Decadal Changes in Land Use and Land Cover Near Industrial Estates in Goa: A Comprehensive Analysis

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "Decadal Changes in Land Cover Land Use Near the Industrial Estate in Goa: A Comprehensive Analysis" is based on the results of investigations carried out by me in the Masters of Arts in Economics at 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 / College 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 "**Decadal Changes in Land Use Land Cover near Industrial Estate in Goa: A Comprehensive Analysis**" a bonafide work carried out by Ms. Glenda Fernandes under my supervision in partial fulfillment of the requirements for the award of the degree of Masters of Arts In Economics in the MA Economics at the Goa Business Schoel, Goa University.

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CONTENTS

PREFACE

Land use and land cover (LULC) patterns plays a critical role in shaping a region's ecological and socio-economic fabric. Understanding these patterns, particularly how they change over time, is crucial for sustainable development. Industrial estates, often catalyze significant LULC transformations in their surrounding areas. This dissertation delves into the decadal changes in LULC patterns near an industrial estate, offering a comprehensive analysis over thirty years.

Policymakers can utilize the findings to formulate informed decisions regarding industrial expansion, environmental protection, and infrastructure development. Urban planners can leverage the knowledge to create sustainable and resilient communities around the industrial zone. Additionally, the research contributes to the broader scientific understanding of the dynamic relationship between industrial activity and LULC patterns.

The methodology employed in this study incorporates advanced techniques in remote sensing and geographical information systems (GIS). This dissertation is structured to provide a clear and concise understanding of the research. The first chapter outlines the research context, highlighting the significance of LULC studies and the specific focus on industrial estates. The subsequent chapters delve into the literature review, detailing existing research on the topic and identifying knowledge gaps. The methodology chapter meticulously describes the data acquisition procedures, utilized tools, and the analytical framework employed. The core of the dissertation lies in the results and discussion chapters. These chapters present the findings of the LULC analysis, including quantifications of changes across different land cover types.

This dissertation contributes to the ongoing conversation about sustainable industrial development and responsible land management practices.

-Glenda Fernandes

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ABBREVIATION USED

Entity	Abbreviation
Land use land cover	LULC

Abstract

Industrial estates are key economic drivers for Goa, their setup puts pressure on the land use land cover pattern due to the limited availability of land This study aims to analyze the impact of Verna and Canacona Industrial Estate on land use and land cover and compare the transformation pattern between the two sites for the 30 years from 1993 to 2023. Satellite Imagery and supervised classification techniques are used to classify LULC into different classes. Classified images are analyzed to identify LULC changes. Results revealed that the expansion of industries took place at the expense of barren land, tree cover, and agricultural land suggesting strategies for sustainable industrial development.

Keywords: Industrial estate, Supervised classification, Verna, Canacona,

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Industrialization is a process wherein there is an increase in several industries contributing towards the growth of the economic GDP, providing more job opportunities and technological advancements in many fields. Industrial Estate is a slightly different but similar concept to industrialization, it is a place where industrial buildings are located with all the amenities and infrastructure required for the working of industries and is mostly funded by the Government. An industrial estate is also called an industrial park, industrial zone, industrial area, etc. The United Nations (1963) has defined an industrial estate as "a planned clustering of enterprises, offering standard factory buildings erected in advance of demand and variety of services and facilities to the occupants." (Sinha, 2014).

Setting industrial estate leads to the development of that region or area in terms of infrastructure such as roads, rails, power supply, etc, this is crucial for backward regions as it can help in its upliftment in various forms. Also, human settlement increases in industrial estate giving way to urbanization in the long run. This is proven by the fact that industrialization is a key to development as most developed nations have gone through this process, and the positive impact of industries trickles down to other sectors of the economy leading toward economic growth (Dua, 2015).

The share of the industrial sector in the GDP has increased over the years in the Indian economy from 15% at the times of Independence to 29% in recent periods. The government tries to establish industries in various parts of the country through various measures such as infrastructure incentives, Relaxation on taxation, easier entry in doing business (Joshi, 2023).

1.1.1. Industries in Goa

Goa is becoming an emerging hub of the industrial estate due to its strategic location it is connected with various roads, rail, and air networks. The most remarkable is the Mormogao

port which has been facilitated as a means of transport for various industrial estates to date. Industrial development in Goa has undergone various changes. The 1st and 2nd five-year plans were not implemented in Goa as it was under the Portuguese regime, so soon after liberation Goa saw a tremendous change towards industrialization which emerged from the mining activities, especially from 1993 to 2002 due to various incentives provided by the government such as sales tax holiday, special income tax concession, etc. Goa Industrial Corporation was established to make Goa a Production-oriented economy, there were around 20 industrial estates set up in Goa over 10 million sq m. The aim was to generate revenue, and employment opportunities and to balance the regional development in the state (Jain, 2017)

Although Goa today is seen as the prime location for industrial setup promoted through various programs such as Invest Goa Summit, the Growth and Investment Promotion Policy 2022, the various Government Policies, etc, it should be noted that there is a limitation on land availability in Goa as it is a small state with around 3702 kmsq and the industrial set up put pressure on the land use land cover pattern (Government, n.d.) .

The Recent government policies and some of the laws and regulations are focusing on bringing new land for industrial expansion One such act passed is the Goa Restriction on Transfer of Agricultural Land Act, 2023 (Goa Act 18 of 2023), which has been passed by the Legislative Assembly of Goa on 31-03-2023, This is to provide restrictions on transfers of certain agricultural lands in the state of Goa provided the collector give grant of permission for transfers, the land is required for purpose of agriculture by industrial or commercial, undertaking in connection with such industrial or commercial operations carried on by such undertaking(Government of Goa, 2023). The New Investment and Promotion Board Policy is looking towards taking land from private landowners in social and corporative forms for setting up industrial expansion firms.

1.1.2. Land Use Land Cover

Land Use Land cover are term related to the earth's surface. Land cover refers to the natural cover of the land that is not touched by human interactions such as Tree cover, natural vegetation, rivers, and rocks, whereas Land Use is utilizing this land for various purposes to satisfy human wants and demands such as urban settlement, industrial activities, etc, these two are linked with each other where changes in Land use causes changes in land cover(Dewan et al., 2012).

Over the decades there have been a tremendous amount of changes in land use and land cover patterns globally, The factors that affect the LULC pattern are an increase in population, structural shifts such as industrial expansion, increase in population density leading to urbanization. To address the above demands, there are changes made in land cover leading to deforestation, conversion of agricultural land to other purposes, diversions of water bodies, etc. Addressing the Changes in the LULC pattern is an important issue, as Land itself is an important economic resource. Changes in LULC have environmental as well as economic implications(G & K, 2021).

Satellite Imagery is one of the tools to monitor LULC patterns, The Remote sensing technique has made it possible to monitor LULC patterns through satellite images. Remote sensing is a technique where information is gathered about an object without coming in contact with it by making use of the sensors. Supervised classification and unsupervised classification are 2 methods to classify images according to their land cover land use. Supervised classification is a more renowned technique has it runs on various algorithms that provide closer to accurate results (Krista Merry, 2023).

This study focuses on analyzing the decadal Impact of Verna Industrial Estate and Canacona Industrial Estate on the LULC pattern, as Verna is one of the oldest and largest industrial estates in Goa housing a diverse range of industries such as pharmaceuticals,

electronics, and engineering goods. Analyzing the impact of the expansion of the Verna Industrial will allow us to observe the changes in land cover, indicating at what expense the industry has expanded whereas the Canacona Industrial estate was set up in 1986 and houses a small range of industrial estates such as electronics, and information technology. Canacona industrial estate is used for comparing the impact of LULC between large and small industrial estates and the development of each region. The Various industrial policy undertaken by the Government focuses on the expansion of existing industrial estates and setting up new estates without considering the problems of existing industrial estates and the problem of Land scarcity. so the government should consider sustainable industrial development along with taking into consideration balanced regional development of that area.

1.2. RESEARCH PROBLEM

There is pressure on land use and land cover patterns due to industrial setup. So this pressure leads to changes in the tree cover, Barren land, agricultural land, water bodies, and built-up areas.

1.3. RESEARCH QUESTION

“Does the industrial estate have an impact on Land use Land cover pattern ?”

“Does the rate of Land use/Land cover changes differ between large and small industrial areas”?

1.4. RESEARCH OBJECTIVES

“To analyze the impact of Industrial estate on Land Use Land Cover pattern in Goa with a focus on Verna and Canacona industrial estates.”

“To Compare the rate of Land Use/Land Cover changes between large and small industrial areas.”

1.5. RESEARCH GAP

“There is a notable research gap in understanding the nuanced alterations in land use land cover patterns around major industrial estates in Goa”

1.6. DATA SOURCES

The data source for this is Secondary data sources, Image area downloaded from USGS Earth Explorer, shapefile was downloaded from the census of India, and Data for the population is collected from the Handbook of Census.

1.7. METHODOLOGY

This study is purely based on using Geo-spatial techniques in the field of Economics as it is the emerging tool for conducting research in Land management practices, environmental concerns, etc. Land is an important economic resource and is limited in nature for industrial growth in Small States like Goa. Using the Geospatial technique is of great significance for analyzing the industrial expansion taking place by changing land use land cover patterns.

LULC images have been created using supervised classification through the maximum likelihood method in ArcGIS Pro software, For assessing the accuracy, the kappa coefficient test has been conducted in ArcGIS Pro. Change detection has been done using the two time period 1993 and 2023. Buffer zones are been created of 2km, 3km, and 4km, have to analyze the changes in the buffer to close vicinity of industrial zones. The area is calculated and tabulated for detailed analysis of change in LULC for both the industrial area

1.8 FINDINGS

The Findings will indicate the Impact of an industrial estate on Land use and Land Cover patterns. In terms of Industrial expansion has taken place at the expense of which land cover class? Also the comparison between large and small industrial estates in terms of their expansion and LULC changes.

1.9 SCOPE

The study is significant for land use planning and policy decisions in the context of future industrial development in Goa.

The findings will be valuable for government agencies, local authorities, and industrial stakeholders to ensure sustainable growth of the industrial estates.

The study will contribute to the growing body of knowledge of the LULC impacts on industrial estates, provide valuable insights for future planning and research efforts

CHAPTER 2: LITERATURE REVIEW

The setting up of Industrial estates has various impacts on land use land cover related environment, and social, and economic implications.The process of industrialization demands more infrastructure leading to the expansion of industries and changes in the landscapes. A study conducted by G & K, (2021) assesses the changes in land use land cover, and environmental conditions in Tripura City due to urbanization and industrial growth, this was done through supervised classification followed by accuracy assessment and Ground truth verification. Results indicate a maximum increase in built-up area and a decrease in fallow lands between 2001 and 2018 with a slight change in cropland, wasteland, and scrubland.A similar study was conducted by Dewan & Yamaguchi, (2009) in Dhaka Bangladesh to explain the driving forces in LULC changes (1975-2003) Anderson scheme level 1 was applied through the supervised classification maximum likelihood method, for misclassification, GIS tools such as area of interest are used. The kappa test was used for accuracy and change detection is done through cross matrix. Greater Dhaka was found to have experienced rapid changes in LULC, particularly in built-up or urban areas.A study on the Impact of industrialization on LULC in Himachal Pradesh was conducted by V. Kumar & Mohan,(n.d.) using primary data and secondary data sources, making topographic maps through digitalization. The area has a negative impact on the environment, while the increase in urbanization and population. Study by Dash, (2009) provides an opportunity to study the impact of mining on land cover status with a focus on forest or vegetation cover. The techniques used for assessing the impact of industrialization in Raigarh include satellite data pre-processing, visual interpretation, and change detection analysis. A random assessment of plant distribution (Trees, Shrubs, and Herbs) was carried out along with calculating the NDVI around the industrial sites. A socio-economic survey with visual recording in the field and satellite was used to know the extent of environmental pollution. Base maps, GPS, scale toposheets, and investigation on site were used

for detailed ground truth collection.The results indicated an increase in disturbed areas from 1972 to 1990 and 1990 to 1999. some of the areas showed seasonal variations and also traces of reclamation activities. Similar study conducted by Qingshui Lu a, (2011)helps to analyze the effects of urbanization and industrialization on agricultural land use in the Shandong Peninsula of China from the year 1978 to 2006. Through supervised maximum likelihood classification, it is revealed that there was a decline in agricultural land due to an increase in urbanization and industrialization. Study by Tian, (2014) portrayed China experience of economic growth and an increase in peri-urban areas along with an increase in industrial land So this was focused on Jiangyin in the Yangtze River Delta and Shunde in the Pearl River Delta, from 2001 to 2010. Through research, they found that Motivated by the GDP and tax contributions of the manufacturing industry, local governments most often lease land for industrial use under the strict land quota system. The heavy reliance of peri-urban areas on the manufacturing industry has enhanced the substantial expansion of industrial land.The next paper focuses on Mining was the driving force for initiating industrialization in Goa. This paper researched on the working of industries in North Goa through primary survey and secondary data it looks at the perception of enterprises in terms of benefits and working conditions and results said that most of them are not in good working conditions and need improvements on the part of the govt(Prof B Ramesh, 2015). Study by N P SINGH, (1997) looks into the matter of rapid industrialization near the Singurali coalfield which is having an impact on the land use dynamics with the help of remote sensing. The study reveals that areas under built-up, mining, and fly ash ponds have increased along with the decline in forest cover and agricultural land, wasteland was further converted through govt initiatives and used for infrastructure development. Similar study is conducted by Palash Basak, (2023) it analyzed the impact of rapid urbanization on Land use/cover change in Bangladesh using Landsat images and ArcGIS which show that during the initial setup of DSSEP the built-up area was less while over the

years there is an increase in the population and economic growth impacting the environment in the broader region. Research study by SHANBHOGUE, (2011) focuses on analyses of industrial development in Goa through the index of industrial production and estimation of elasticity and returns to scale of industrial production using secondary data sources. The high score of CARG indicates a vibrant manufacturing sector contributing significantly to the economy of the state. The regression analysis reveals the economy of Goa is characterized by increasing returns to scale and also employment and fixed capital together have a tremendous impact on the net value added in the manufacturing sector contributing significantly to the economy of the state.Study conducted by Christina, (2007) in Izmir Turkey analyzed the agricultural and environmental loss due to urbanization and industrialization growth from 1965 to 2001 through GIS methods which revealed 4.742.357 m2 of agricultural land lost due to unplanned urban growth due to industrial setup.A study was conducted by Yurui LI, (2010) in three phases to know the interaction between industries, environment, and LULC using Landsat and socio-eco data. The results indicated a decline in agricultural land which was replaced by construction and built-up areas influenced by industrialization, rural housing construction, farmland adjustments, etc.

Urbanization is a global phenomenon that has an impact on the environment, society, and economy. Understanding the dynamics of urbanization is crucial for sustainable development and resource management.A study was conducted by Bhatia et al., (2023) to understand the urban sprawl in Mumbai city using socio-economic and satellite data, It used supervised classification, maximum likelihood algorithm, and kappa coefficient for accuracy purposes, Urban growth quantification and various urban sprawl index are being used. Continuous monitoring and analysis of urban growth dynamics can help planners to manage urban sprawl and ensure sustainable development.A similar study was conducted on coastal areas of Turkey ,under the title "Analysing Landscape Change and Urban Sprawl in a Mediterranean Coastal

Landscape," (2012) to monitor the urban sprawl, supervised classification was used using 22 classes, and a 'from-to' matrix was used. Urban sprawl in that area was at the expense of agricultural land and the study could help in sustainable planning. Study done by Pattanayak & Diwakar,(2016)Presented urbanization in Delhi, he focused on natural to urban areas and agriculture to urban areas, panel data was combined with remotely sensed data and a regression model was run. Wherein the increase in population and immigration was due to employment opportunities has led to urbanization.Study by Wilson & Wilson, (2016) aims to structurally characterize and spatially understand the drivers to analyze the outcome of the 1974 Tulsa Metropolitan Statistical Area (TMSA) comprehensive land use plan, through object-based classification of the image into 6 classes. In assessing the accuracy of image classification, 1200 reference points (ground reference information) were obtained for each image through a stratified random sampling technique. The results indicated temporal and spatial patterns within the spatial development are different from the goals and objectives.A recent study was conducted by Seyam et al.,(2023) in Bangladesh where the area is recently industrialized with urban growth, supervised classification was developed for 5 classes with a maximum likelihood algorithm for the years 2002 -2022, and data was collected through primary and secondary means and kappa coefficient for accuracy assessment. Post-classification comparison was conducted by converting the classified raster images into vector layers. The results indicate that rapid urbanization and industrial activities are the driving factors to trigger the transformation in the study area during the last two decades.Study by Dada Ibilewa1*, (2021) on Urban Growth and its Impact on Urban land cover change in the Akure South Local Government area , investigated to bridge the knowledge gap created by data deficiency on the nature, scope, and magnitude of urban threat on the land use/land cover type The data sources are USGS, surveyor General of Federation. ArcGIS was used for image processing, and classification through the maximum likelihood method, vectors, and geometrics calculation.

The 2030 projection was made using the forecast function of Microsoft Mapsffice Excel, In the last 20 years the built-up areas have increased at a geometric rate. Agricultural land increased in the first period and reduced in the second due to rapid urbanization in the study area. The loss of farmlands to urbanization will impact negatively on food production in the study area. The study by Ernest Biney∗, (2021) focused on Takordi Metropolis which serves as an industrial and commercial center and attracts migrants across the nation to the Metropolis. Takoradi in Ghana houses about 10.2% of all industrial establishments across the country. The data is categorized into reference data and remote sensing (RS) data. A supervised classification scheme has been used for 1991, 2002, 2008, and 2018 to perform the accuracy assessment Kappa statistics and overall accuracy were calculated. Results of the study showed considerable change in the land covers in which settlement or built-up had an average yearly increment over the 27 years (from 1991 to 2018). There were fluctuations in the rate of change in Water bodies over the study period. Vegetation and bare land showed a constant decrease from 1991 to 2018. The increasing urban population and its associated demand for residential, industrial, and commercial purposes was identified as the major factor behind the increase in settlement and built-up.

Land use and land cover change detection using remote sensing is a crucial field that harnesses advanced technologies to monitor and analyze alterations in the Earth's surface.A study was conducted by S. Kumar et al., (2020) on multitemporal land data for changes in land use land cover in Haridwar using remote sensing it explored changes in orchid, agricultural land, and urban land and its impact for 21 years (1996 - 2017), Data collection done by primary and secondary methods GPS is used to collect ground points and Landsat images of 30-meter resolution respectively, pre-processing is done through geometric and atmospheric correction and pixel-based land classification is done, for accuracy assessment confusion matrices class statistics was used.The result of the LU/LC change assessment shows degradation in orchard

framing and vegetation plants during 21 years (1996-2017) due to human activities. A similar study was conducted by Halimi et al., (2018) for the period of 17 years(2000-2016) using supervised classification for 5 classes and maximum likelihood method, overall, producers and users accuracy were conducted along with kappa coefficient for 40 samples. The results highlighted the decline in water, barren land, and gardens while increase in other classes.A Study was conducted by Pattanayak & Diwakar, (2016) which presented the district-wise change analysis using supervised classification and the minimum likelihood algorithm was used for classification for accuracy purposes error matrix and kappa method were used, and the results showed rapid changes in the landscapes.Study by Dewan et al., (2012) analyzed land fragmentation in Dhaka Bangladesh, primary data such as multi-year topo sheets, and field surveys and secondary data such as Landsat images were used, multi GIS layers were developed using ArcGis, Geometric rectification was done using the salve approach, Anderson classification 1 was applied using the supervised classification of maximum likelihood, kappa test was conducted for accuracy purpose, to determine the important sources of fragmentation, the correlation between variables was derived. The study reveals that human activities in Dhaka have increased in the recent past resulting in land fragmentation. The paper by Mmanjunatha M.C, (2020) aimed at assessing the changes in LULC in Mysuru Taluk Karnataka state.The methodology adopted consists of meaningful information extraction from Remote Sensing Satellite images, data preparation, interpretation (on-screen visual), Ground Truth Check (GTC), map finalization, and database organization. (NRSC, 2011)On-screen Visual Image Interpretation Techniques (VIIT) are extracted manually and compared with digitally extracted vector layers in delineating land use land cover categories. Supervised image classification and maximum likelihood method are used.The present study reveals that 5 major classes in Level I 16 classes in Level II and 2 classes in Level III have been effectively generated by satellite images.The major crops grown are cotton, ragi, vegetables, and mango practiced in large

agricultural fields.Study by CGWB, (2012) focused on showing LU/LC changes due to enhanced human occupation to the changing social, economic, and natural environmental conditions. The area occupied by built-up land increases as there is an increase in population, which can negatively impact biodiversity and also disturb natural land cover, increase soil erosion into streams and lakes The final results highlight the potentiality of geospatial technique in optimal and sustainable land use planning of natural resource and its management.The study by Barbara Wiatkowska *, (2021) aim was to analyze land use and land cover changes in the urban area of Opole Poland. Next, color compositions were developed for the acquired images to visualize land cover features for data processing.Various indices such as NDVI, NDBI, and NDBL were developed.They used supervised classification and likelihood algorithm and kappa coefficient along with confusion matrix to know the accuracy. Spatially delimited buffer zones were designated, whose equidistances from the city center were determined based on the identified characteristics of each zone in the urban organism. To assess whether the growth of built-up areas in relation to the changing population was sustainable, the following formula was used: Ratio of Land Consumption Rate to Population Growth Rate (LCRPGR) proposed by UN-Habitat. land consumption in relation to the total area of the city increased from 15.4% in 2000 to 21.3% in 2020.The study by Zahra Hassan, (2016) aimed to identify and analyze different LULC categories and patterns of land use change along with the factors contributing to it in Islamabad from 1992 to 2012. Satellite image pre-processing before change detection of satellite data was done through ERDAS 2011 software in an image format for geometric correction. Using per pixel signatures and differentiating the land area into five classes based on the specific Digital Number (DN) value and color for different landscape elements. For the Accuracy assessment, the Kappa test was also performed to measure the extent of classification accuracy as it not only accounts for diagonal elements but for all the elements in the confusion matrix. For Post-classification

change detection technique, performed in ArcGIS. The regression analysis of land use parameters in relation to climatic variables, population, and economic factors strengthened the influence and role of all these factors in land use conversion patterns in the study area.There was an increase in the built-up areas and agricultural land and forest declined. The study by Hoover et al.,(2017) combined lacked socio-economic data, that is the participatory data with remote sensing data at the village level the former was collected through interviews and surveys, for latter classification was done in two categories, and accuracy assessment was done through a k-test. It also compared the results from participatory and remote sensing data.

Remote sensing, an evolution from aerial photography, involves utilizing a diverse array of sensors installed on aerial and satellite platforms. It holds a unique significance in monitoring transient occurrences like changes in land use and land cover.A study was conducted by J.A, (1980) on remote sensing in land use and land studies, where it is theoretically based on explaining image acquisition through various sensors and their scales, image processing, product, and interpretation. It showed land use land cover classification and also highlighted the problems related to remote sensing data, such as cloud cover, and cost constraints.

CHAPTER 3: DATA AND METHODS

3.1. STUDY AREA

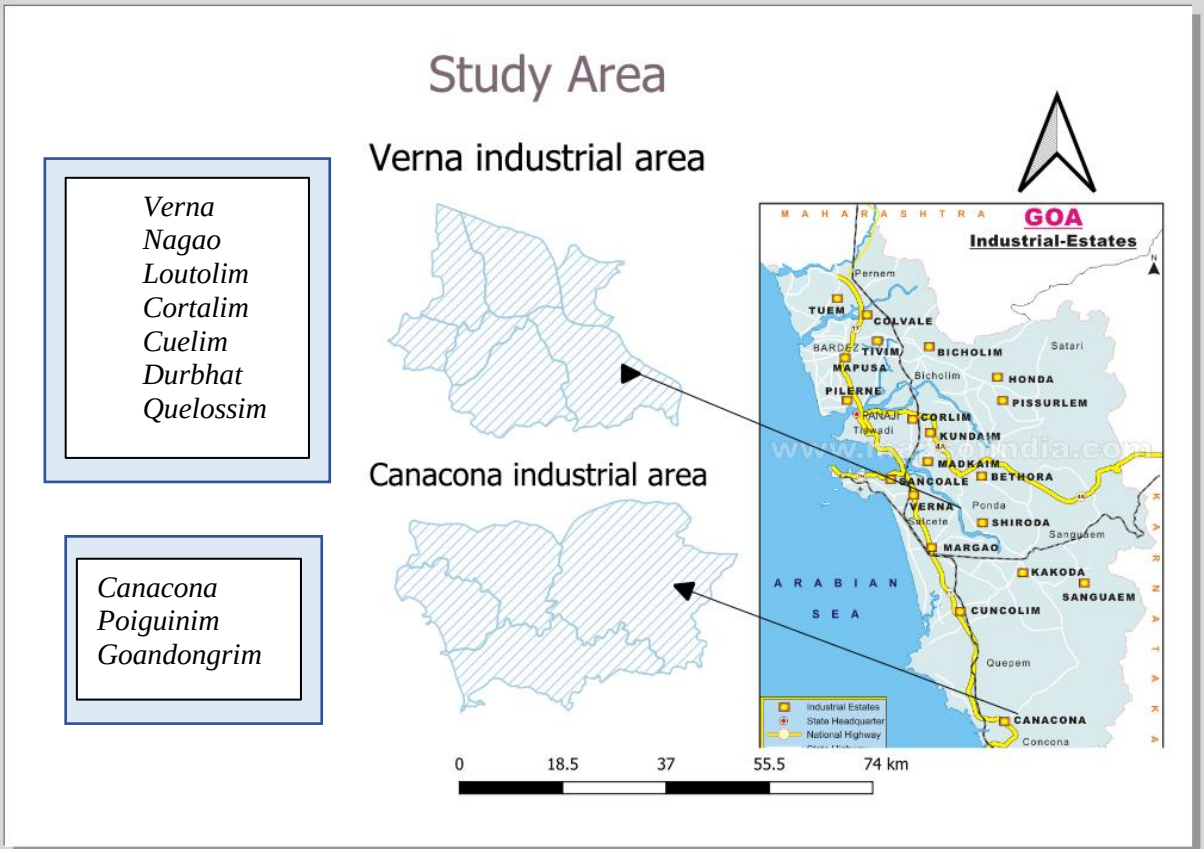


Fig 3.1: Map of the study area

The study area of the Verna Industrial estate is made of a combination of villages namely Loutolim, Nagao, Verna, Quelossim, Cortalim, Cuelim, and Durbhat. The Estate is the sub-locality in Salcete taluka, South District, Goa. The nearby towns and cities are Talaulim, Kesarvale,

The study area for the Canacona industrial estate is a combination of villages namely Canacona, and Gaondongrim. Poinguinim. Canacona Industrial Estate is a locality in Goa, India, 403702.

Palolem is the nearby area of Canacona Industrial Estate. Quisconda, Uttar Kannada, Poinguinim, Loilem, and Gaodongrem are the nearby cities of the Canaconal Industrial Estate.

Verna is a major industrial hub for industrial estate, especially in South Goa, it employs many people and supports them to earn their livelihood as it houses hundreds of companies/firms and other MSMEs. The Industrial Estate is looked at by the Goa Industrial Development Corporation and it contributes to the village to a large extent by paying house taxes to the panchayats contributing to their revenue, under Corporate Social Responsibility activities, the industrial estate provides many facilities, and necessary equipment to around seven neighboring schools

Two important freshwater sources flow to the nearby industrial town part of the river sal these water bodies heavily contribute to the flora and fauna of the close by areas. There are fish hatcheries for breeding fish in these water

Canacona is at the extreme of the South Goa district, on the north side it has Quepem taluka on the northeast it is situated with Sanguem, on the south by the state of Karnataka, and the west it has the Arabian Sea.

Chaudi town is the headquarters of the taluka Canacona It has the Government Industrial Training Center one of the most prominent institutes established in 1980 since then it has been running as one of the most reputed Institutions in Goa Imparting Technical Education and Vocational Training to the trainees in different trades.

3.2 DATA SOURCES

Data was downloaded from USGS Earth Explorer for the years 1993 and 2023 for the Verna and Canacona industrial area The details of the satellite image are displayed in the table below:

Table 3.1: Details of Data Sources

Sensor	Characteristics	Path and Row	Date of Acquisition	Data Source
Landsat 4-5 TM C2 L1	Number of bands:7 Cloud cover:1.00	Path: 146 Row: 49	16th December 1993	United States Geological Survey
Landsat 4-5 TM C2 L1	Number of bands:7 Cloud cover: 0.00	Path: 146 Row: 49	30th November 1993	United States Geological Survey
Landsat 8-9 OLI/TIRS C2 L1	Number of bands:7 Cloud cover:0.00	Path: 146 Row: 49	27th December2023	United States Geological Survey
Landsat 8-9 OLI/TIRS C2 L1	Number of bands:7 Cloud cover: 0.00	Path: 146 Row: 49	27th December2023	United States Geological Survey

Along with these the Industrial maps were collected from regional development plans.

3.3 METHODOLOGY

The methodology used in this study is divided into various parts which are explained below in detail. The spatial technique is used in this study with ArcGIS Pro as the main tool and QGIS as the supporting tool. Spatial technique is very important as it provide precise and comprehensive changes data on land use land cover changes over time.

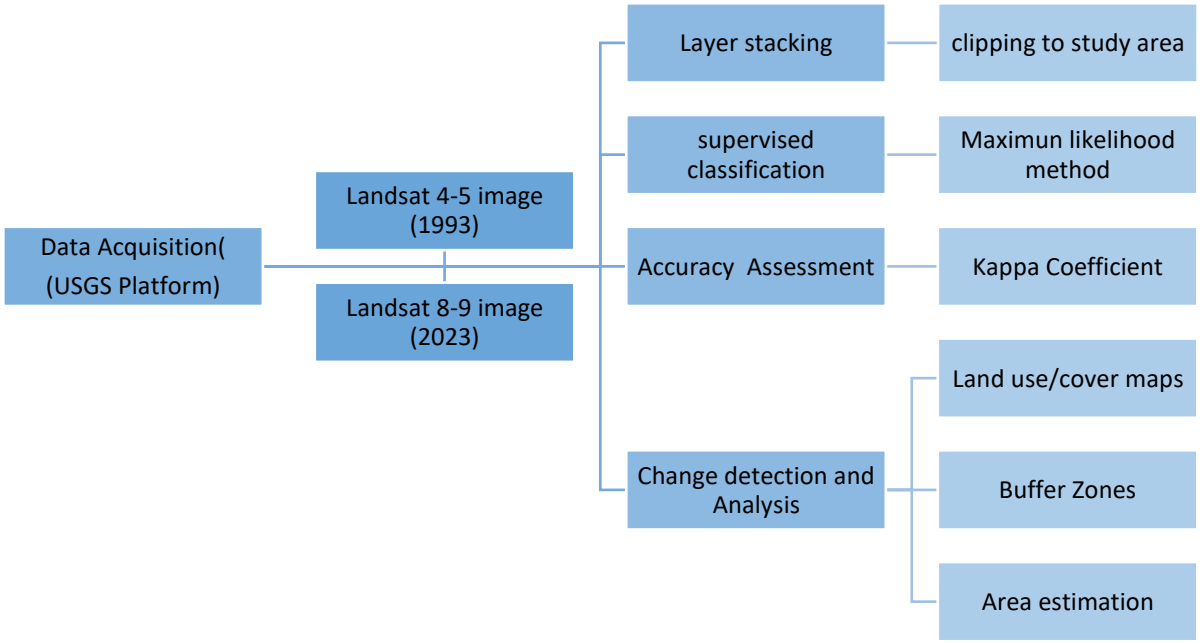


Fig 3.2: Flow chart of Methodology

Layer Stacking

The data is downloaded from USGS Earth Explorer and the shape file is downloaded from the census of India for the years 1993 and 2023 for the Verna and Canacona study area. The Shape is extracted using Qgis software and Goa Shapefile. Layer stacking is done in ArcGIS Pro also called band stacking, it is a tool in supervised classification to combine

multiple bands or layers into a single image. By stacking these bands the composite image enhances its features, making each feature distinguishable for classification. In this study false-color composite[1] combination is used to have a clear view of the image (4,3,2). The stack layer is clipped with the study shape file. Separate Shapefiles are created for Verna and Canacona Industrial Estate to mark the industries in the study area Using the create feature tool in the ArcGIS pro for this Georeferencing is done to get the accurate outcome.

Image classification

Image classification involves extracting information from the multiband raster image to get information about different classes. There are two main ways for Image classification one is supervised classification and the other is unsupervised classification. This study uses the supervised classification for the accuracy and reliability of the results[2]. This Supervised classification runs on various algorithms such as maximum likelihood, minimum distance, etc. In this study. Maximum likelihood classification will be used as it is a statistical decision criterion that helps classify overlapping signatures, with pixels reassigned to the class with the highest probability (Fabio Maselli 1, 2015). The various land use land cover classifications considered in this study include Tree cover, water bodies, agricultural land, built-up areas, and Barren land. The supervised image classification is done using ArcGIS Pro software[3]. Around 20 samples are taken for sample in each class cover and the maximum likelihood algorithm is used to get the classified image.

Accuracy Assessment

[1]https://gsp.humboldt.edu/olm/Courses/GSP_216/lessons/composites.html#:~:text=False%20color%20images%20are%20a,(i.e.%20near%2Dinfrared).

[2] https://link.springer.com/chapter/10.1007/978-3-662-02462-1_8#:~:text=Supervised%20classification%20is%20the%20procedure,ground%20cover%20types%2C%20or%20classes.

[3] https://www.youtube.com/watch?v=q-s9eCX-6-Y

Accuracy assessment in geo-spatial analysis is important to determine the quality of your classified data. It involves comparing your data to a reference data set or ground truth to determine the level of agreement and disagreement. In this study for conducting accuracy assessment, ArcGIS Pro is used for Accuracy Assessment[4]. There were around 100 sample points taken for accuracy assessment and a stratified random sampling strategy was used. In this study, the Kappa Coefficient test is used to assess the accuracy of the classification which presents the results about user accuracy, producer accuracy, and overall kappa test.

Change Detection

the change detection feature is used to compare two or more raster datasets to identify and visualize changes that have occurred between them. The tool can also quantify the changes, providing information on the extent and magnitude of the changes. The change detection for the Verna and Canacona Industrial Estate is done for the years 1993 to 2023 using ArcGIS Pro.

Buffer Zones

To detect the changes in the close vicinity of the industrial estate and to see the industrial expansion, buffer zones of 2km,3km, and 4km are used, the point for the buffer is the center point of the industrial estate.

Tabulate Area

The Calculated area feature provides us with information in a quantitative form of each land cover, the area for the entire study area is calculated along with each buffer excluding the area of the preceding buffer in ArcGIS Pro.

[4] https://www.youtube.com/watch?v=-x1ipu5-7L8

Analysis

The analysis is done using Change detection maps and LULC maps also the help of calculated area in meter squares by creating various graphs with available data and also by analyzing policy differences.

CHAPTER 4: RESEARCH ANALYSIS

4.1. SOCIO-ECONOMIC DATA

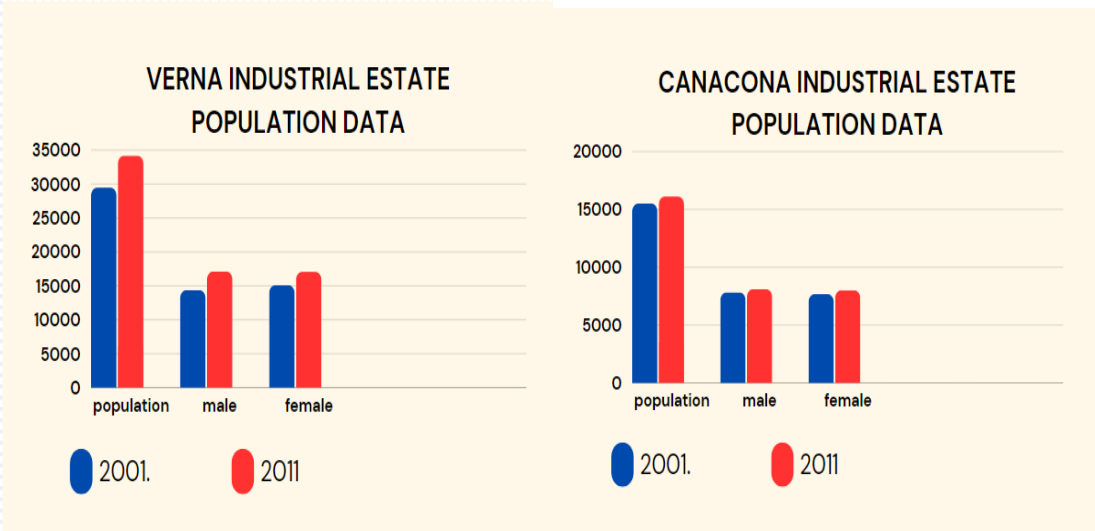


Fig 4.1: Verna Industrial Estate Population data Fig 4.2: Canacona Industrial area Population Data

The above graph shows the population data of the Verna industrial area and the Canacona industrial area. As per 2001 census data, the population of the Verna industrial area was 29482 wherein there were more females (15110) compared to males (14372) whereas the population of the study area increased to 34188 total population as per the 2011 census out of which 17118 are male and 17070 are females, this shows that there is an overall increase in the population but the number of females has declined to a marginal extent

For the Canacona Industrial area as per the 2001 census, the total population was 15510 out of which 7829 are male and 7681 are female, the number of males is more compared to females. As per the 2011 census, the total population is 16118 out of which 8109 are males and 8009 are females. Overall there is an increase in the population between 2001 and 2011

Household Report

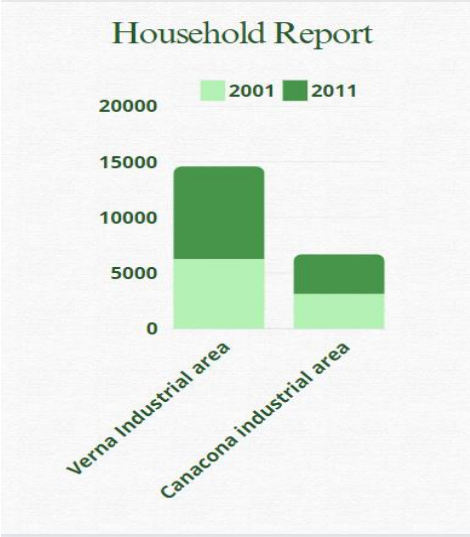
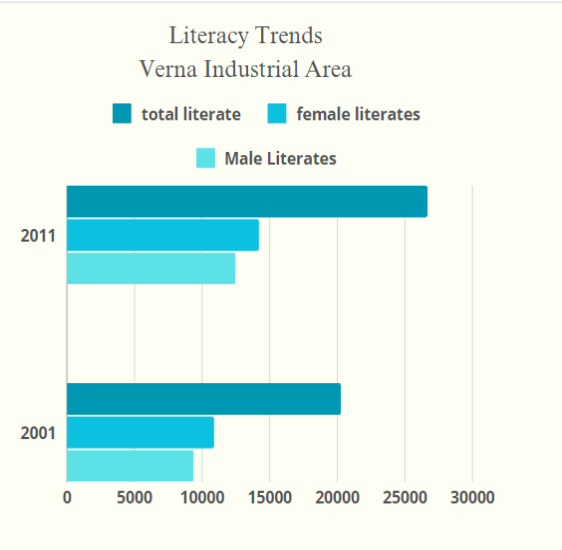


Fig 4.3: Household report of Verna and Canacona industrial area

The No of households has increased from 6258 to 8326 from 2001 to 2011 for the Verna industrial estate, while for the Canacona industrial estate, No households increased marginally from 3121 to 3571 from 2001 to 2011

Literacy Rates



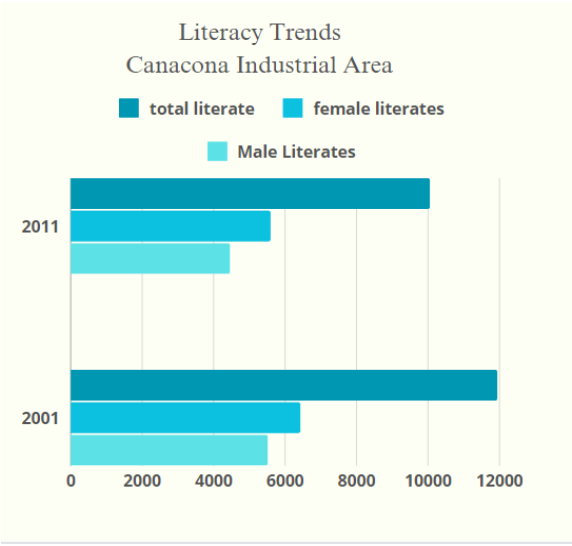


Fig 4.4: Literacy trend Verna industrial area Fig4.5: Literacy trend Canacona industrial area

The literacy rate in the Verna industrial area was 20273 population was literate out of 29482 population out of which 10886 were male literate and 9387 were female literate. As per the 2011 census, there was an increase in literacy wherein 26673 people were literate out of 34188 out of which 14202 were males and 12471 were females.

The literacy rate for the Canacona industrial area was 10058 population was literate out of 15510 population out of which 5595 were male literate and 4463 were female literate. As per the 2011 census, there was an increase in literacy wherein 11946 people were literate out of 16118 out of which 6427 were males and 5519 were females.

Industrial Estates Profile in Goa

At present, there are around 20 industrial estates in Goa Verna Corlim, Margao, Sancoale, Daman, Mapusa, Tivim, Bicholim, Kakoda, Honda, Bethora, Canacona, Kundaim, Diu, Tuem, Verna, Cuncolim, Pilerne, Marcaim, Pissurlem, and Colvale. The Government proposes to set up new industrial estates in Latambarcem (Bicholim), Carambolim (Tiswadi), Shiroda (Ponda), Sacordem (Dharbandora), and Poinguinim (Canacona). The Verna Industrial Estate houses around 532 units of industries over an area of 689.58 ha while the Canacona Industrial Estate houses only 63 units of industries over 14.10 ha of land. The First industrial unit setup in Goa was Zuari Agro Chemicals, Manufacturing chemicals fertilizers. Presently Goa has over 700 small-scale industrial units as well as 150 large and medium-scale industries employing over 55000 people.

4.2 LAND USE LAND COVER MAP

LULC Map is a thematic map that represents different categories of land use and land cover classes in a particular study region. The different classes mentioned in this study are tree cover, built-up, barren land, water bodies, agricultural land, and coastal areas. This thematic map is created using satellite imagery collected from remote sensing data. Different color codes and unique labels or codes are used to differentiate between classes.

4.2.1 LULC of Verna Industrial Area

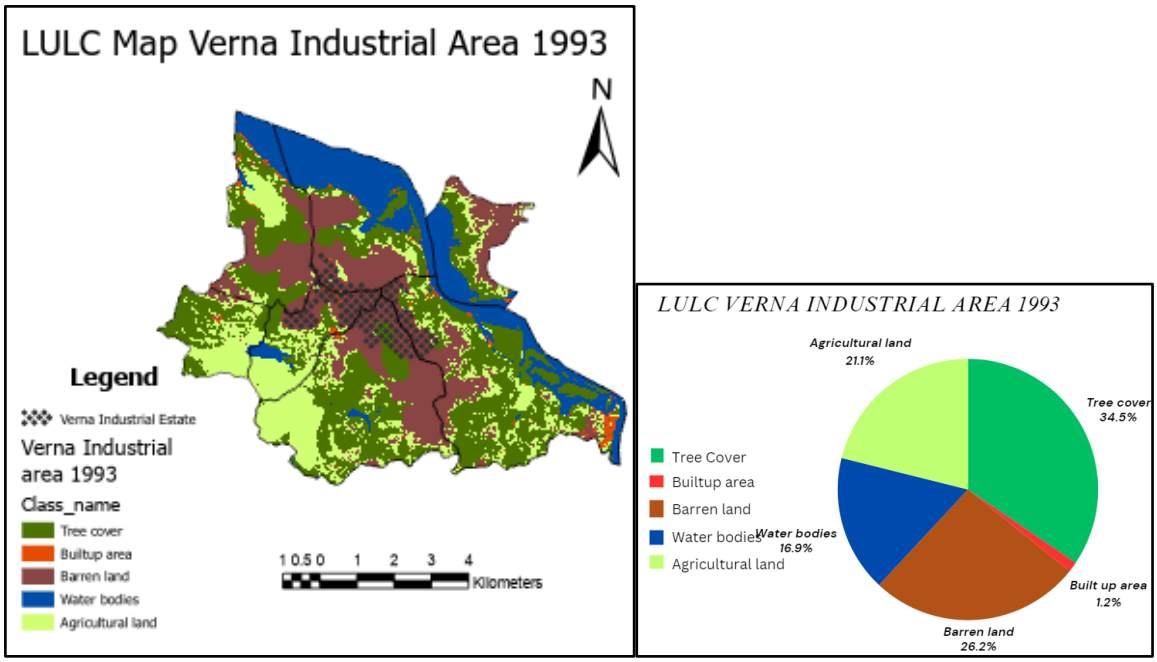


Fig 4.6: LULC Map & Pie Chart of Verna Industrial Area 1993

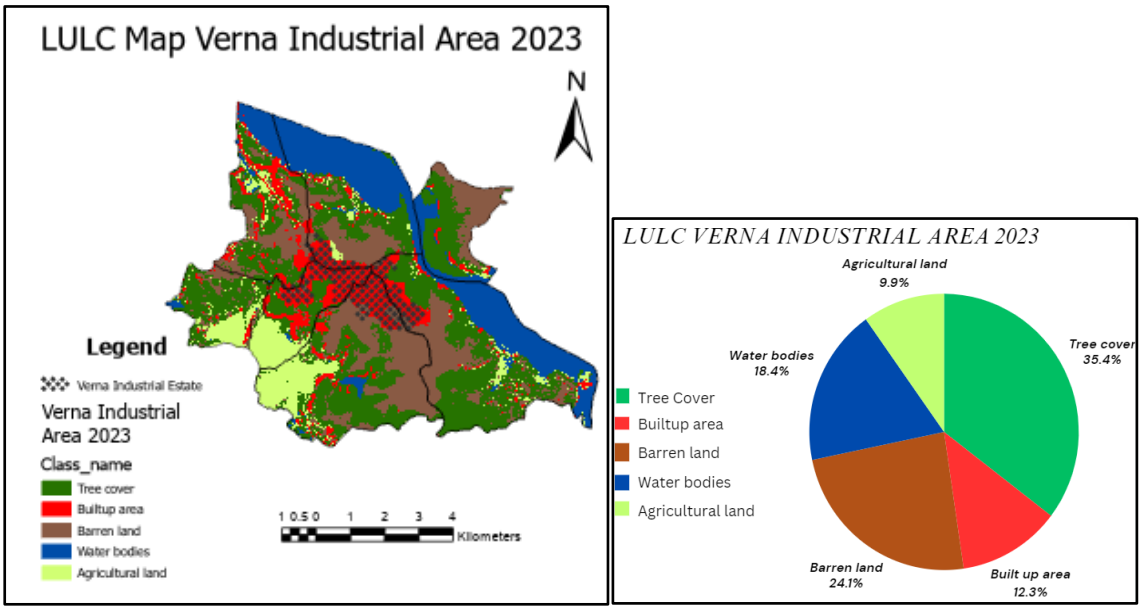


Fig 4.7:LULC Map & Pie Chart Of Verna Industrial Area 2023

Table 4.1: Area in m2 of Verna Industrial Area 1993 and 2023				
Classes	1993 area m2	Percent	2023area m2	Percent
Tree cover	23563800	34.49084	24174900	35.38532
Built up area	846900	1.239626	8390700	12.28165
Barren land	17919900	26.22975	16449300	24.0772
Water bodies	11560500	16.92135	12571200	18.40074
Agricultural land	14427900	21.11843	6732900	9.855092

The above LULC images depict the changes in the Verna industrial area for 30 years from 1993 to 2023. Table 1 shows the area of classes in square meters and percentages. There are 5 classes Tree cover, built-up, Barren land, water bodies, and agricultural land. The LULC in the Verna Industrial area has transformed from 1993 to 2023. The Tree cover has the largest share in the verna industrial area holding its rank till 2023. The significant change observed is an increase in the built-up from 1.24% in 1993 to 12.28% in 2023. There is a decline in the barren land from 26.2% in 1993 to 24.1% in 2023. This increase is mainly due to industrial expansion supported by various industrial policies along with the Mormugoa Port established in 1888, 21.1 km away from the site, and the Dabolim airport in the neighboring villages along with an increase in the population of the area as per census. There is around a 2% increase in Water bodies from 16.9% in 1993 to 18.4% in 2023. This is attributed to the increase in fish hatchery at the riverbanks (Sayed, 2023). The most significant decline is in agricultural land from 21.1% in 1993 to 9.9% in 2023, which can be attributed to a shift in job structure due to industrial setup. and In this issue of decline in Agriculture Manoj Kamat expert in economics said that the state should be the preferred investment destination as agriculture declines year by year.

4.2.2 LULC OF CANACONA INDUSTRIAL AREA

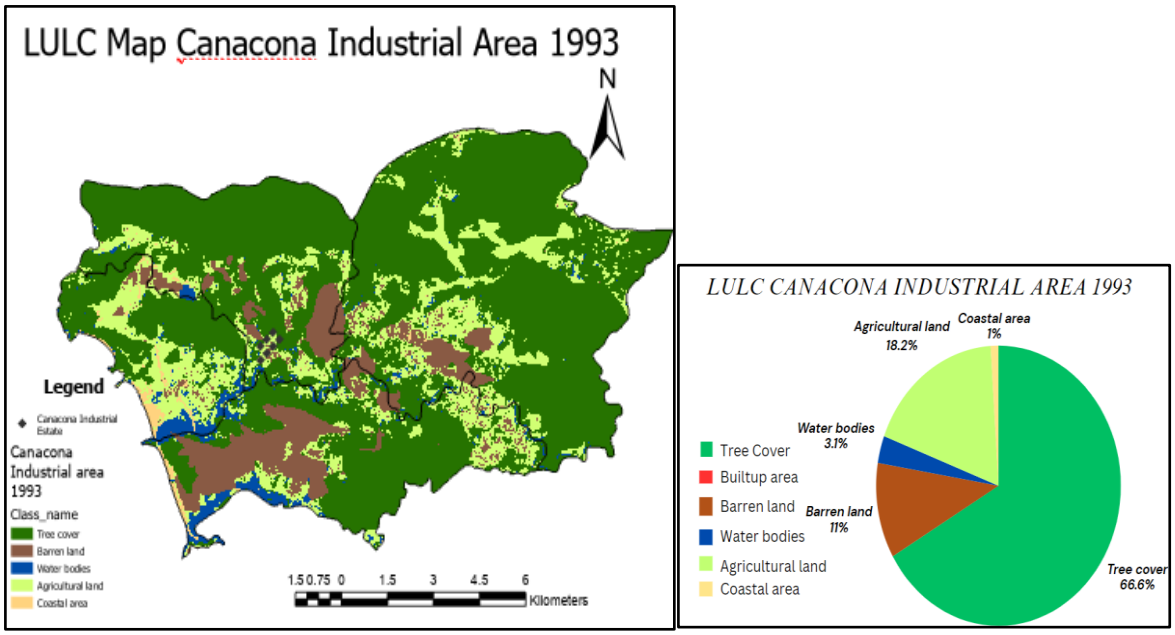


Fig 4 .8: LULC Map & Pie chart of Canacona Industrial Area 1993

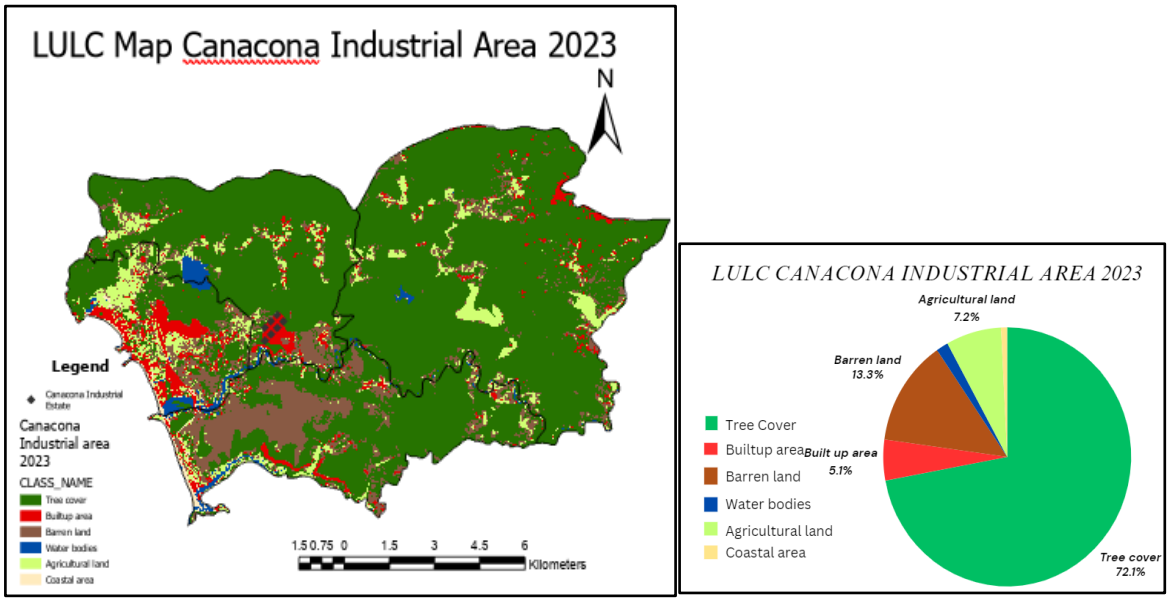


Fig 4.9: LULC Map & Pie chart of Canacona Industrial Area 2023

Table 4.2: Area of LULC Of Canacona Industrial Estate				
Classes	1993 area m2	Percent	2023 area m2	Percent
Tree cover	105493500	66.607	113972310	72.06957
Builtup			8047767.9	5.088948
Barren land	17437500	11.00977	20980270	13.26672
Water bodies	4983300	3.14638	2470307.3	1.562081
Agricultural land	28834200	18.20548	11410238	7.215182
Coastal areas	1633500	1.031367	1261167	0.79749

The above LULC images depict the changes in the Canacona industrial area for 30 years from 1993 to 2023. Table 4 shows the area of classes in square meters and percentages. There are 6 classes Tree cover, built-up, Barren land, water bodies and agricultural land, coastal area. The land use and land cover (LULC) near the Canacona industrial estate have undergone significant changes from 1993 to 2023. Tree cover increased from 66.6% in 1993 to 72% in 2023. This is due to the Goa Govt has decision to constitute an area of 82.75 hectares in Gaondongorim of Canacona Taluka as a reserve forest the proposal is under the Indian Forest Act 1927 to prevent land from any further development(“Canacona to Get Reserve Forest.,” 2010) also due to Neighbouring Wildlife Sanctuary was established in 1968 is declared as protected forest to provide with complete protection to the fauna & flora to conserve the unique biodiversity of the State (Forest Department, n.d.).It's one of the 4 talukas of Goa having a total forest cover of the state of around 185.81 sq km(Fernandes, 2016). There was no evidence of Built-up area in 1993 as it was undetectable during supervised classification as the roofs top of houses in the village of Canacona were made of leaves in older times and they were unrecognizable due to thick dense forest But in 2023 the built-up area increased to 6.% this can

be associated to human settlements as the population has increased in that area as the population census data. Barren land also experienced a marginal increase, from 11% in 1993 to 13.26% in 2023. This could be attributed to natural processes or abandoned agricultural land turned into barren land. Water bodies saw a significant decline, from 3.14% in 1993 to 1.56% in 2023. According to the locals interviewed by Times of India Journalists said that the ponds are drying and creepers and natural vegetation grow in them, also most of the water bodies were next to the fields which are now being abandoned and also drying up leading to a decline in the water bodies. and the water bodies are unutilized. (Fernandees, 2022)Agricultural land decreased drastically from 18 % in 1993 to 7.21% in 2023 this is attributed to poor subsidies, low income from the agricultural sector the use of old methods for cultivation, etc (Times, 2015). Coastal areas also declined from 1.03% in 1993 to 0.75% in 2023 this can be attributed to an increase in tourism activities in the coastal belt (costa, 2021) .

4.2.3 ACCURACY ASSESSMENT

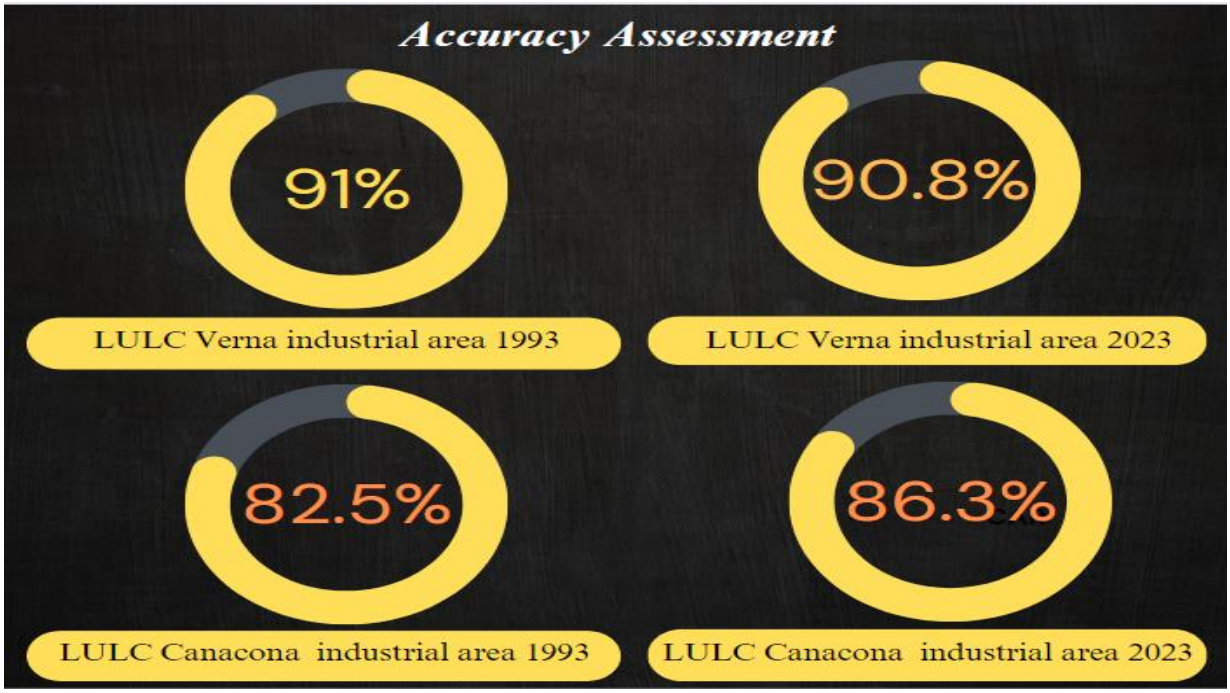


Fig4.10: Report Profile of Accuracy Assessment

The Kappa Coefficient test is used for accuracy assessment purposes, kappa coefficient is a form of statistical test used to test the accuracy of an image classification model. It measures inter-raster agreement for categorical items. How well the classification has performed as compared to just randomly assigning values. The kappa coefficient ranges from -1 to 1, where 1 indicates perfect agreement, and 0 means agreement similar by chance. (Cohens kappa, n.d.)

For the 1993 LULC supervised classification image for Verna Industrial Area. The Kappa Coefficient is 0.91(91%) showing a high level of agreement between the predicted classes beyond what would be expected by chance and actual class. In this case, the model performed well in predicting the class. For the 2023 LULC supervised classification image for Verna Industrial Area. The Kappa Coefficient is 0.908(90.8%) showing a high level of agreement between the predicted classes beyond what would be expected by chance and actual class. In this case, the model performed well in predicting the class. For the 1993 LULC supervised classification image for the Canacona Industrial Area. The Kappa Coefficient is 0.825(82.5%)

showing a high level of agreement between the predicted classes beyond what would be expected by chance and actual class. In this case, the model performed well in predicting the class. For the 1993 LULC supervised classification image for the Canacona Industrial Area. The Kappa Coefficient is 0.863(86.3%) showing a high level of agreement between the predicted classes beyond what would be expected by chance and actual class. In this case, the model performed well in predicting the class.

4.3 CHANGE DETECTION OF VERNA AND CANACONA

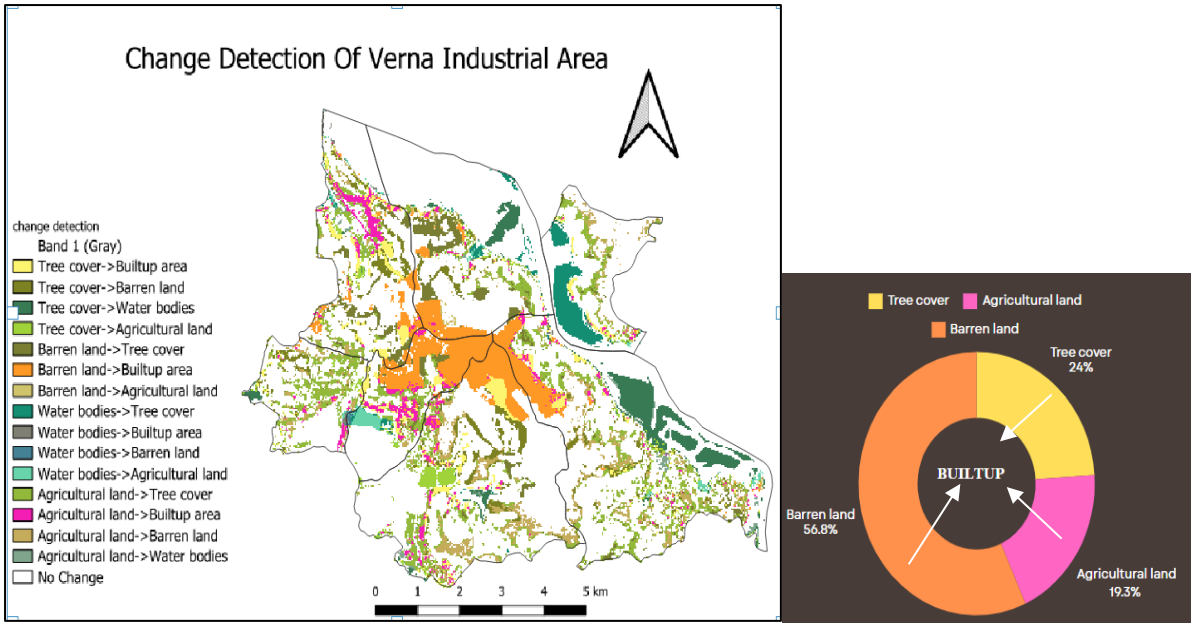


Fig 4.11: Change detection of Verna Industrial Area 1993 to 2023

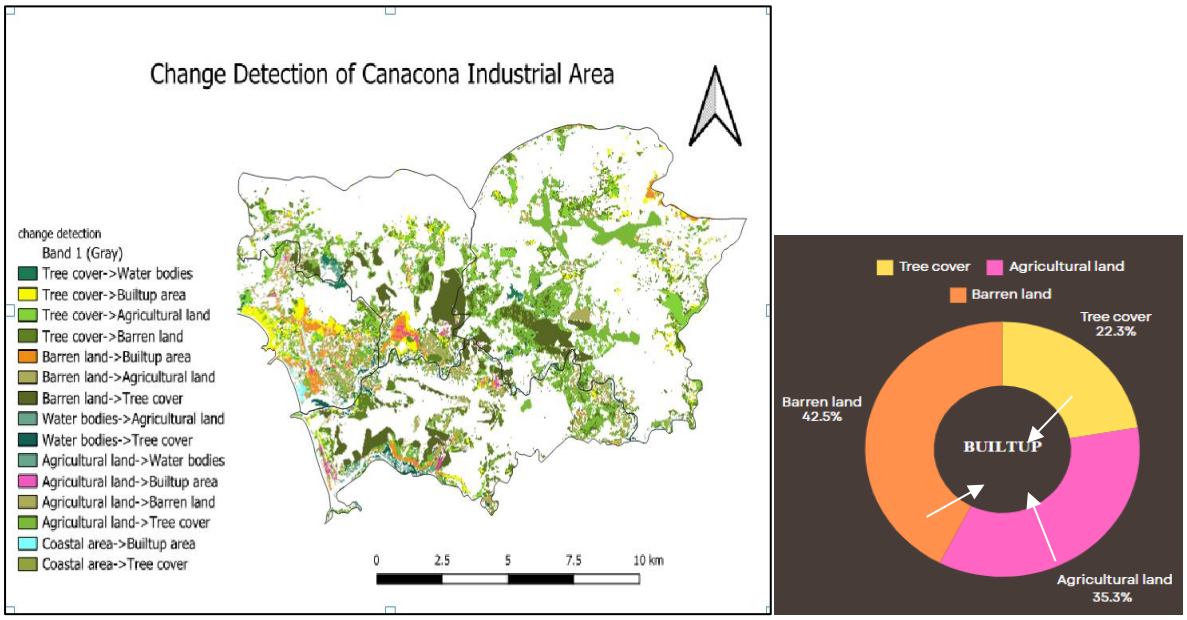


Fig 4.12: Change detection of Verna Industrial Area 1993 to 2023

The above images provide us with the change detection scenario for Verna and Canacona Industrial estates from 1993 and 2023. First, let's examine the Change detection scenario of the Verna Industrial estate from 1993 to 2023 followed by the Canacona Industrial area.

In the Verna industrial area, the tree cover has been converted to a built-up area of around 130500m2, this shits is due to an increase in population demanding more infrastructure development, and expansion of economic activities, also natural vegetation is replaced by human structure. Tree cover is also being converted to Barren land to an amount of 1927800m2. The change detection image also shows the conversion of tree cover to water bodies this change is detected at the edge of the river this is possibly due increase in the fish hatchery in the village of Loutolim. Also Tree cover has shifted to agricultural land over the years.

The change of barren land to build up is very significant to 4569300 m². This shows the expansion of industrial areas and Human settlement, into previously unused land. Also, there is a considerable decline in barren land to agricultural land which provides the potential expansion of agricultural land to previously non-cultivable land of around 145800 m². There is also the conversion of Barren land into natural vegetation.

Water bodies are also shifted to other land cover such as tree cover of around 1197000 m². This is attributed to the riparian bushes found at the bank of the river to support the unique ecosystem. There are minimum changes of water bodies to built-up areas these are the local boat docks used by the local fishermen. The shift of water bodies to barren land is due to the railway track crossing in the middle of the agricultural field which had water bodies in the surrounding area. The transformation of water bodies to agricultural land occurred in the vicinity of lakes, where fields are cultivated. This shows that the agricultural land is encroaching on lakeshores leading to the conversion of water bodies to agriculture.

Agricultural land has transformed into a built-up area of totaling area 1548900m2. Also, the tree cover has been grown as a natural ecosystem process of around 4768200 m2. There is the change of agriculture to barren land as people have left land uncultivated for many years, also the conversion of agriculture to water bodies depends on the interplay between crops and water bodies such as lakes, and ponds.

Overall the increase in built-up area, to a large extent contributed to the transformation from Barren land of 4569300 m2 followed by Tree cover wherein an area of 1927800 m2 is converted to built-up area lastly built-up is grown at the expense of agricultural land of 1548900.

Whereas in the Canacona industrial area, as observed from figure 4.37, the tree has been converted to barren land to the extent of 8377270 m 2 and also transformed to agricultural land 4980116.41m2 land converted for agricultural purposes, In addition, the tree cover is converted to built-up of around 3677520.67m2 due to human settlement, expansion of economic activities, infrastructure development. Tree cover has also been converted to water bodies 549171.69 m2 showing this change at the bank of rivers.

The Barren land has also transformed, the highest conversion of barren land is to tree cover of 9061326.15m2 along with conversions to built-up areas of around 520267.53m2, agricultural land totaling to 1168675.03m2. These indicate changes due to the interplay between humans and the environment. Water bodies show show conversion to some extent especially to agricultural land of around 691763.123m2. and due to algae, the water is shown to be converted to tree cover in an area of around 1583925.59m2.

Agricultural land shows conversion to the barren land of the area around 5331778m2, they are also being converted to tree cover to a large extent of 15613806.7m2. Agricultural land has also been converted to a built-up area by 3052236.18m2. The coastal area was also

converted to a built-up area of around 347808.478 m2, and a tree cover of 159934.093 m2. This conversion shows changes in coastal ecosystems over the years.

Overall the built-up area has been increased due to its conversion largely from the tree cover by 3677520.67 m followed by agricultural land of area 3052236.18m2. And lastly from barren land and coastal areas to a marginal extent. Also from barren land 520267.53m²

4. BUFFER ZONES

4.4.1 Buffer Zone Analysis of Verna Industrial Area

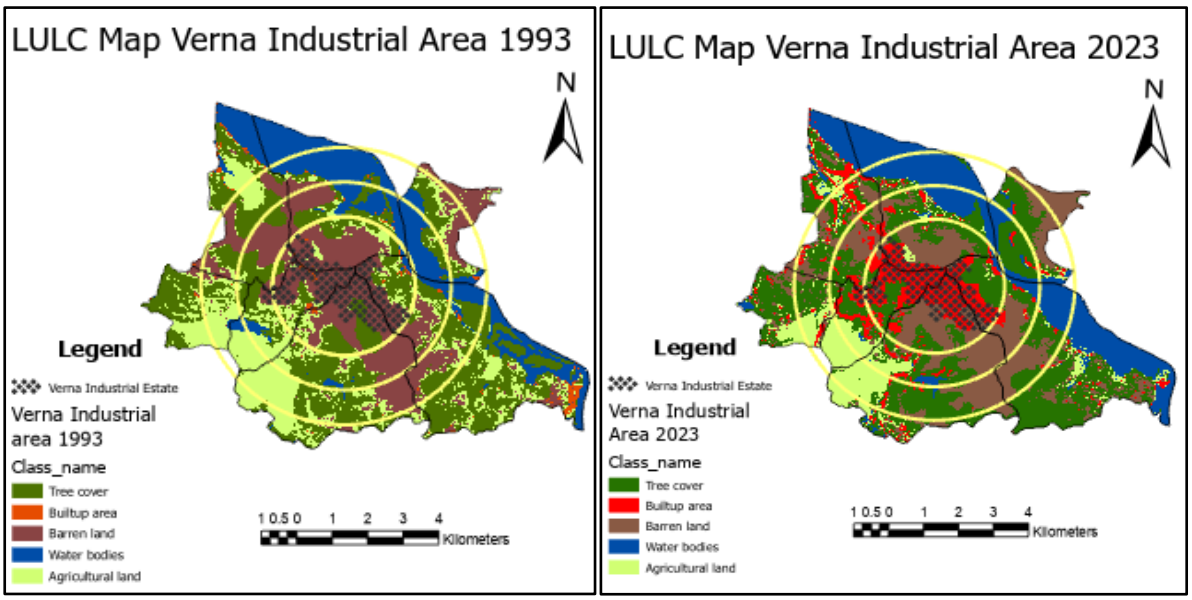


Fig 4.13: Buffer zone of LULC Verna Industrial Area 1993 and 2023

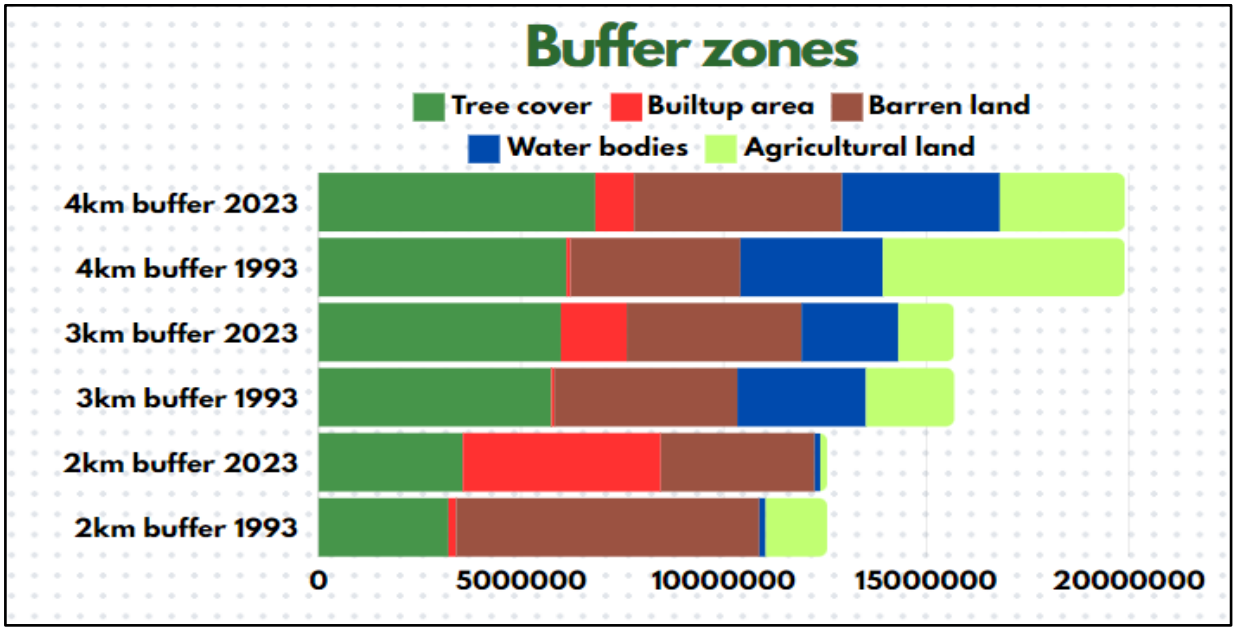


Fig 4.14: Bar graph representing Buffer Zones Of LULC Verna Industrial Area 1993 &2023

Table 4. 3: Area in m2 Buffer Zones in Verna Industrial area 1993 and 2023						
classes	2km 1993	2km 2023	3km 1993	3km 2023	4km1993	4km 2023
Tree cover	3204000	3558600	5745600	5980500	6116400	6831000
Buitup area	189000	4885200	72000	1624500	101700	951300
Barren land	7487100	3798000	4518900	4315500	4194900	5138100
Water Bodies	155700	139500	3172500	2386800	3512700	3893400
Agricultural land	1515600	170100	2178900	1380600	5974200	3086100

Analyses through buffer zones, to detect the changes in land use land cover pattern as the distance increases from the industrial area and the expansion of industrial estate that have taken place at the expansion of other land cover classes. To create the buffer, the center of the industrial estate is marked as the point for the buffer. The above LULC images depict the changes in the Verna industrial area for 30 years from 1993 to 2023 in terms of buffer zones of 2km, 3km, and 4km buffer. The table shows the area of classes in square meters and percentages. There are 5 classes Tree cover, built-up, Barren land, water bodies, and agricultural land. The area marked with a black square is the Verna Industrial Estate.

In the 2km buffer zone for the Verna Industrial area, the most significant increase is in the built-up area in terms of expansion of the Verna industrial estate from 189,000 m² in 1993 to 4,885,200 m² in 2023, showing a growth of 4,696,200 m². This is the most significant increase in built-up among all the buffers. This growth of Verna industrial estate is at the expense of barren land which has declined from 7,487,100 m² in 1993 to 3,798,000 m² in 2023, showing a decline of 3,689,100 m². Also, there is a decline in the agricultural land from 1,515,600 m² in 1993 to 170,100 m² in 2023, showing a significant reduction of 1,345,500 m². The water bodies have declined in a 2km buffer from 155,700 m² in 1993 to 139,500 m² in 2023, showing a decrease of 16,200 m². However, the expansion of industry does not impact

the tree cover much as the area of tree cover is holding the same rank in 2023 as it was in 2023 with a marginal increase.

Similarly, in the 3km buffer zone, the results indicate an increase in the built-up area in terms of further expansion of industrial estate and another built-up area such as infrastructure development, houses, etc that is area accounting from 72,000m2 in 1993 to 1624500m2 in 2023 showing an increase of 1552500m2. This increase in the built-up area is due to the conversion of barren land cover from 4518900 m2 in 1993 to 2315500 m2 in 2023 showing a reduction of 203,400 m2. The agricultural land is also affected by the expansion of the built-up and industrial estate wherein it showed a decline from 2,178,900 m² in 1993 to 1,380,600 m² in 2023, indicating a decrease of 798,300 m2. The water bodies also indicated a slight decline in the 3km buffer from 3,172,500 m² in 1993 to 2,386,800 m² in 2023, showing a decrease of 785,700 m². But the Tree cover has been unaffected indicating a rise from 5,745,600 m² in 1993 to 5,980,500 m² in 2023, representing an increase of 234,900 m².

In the 4km buffer zone, there is an increase in the built-up area from 101,700 m² in 1993 to 951,300 m² in 2023, indicating a growth of 849,600m2. This increase in the buildup is other infrastructure other than industrial areas. In the case of the barren land it increased in the 4km buffer from 4,194,900 m² in 1993 to 5,138,100 m² in 2023 showing a growth of 943,800 m².The 4km buffer, covers the river Zuari which indicates an increase in water bodies from 3,512,700 m² in 1993 to 3,893,400 m² in 2023, indicating an increase of 619,300 m². The agricultural land declines in 4km from5,974,200 m² in 1993 to 3,086,100 m² in 2023, showing a decrease of 2,888,100 m².Indicating this decline as one of the highest in terms of buffer. The tree cover is said to expand from 6,116,400 m² in 1993 to 6,831,000 m² in 2023, showing an increase of 714,600 m². This is indicated as the highest increase in tree cover as compared to other buffers possibly because it covers the area at the bank of river .

4.4.2 Buffer Zone Analysis of Canacona Industrial Area

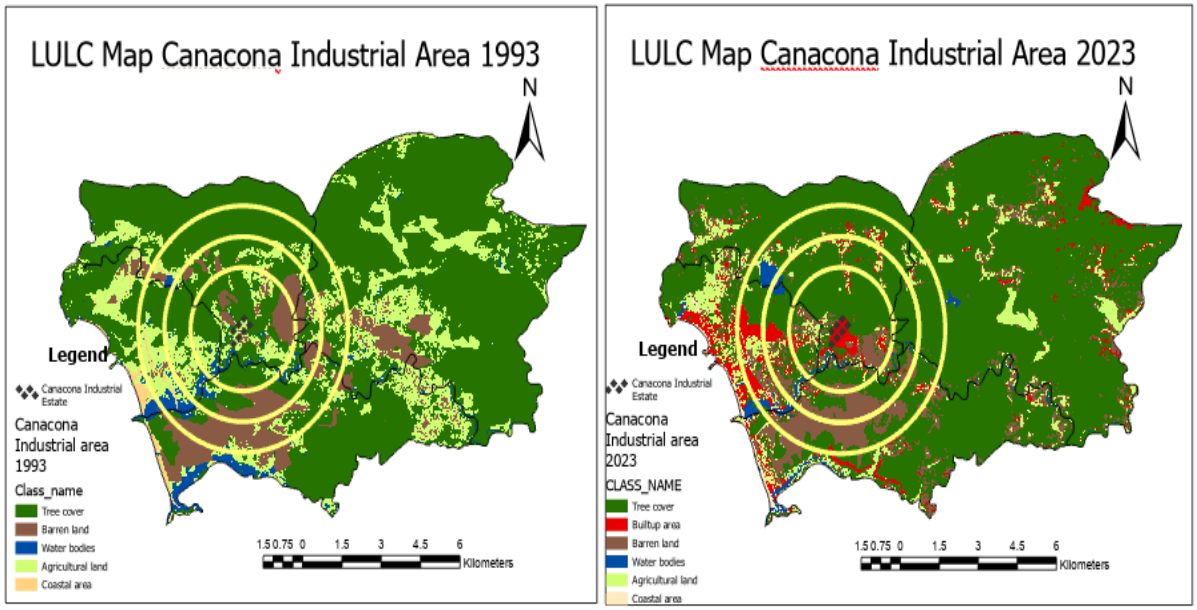


Fig 4.15: Buffer Zones for LULC Canacona Industrial Area 1993 &2023

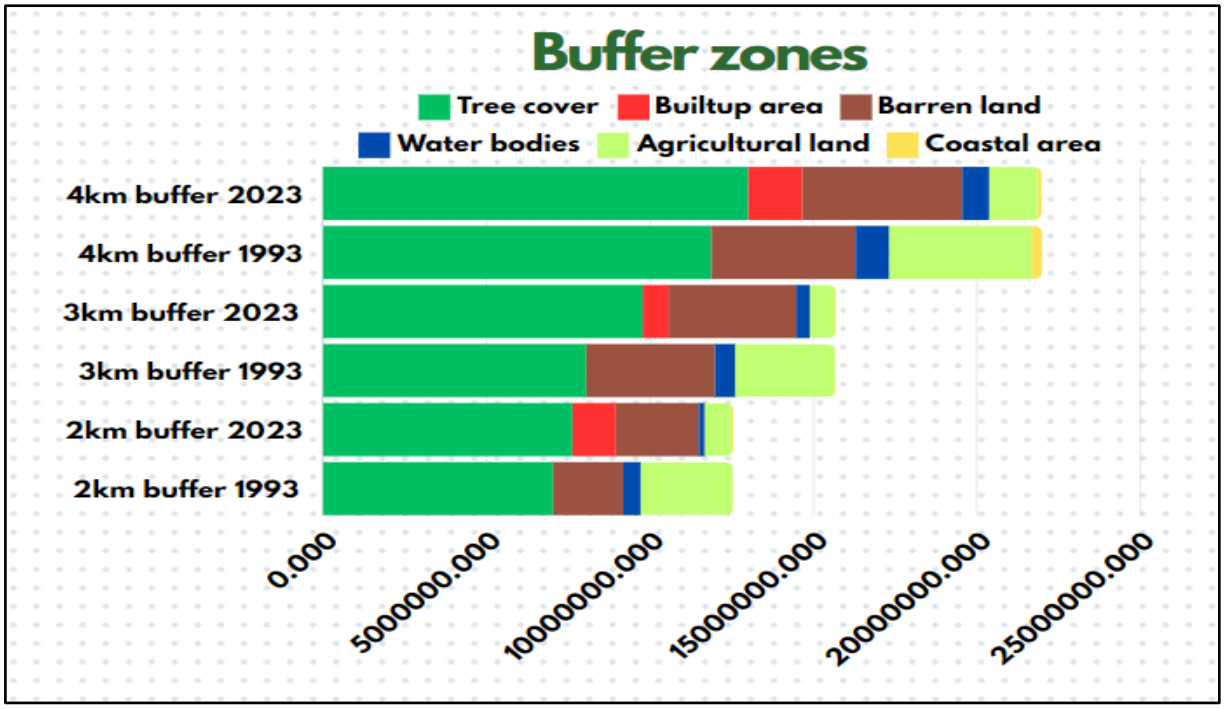


Fig 4.16: Bar graph representing Buffer Zones Of LULC Canacona Industrial Area 1993 &2023

Table 4.4: Area in m2 of Buffer Zones of Canacona Industrial Area						
	2km 1993	2km2023	3km 1993	3km 2023	4km 1993	4km 2023
Tree cover	7037100	7627700	8050500	9775249	11871000	13000907
Builtup		1332463		799670.5		1655222
barren land	2147400	2535822	3940200	3898153	4419000	4889551
Water bodies	529200	179203.3	623700	414287.1	1030500	830501.1
agricultural land	2803500	810268.5	3041100	764986	4350600	1477945
coastal areas	34200	62624.8	26100	41428.71	329400	126213

Analyses through the buffer zones, to detect the changes in land use land cover patterns as the distance increases from the industrial area and the expansion of industrial estate that has taken place at the expansion of other land cover classes. To create the buffer, the center of the industrial estate is marked as the point for the buffer. The area marked in black square is the Canacona industrial area

In the 2km buffer zone for the Canacona Industrial area, for the year 1993, there was no trace of the built-up area but as of 2023, the results show built up of 1,332,462.952 m² this is due to Canacona industrial expansion. This industrial expansion has taken place at the expense of Agricultural land which showed a decline from 2,803,500 m² in 1993 to 810,268.505 m² in 2023, showing a reduction of 1,993,231.495 m². Water bodies have decreased from 529,200 m² in 1993 to 179,203.2603 m² in 2023, showing a decline of 349,996.7397 m. Whereas the tree cover showed an increase from 7,037,100 m² in 1993 to 7,627,700.065 m² in 2023, showing a growth of 590,600.065 m².Not being affected The barren land also showed an increase in 2km buffer 2,147,400 m² in 1993 to 2,535,822.48 m² in 2023, showing an increase of 388,422.48 m². The coastal areas increased from 34,200 m² in 1993 to 62,624.79528 m² in 2023, showing an increase of 28,424.79528 m².

In the 3km buffer zones, the built-up area further increased to 799,670.4628 m² in 2023 this is due expansion of infrastructure such as houses, roads, etc other than the industrial estate.

while in the 3km buffer zone, barren land decreased from 3,940,200 m² in 1993 to 3,898,152.641 m² in 2023, showing a decrease of 42,047.359 m². This decline in barren land is associated with an increase in the built-up area. The agricultural land further declined from 3,041,100 m² in 1993 to 764,985.9608 m² in 2023, showing a decrease of 2,276,114.0392 m². As it shifts to built-up areas and barren land. Water bodies also saw a decline from 623,700 m² in 1993 to 414,287.1072 m² in 2023, showing a decrease of 209,412.8928 m². tree cover increased from 8,050,500 m² in 1993 to 9,775,248.814 m² in 2023, showing an increase of 1,724,748.814 m². The coastal area increased 26,100 m² in 1993 to 41,428.71072 m² in 2023, showing a growth of 15,328.71072 m².

In the 4km buffer, the built-up area has increased to 532,792.4892 m2 this expansion of built-up is more inclined towards the coastal zones indicating the presence of economic activity about tourism activity. , barren land showed a significant growth from 4,419,000 m² in 1993 to 4,889,551.324 m² in 2023, showing an increase of 470,551.324 m². and Water bodies declined from 1,030,500 m² in 1993 to 830,501.1312 m² in 2023, showing a decrease of 199,998.8688 m². Agricultural land showed a decline from 4,350,600 m² in 1993 to 1,477,945.169 m² in 2023, showing the largest decrease of 2,872,654.831 m² among all the zones. In the 4km buffer zone, tree cover increased from 11,871,000 m² in 1993 to 13,000,907.5 m² in 2023, showing an increase of 1,129,907.5 m² This increase is highest among all the zones as it is further away from the industrial estate. coastal areas declined from 329,400 m² in 1993 to 126,213.0489 m² in 2023, showing a decrease of 203,186.9511 m².

Overall the tree cover has been increased among all the buffer zones. No data is available for the 2km, 3km, and 4km buffer zones for 1993. Barren land has increased in all zones except the 3km zone. For water, bodies decline in all zones The largest decrease in water bodies is in the 2km zone. The agricultural area declined in all the zones.

5. COMPARISON OF LULC BETWEEN SMALL AND LARGE INDUSTRIAL AREA

The changes in LULC pattern between the small industries are contrasting to each other although the industries expansion at both the industrial area took place at the expense of Tree cover, Barren land, and Agricultural land. There are contrasting LULC patterns between Verna and Canacona industrial areas, with Canacona exhibiting more extensive tree cover and potentially better environmental quality as the Goa Govt has decided to constitute an area of 82.75 hectares in Gaondongorim of Canacona taluka as a reserve forest the proposal is under Indian forest act 1927 to prevent land from any further development("Canacona to Get Reserve Forest.," 2010) also, Neighbouring Wildlife Sanctuary was established in 1968 and is declared a protected forest to provide complete protection to the fauna & flora to conserve the unique biodiversity of the State (Forest Department, n.d.). It's one of the 4 talukas of Goa having a total forest cover of the state of around 185.81 sq km(Fernandes, 2016)

The Builtup area especially with regards to industrial expansion through LULC changes is larger in Verna industrial areas compared to Canacona industrial areas This is because the industrial policies formulated in state the initial policy focused on industrial expansion as a means for economic growth by setting up various industrial estates in various parts of the state to achieve balanced industrial growth. But later industrial policies such as industrial policy 2014 and the latest one in 2022 focus on further expansion of industrial estates without revival of the poor infrastructure of the existing ones. The same case is of the Canacona industrial estate, around 40 entrepreneurs working there raised issues regarding poor infrastructure facilities at the 18th GIDC Connect program but they are focusing on setting up a new industrial estate in the neighboring village without addressing the problems of the existing ones ("Resolve Issues at Canacona Industrial Estate.'," 2023). At the same time times, Verna Industrial Estate has the largest investment made by the Government. The State government has proposed setting up MSME Incubation Park in Verna Industrial Estate as the Goa Industrial Development

Corporation (GIDC) has partnered with Invest India(“MSME Incubation Park Proposed at Verna IDC.,” 2023). Under the PM Ghati Shakti Schemes 19 cr are allocated to Verna Industrial Estate to develop in 4 phases(“Goa to Develop Verna Ind Estate with Rs 19cr under PM Gati Shakti.,” 2023)

The Agricultural land has declined near both the industrial estate, In Canacona Industrial area low income, stress, and no security jobs have made the poor farmers abandon their green fields where others take advantage of uncultivable land for dumping mud and the issue of decline in Agriculture Manoj Kamat experts in economics said that the state should be preferred investment destination as agriculture decline by year by year.

The Barren land cover has declined near the Verna industrial area as the expansion of industrial activity has typically taken place at the expense of barren, Whereas the barren land in Canacona has Increased over the years. Similarly, there is a decline in water bodies in the Canacona industrial area whereas there is an increase in water bodies near Verna industrial estate.

Overall, the change in the LULC through industrial expansion is affected by Industrial policy which plays a significant role in industrial growth having an impact on LULC patterns.

6. POLICIES FOR INDUSTRIAL DEVELOPMENT IN GOA

Industrial Policy 1991

Industrial Policy 1991 was of great importance not only in Goa but in India as well as it aimed to liberate the country from the licensing system and to foreign investment in developing industries. , to achieve long-term productivity growth along with improving employment opportunities along with focusing on the worker class with providing them with advanced technological equipment The state focused on the establishment of industries in the backward regions through various measures with proper infrastructure, institutions, and incentives investments. Overall the Industrial policy was aimed at modernizing and liberalizing the Indian economy, promoting industrial growth, and integrating India into the global economy.

After the implementation of the policy, the government invested 480 cr worth of exported-oriented units to create skilled labor and increase job opportunities, and at the same time, 864 cr of foreign investment was secured by the state. Around 18 industrial units were set up all over the state in various takula to ensure the balanced growth of the state. to link the industrial estate to highways invested of rs 4.5 crore was done by the center. The state had fixed investment of 2235 crore and 6157 small-scale industries at the end of 2001 as per the finance department report (Prabhugoakar, 2002).

Goa Industrial Policy 2003

Goa Industrial Policy 2003 focused on creating employment opportunities for the people of the state along with overall economic growth of the state through accelerated industrial development. The means to achieve this was providing industry access to high-quality infrastructure, extending institutional support, technology upgradation, deregulating the business environment for an efficient, transparent, and proactive administrative framework, and catalyzing the creative as well as environmental capabilities of the human resources and providing market support as stated in the policy document.

There were various objectives provided by this policy but these were concerned with the setting of industrial estates. The state ensured eco-friendliness and less wasteful intake of resources should be promoted along with focusing on issues such as regional economic and social disparities in the state. It provided various schemes to improve and rehabilitate the sick industrial units**.**(*GOVERNMENT OF GOA Department of Industries, Trade & Commerce Notification 1/49/2000/S(IND)/Vol. II INDUSTRIAL POLICY OF GOA 2003*, 2003)

In a statement made by State Chief Minister Manohar Parrikar about Goa Industrial Policy 2003, He told **ET** that the government is focusing on creating more employment generation, administration sensitive to the needs of the industry, encouraging self-employment among the women, also providing power and water subsidies to the sick units improvement. The main focus on to have balanced industrial growth. The state government was also armed with a Rs. 5 crore allocation from the center under Integrated Rural Development to undertake infrastructure improvement in backward regions of industrial estates and use the funds to support various traditional industries in rural areas. It has also given incentives to the industry consuming local raw materials and also a preferential purchase scheme for ssi in govt purchases. The most important thing is that the government accepted the suggestion of not increasing the industrial units to more than 30 before developing the infrastructure of the existing industry (Kamat P, 2003).

Goa Investment Policy 2014

The policy aims at creating over 50,000 job opportunities, through the 25000 crores by making new investments for high-quality power supply, high-quality infrastructure, and logistics infrastructure to the industries. Various Investment Promotion Board will be given roles and responsibilities The most important is making land available for industrial development through innovative and socially acceptable mechanisms.

The government proposes to establish new ne industrial estates in Latambarcem(Bicholim), Carambolim(Tiswadi), Shiroda(Ponda), Sacordem(Dharbandora), and Poinguinim(Canacona) and expand 8 the existing ones in taluka of Salcete, Mormugao, Canacona, Pernem, Bardez, Tiswadi,ponda and Bicholim. So Under this process, the Government was trying to acquire land for the new industrial estates.

Goa IDC was given the entire responsibility as an infrastructure provider for newer industrial estates which include power, water, data connection, effluent treatment solid waste plant, etc. At the same time, The IDC is trying to set up utilities to be augmented, operated, and maintained by a separate entity for larger industries such as the Verna industrial estate. A Verna Power Distribution Company Ltd. is being considered for power distribution in Verna Industrial Estate

The Industrial Policy 2014 makes a statement regarding Goa being a small state that has limited availability of land. So it ensures that optimal allocation of land for industrial purposes is done So it provides certain regulations for land allocation and transfer of plots for industrial purposes. The important regulation to be focused on is the Allocation of land for balanced development.

Goa Industrial Growth and Investment Promotion Policy 2022

This industrial policy focuses on strengthening online single windows to provide time-bound clearances with no physical touch. to attract new investment and provide support to local and existing ones, to promote local employment and skill development through various schemes, and attract investments worth 20,00 crore in 5years

This policy again focuses on the fact of using innovative and careful measures to manage the limited land resources to encourage industrial growth in land scare states like Goa. The Government is trying to collaborate with the private sector to make optimal use of limited land

resources. Further PPP policy may evolve providing guidelines for various industrial parks. Also due to the limited availability of land private landowners will be provided facilitation to give land on lease/ sell to investors for industrial setup. Or the landowner may register their land with departments. Communidade landowners may need to lease land for industrial or commercial use.

The Goa Restriction on Transfer of Agricultural Land Act, 2023 (Goa Act 18 of 2023), which was passed by the Legislative Assembly of Goa on 31-03-2023, is to provide restrictions on transfers of certain agricultural lands in the state of Goa provided the collector give a grant of permission for transfers, the land is required for purpose of agriculture by industrial or commercial, undertaking in connection with such industrial or commercial operations carried on by such undertaking(Government of Goa, 2023) .So this is one of the points to focus on even agricultural land can be used for industrial development

CHAPTER 5: CONCLUSION

5.1 RESULTS AND CONCLUSION

Studying the impact of Verna and Canacona Industrial estates on LULC is worthwhile as Goa is the most preferred destination for industrial setup and Comparing these two estates allows for a nuanced understanding of how the age and growth trajectory of an industrial zone influences LULC transformations. The results indicated the expansion of industries or buildup has taken place at the expense of tree cover, and agricultural and barren land in the vicinity of the industrial estate. In the Verna industrial area the major change in the land cover for barren land of around 56% wherein the expansion of built-up (industrial area) has taken place at the expense of Barren land, followed by tree cover at 24% and agricultural land at 19%. Whereas in the Canacona Industrial area, the industrial expansion has taken place of Barren land to a large extent of around 42%, followed by agricultural land at 35% and Tree cover at 22%.In economic The decline in the barren land is seen from the positive perspective as utilisation of unproductive land to some productive use such as industrial expansion leading to economic growth while attention should be paid towards industrial expansion encroaching the natural habitat such as tree cover and conversion of agricultural land which can have impact on food productivity.

Results for the comparison between the LULC of small and Large Industrial estates indicated there are more changes in LULC near large industrial estates in the Verna industrial area compared to small industrial estates like Canacona, This is likely the outcome of the various policy implications as most of the policy focus on More investment towards the expansion of already existing industries and setting up new industries, ignoring the revival of the poor infrastructure of the existing ones.Goa has limited land resources so the focus of all the policies should be concerns about the LULC changes as the more industrial setup will lead

changes in LULC,So the focus is to use strategies for sustainable industrial development concern with environment and focusing on Balanced Industrial growth.

5.2 LIMITATIONS

Findings from this study might not be directly applicable to other regions or contexts due to specific characteristics of south Goa industrial estate and Landscapes of Goa

Remote sensing may not capture all aspects of land use change, such as the qualitative aspects of development or community impacts.

5.3 POLICY IMPLICATION

Implementing Effective Land Use Planning Policies - In a State like Goa with limited land available for industrial growth, the Government should implement policies for optimal land use of the existing available land resource without encroaching into the natural ecosystem.

Resource Management Policies – Industrial expansion often leads to increased demand for natural resources such as water, electricity, and raw materials. So it's important to develop policies focusing on sustainable resource management practices to ensure long-term resource availability and minimize environmental degradation.

Policies should promote Community engagement and stakeholder participation in the decision-making process related to industrial expansion which can help in addressing local issues, ensure transparency, and promote sustainable development.

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