision-making processes.
- Stakeholder Engagement: Foster collaboration and engagement with local communities, policymakers, and stakeholders to

incorporate diverse perspectives and local knowledge into land management practices. Adopt participatory approaches that empower communities to actively participate in decision-making processes and promote ownership of sustainable land management initiatives.

- Capacity Building: Invest in capacity-building initiatives to enhance the technical skills and knowledge of stakeholders involved in land management and environmental conservation. Provide training programs, workshops, and educational resources to empower local communities and decision-makers to implement sustainable land use practices effectively.
- Policy Support: Advocate for the development and implementation of policies and regulations that promote sustainable land management practices, biodiversity conservation, and climate resilience. Support initiatives that incentivize the adoption of sustainable land use practices and provide financial and technical assistance to landowners and communities.

- By pursuing these future recommendations, we can enhance our understanding of land use/land cover dynamics in Salcete Taluka and contribute to the development of evidence-based policies and strategies for sustainable land management and environmental conservation.

References:

1 Damau, S. Z., et al. (2020). Extent and Rate of Changes in Land Use/Land Cover Around Kaduna Refining and Petrochemical Company, Chikun Local Government, Kaduna State. International Journal of Scientific Research in Science and Technology, 07 Sep.

2 Daramola, J., et al. (2022). Assessment of Land Use/Land Cover Dynamics of Kaduna Watershed, Using Remote Sensing Data and GIS Techniques. Geografia, 31 May.

3 Sajib, A. M., et al. (2022). Driving Forces of Land Use and Land Cover Changes in the North-eastern Part of Dhaka Conurbation. The Dhaka University Journal of Earth and Environmental Sciences, 19 Jan.

4 Gaonkar, V. G. P., et al. (2023). Transition Modelling of Land Use Land Cover Dynamics in Bardez Taluka of Goa-India (1991-2021). Disaster Advances, 15 Jan.

5 Nadaf, F., et al. (2022). Analysis and Prediction of Land Cover Changes using the Land Change Modeler (LCM): A Case Study of Candolim, Bardez-Goa, India. Disaster Advances, 25 Jul.

6 Vennithasari, R., et al. (2020). Analysis of Green Land Changes to Building Land Using Geographic Information System (GIS) in Salatiga City from 2013 to 2019. Journal of Applied and Natural Science, 03 Jul.

7 Koppad, A. G., et al. (2020). A Study on Land Use and Land Cover Classification Using Microwave Data in Joida Taluk of Uttara Kannada District, Karnataka. Journal of Applied and Natural Science, 15 Mar.

8 Statistical Hand Book Of Goa

9 Goa At A Glance