Quantifying Spatio Temporal Changes in Coastal Buit-up area of South Goa based on Landsat Imageries using Google Earth Engine

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Abstract*: *Urban flooding has become a significant concern across many towns and cities in the Asia Pacific. Vulnerability and its components must be understood in order to minimize flood risks. Rapid urban growth occurs in developing countries, resulting from unplanned settlements growing along the rivers, and coastlines are at greater risk. On average, a total of 40% of the world's population lives in narrow coastal belts that take up 7% of the total world land area. Coastal areas are urbanizing at an unprecedented rate that is posing a common threat to humans and ecosystems. Low-lying coastal areas are especially susceptible to climate change related coastal hazards such as; sea level rise, storm surge, coastal flooding, land subsidence etc. This study has been carried out across four talukas of South Goa district, India's smallest state, located along the Arabian sea. The low-lying coastal belt of South Goa district is dotted with world famous sandy beaches of Palolem, Agonda, Colva etc. which attract millions of tourists every year. The present study has assessed the spatio-temporal growth of built-up land in low-lying coastal areas (Marmugao, Salcette, Quepem and Canacona) of South goa district. Google Earth Engine platform was used to estimate Normalized Difference Build Index (NDBI) based on Landsat ETM+/OLI imageries for 2009, 2015 and 2020 to determine and map spatio-temporal changes in the total built-up area. The result revealed that there had been a rapid built-up area increment in South goa coastal belt by 24.94 Sq. Km between 2009 (88.46 Sq. Km) and 2015 (113.40 Sq. Km) and by 15.14 Sq. Km between 2015 (113.40 Sq. Km) and 2020 (128.54 Sq. Km). The main driving force behind this phenomenon is the extensive land use changes for haphazard tourism development (in Salcette and Canacona) and immigration (in Marmugao). However, the conversion of traditional paddy fields and modification of natural drainage system to increase built-up areas can significantly increase the physical and social vulnerability in low lying areas of Salcette and Canacona against the coastal hazards. This study may help urban planners/ authorities to let the region develop in sustainable manner.

***Keywords*: Coastal hazards, South Goa, Urbanization, Vulnerability, NDBI, Google Earth Engine.**

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I. INTRODUCTION

Urban sprawl is a global phenomenon occurring worldwide, considerably more quickly in emerging countries than in industrialized countries. Land Use Land Cover transformation led by human actions is the key reason behind the change in local and global environment. Land cover dynamics have been changing rapidly in recent years, involving the conversion of natural resources or green spaces into land-use classes, which severely influences biological and ecological processes [1,2]. Urbanisation is a complicated dynamic phenomenon that involves large-scale changes in land usage at local levels. Analysing changes in urban land use provides a synoptic view for assessing the spatio-temporal trend of settlement and its linkages with various climatic variables, which in turn aids in the development of better regional plans and governance to manage and minimize risk. Urbanization refers to an index of transformation from conventional rural economies to modernized industrial one [3–5]. It usually occurs in an unplanned and irregular manner, resulting in profound transformation in patterns of land use and land cover [6,7]. Rapid urbanization with inadequate planning can have a negative impact on the environment with growing population

[1,8,9]. In recent scenario the importance of local urban planning and administration cannot be overstated. Maintaining and planning sustainable urban development becomes one of the major necessities for the government and policy makers [10].

The rapid development of urbanization expansion and heavy burden of human activities have impaired ecosystem functions in coastal areas. Urbanization in the coastal areas is under surprising toll, particularly in low- and middle-income countries [11–13]. Combinations of long term and emerging problems in these urban environments generate vulnerability for the well-being of population and ecosystems in a similar way [14,15]. Environmental issues associated with urban sprawl necessitate improved methodologies for understanding spatial patterns of temporal urbanisation in order to manage natural resources sustainably in rapidly urbanising regions [4].

Converting wetlands/ natural vegetation/ open space/ bare soil to urban built-up areas has marked effects on environment and socio-economy, such as local and regional climate change, decline in biodiversity, hydrological circle alternation, etc. increasing the physical and social vulnerability especially in low lying areas [16–19].

Regional and local case-study literature shows that there are different types of vulnerability in urban coastal areas and the challenges outlined above are unevenly distributed geographically. For example, urban areas facing floods show significant variations in rates and magnitudes of urban expansion, contributing to substantial variations in exposure [17–22].

Geospatial techniques have emerged as an essential tool to assess urban sprawl based on several remote sensing indices, viz. Normalized Difference Built-up Index (NDBI), Normalized Difference Bareness Index (NDBaI), and Normalized Difference Soil Index (NDSI). Most of these spectral indices have utilized Short Wave Infrared (SWIR) and Near-infrared (NIR) bands. In addition to satellite data, several studies also proposed various models and machine learning methods that showed greater accuracy while dealing with complex landforms.

In this study an initiative has been taken to quantify spatio-temporal changes in coastal built-up area based on Landsat remote sensing imagery during 2009, 2015, and 2020 using GIS techniques over South Goa talukas. This study also highlighted the urban patches at risk and susceptible towards coastal flooding using ALOS based DEM data. These analyses have been performed using Google Earth Engine platform.

II. Study Area

Goa is the smallest state of India with 3702 Sq.km land area. It is located in between the Arabian sea to its west and the Western ghat marking its eastern boundary. Maharashtra state is located in its north and Karnataka state is located in its east and south. It majorly consists of 2 districts; North Goa and South Goa. The study area lies in South Goa district having six talukas (i.e., sub-districts), out of which four coastal talukas from north to south; Marmugao, Salcete, Quepem and Canacona, respectively were considered to map built-up expansion during 2009, 2015, and 2020.

Marmugao is the transport hub of Goa state and is considered the commercial capital of Goa, located in Salcete. Additionally, the coastal belt of Salcete, Quepem and Canacona is dotted with numerous sandy beaches viz. Colva, Agonda, Palolem, Cola etc. famous all over the world. However, Quepem has huge iron-ore mining potential [10].

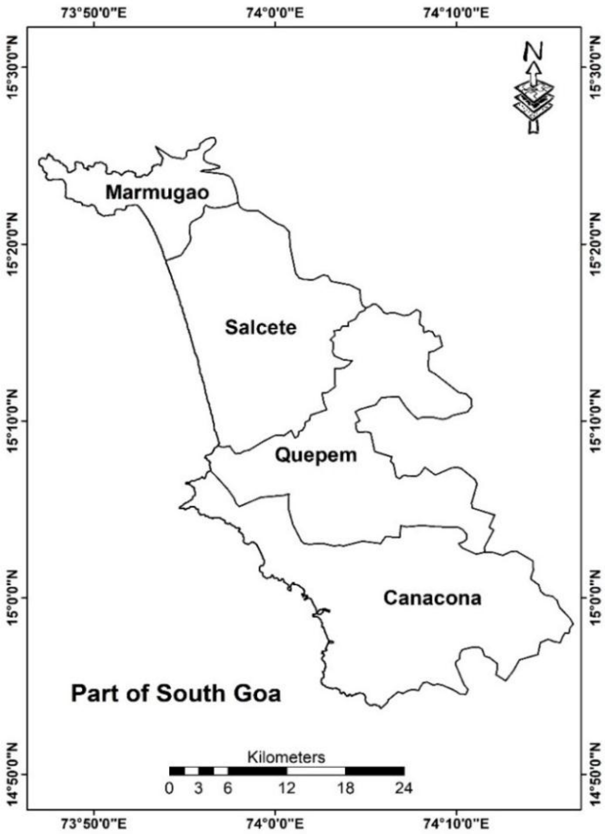

Fig. 1. Study region

III. MATERIALS AND METHODS

In the present study, multi-temporal LANDSAT satellite data set during 2009 (LANDSAT 7-Enhanced Thematic Mapper (ETM+), 2015 and 2020 (LANDSAT 8- Operational Land Imager (OLI)) has been used and processed using Google Earth Engine (GEE) platform to calculate urban area during 2009, 2015 and 2020. Further, ALOS based DEM data was obtained from the Alaska Satellite Facility website (ASF) to map vulnerable zones due to coastal floods. The detailed overall methodology adopted is provided in Fig 2.

TABLE I. LIST OF DATA USED IN THE STUDY

Study Area	Sensor	Date	Spatial Resolution
South Goa	Landsat 7 ETM+	03-04-2009	30 m
	Landsat 8 OLI	18-04-2015	30 m
	Landsat 8 OLI	28-04-2020	30 m
	ALOS DEM	-	12.5 m

Materials:

(a) Landsat 7 ETM+/ 8 OLI: Landsat mission was launched by NASA and dataset are distributed through US Geological Survey in geographically tagged image file format (Geo-TIFF). Landsat 7 has eight spectral bands whether Landsat 8 has 11 spectral bands with 30m spatial resolution. Here for the analysis, SWIR (band 5 in Landsat 7 and band 6 in Landsat 8) and NIR (band 4 in Landsat 7 and band 5 in Landsat 8) bands were considered as it measures the percentage of reflection. However, thermal band measures the radiation temperature [23,24]. The optical bands have been used in developing NDBI.

(b) ALOS based DEM: The ALOS (PALSAR) based DEM data are freely available at Japan Aerospace Agency (JAXA) portal having 12.5 m spatial resolution. The DEM has been used to show urban areas at very low elevation that might be more susceptible towards coastal flooding [18,19].

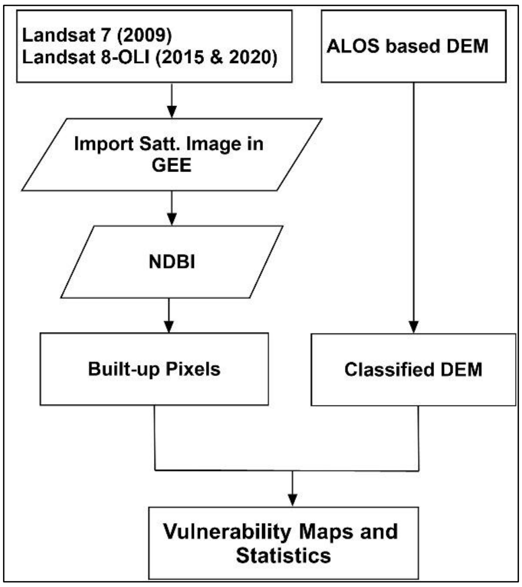

Fig. 2. Shown methodology adopted in the study

Methods

In this study satellite data (Landsat 7 ETM+ and 8 OLI) during 2009, 2015, and 2020 has been taken, pre-processed, and imported in Google Earth Engine platform to map built-up areas in South Goa region [9].

Normalized Differential Built-up Index: The Index value lies between -1 to +1. Here, negative value represents water bodies whereas the higher value represents built-up areas.

$$NDBI = (SWIR - NIR) / (SWIR + NIR) \quad (1)$$

Where, SWIR band wavelength is between 1.57 to 2.29 and NIR band wavelength is between 0.85-0.88 micrometre. NIR is band no. 5 and SWIR is band no. 6 (SWIR 1) and 7(SWIR 2) in Landsat 8 OLI data with 30m resolution. Threshold used for built-up extraction is ($-0.18 > NDBI > 0.3$).

Vulnerability Assessment: Extracted built-up pixels and classified ALOS based DEM data were assessed together to map built-up area in different elevation zones using Arc GIS domain.

Finally, three built-up maps (2009, 2015, 2020) has been created with different elevation zones to show which region is being more vulnerable towards coastal flooding.

IV. RESULTS AND DISCUSSION

The present study has assessed the increment in the built-up land use in a span of 12 years in the coastal belt of south goa, between 2009 to 2020 (Fig. 3).

Goa has seen rapid development since the turn of the millennium. Two prominent sectors which earn goa a huge share of economy are tourism and mining. The study area has prominent sites catering for both of these sectors.

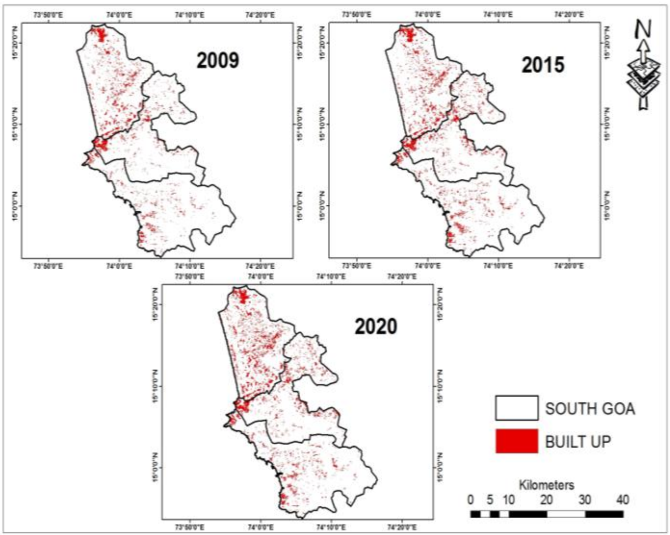

Fig. 3. Built-up areas shown in red colour during 2009, 2015 and 2020

Marmugao is the northernmost taluka of south Goa. This taluka has seen the highest amount of development which is evident from its strategic location (Central part of Goa). It hosts the sole seaport and airport of the state along with the railway terminus, which makes it the transportation hub of the state. Consequently, it receives the highest number of migrants due to the domino effect of the majority of migrant population already present there since the fourth quarter of twentieth century. From 2009 till 2020 the areas hosting urbanization have been similar. The Marmugao plateau on the southern belt of taluka was once a barren land which has now been urbanized extensively since early 2000's. Additionally, the Goa industrial estate is located on the eastern side of taluka which has rapidly expanded since the last decade.

Salcete is an extensively low-lying taluka of South Goa. Margao, Goa's economic capital is located in Salcete acting as the most prominent economic node of South Goa. Traditionally it was developed along the coastline with several coastal villages. Presently, the National highway 66 which connects Margao with Panjim has been the most prominent zone of built-up area, as it serves the purpose of heavy tourist flow along with mining ore transportation. The other significantly modified areas are located at the southern end of Salcete.

Quepem is primarily a mining sub-district which has witnessed urbanization at quite a lower rate than the neighboring sub-districts. Canacona is a world-famous beach tourism destination which has witnessed a boom in tourist infrastructure. The main driving force behind the urbanization of Canacona is the haphazard development in the tourist belt of North Goa district.

The rate at which the built-up has increased between 2009-2015 (28.19%) is quite daunting. This amount of alteration of land use clearly suggests rapid haphazard development in the study area. The main driving force of which are (i) extensive conversion of vegetative land cover to built-up to fulfill ever-increasing tourism infrastructural demand (in Salcete and Canacona) and, (ii) rapidly increasing migrant population (in Marmugao), both of which are putting immense pressure on the limited land available in the state. Since the last two decades, Goa has turned out to be a cheaper tourism destination due to ample amount of low budget accommodation availability which caters to a large number of low budget tourists as well as lower class migrants who come in search of jobs which are plenty [10]. This trend has become a vicious cycle due to which a greater number of cheap accommodation options are coming up leading to an increase in unplanned built-up areas.

The phase between 2015-2020 conversion of vegetative land to the built–up areas was dropped to 13.35%, which may be attributed to the complete ban on mining activities, an unusual long lean phase in tourism industry since 2018 and at the grass-root level, several effective protests at the village level against haphazard developmental activities, which could further increase the vulnerability in coastal villages.

TABLE II. INCREMENT IN THE BUILT-UP AREA DURING DIFFERENT PERIODS

Year	Area (sq.km)	Increment in Built-up (%)
2009	88.45	–
2015	113.39	28.19
2020	128.53	13.35

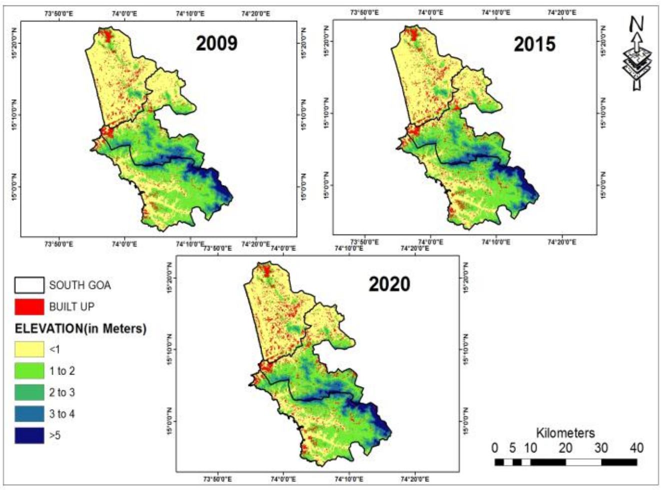

Fig. 4. Showing elevation map and built-up areas as well during 2009, 2015 and 2020.

The spatio-temporal pattern of built-up areas as per the different elevation classes during 2009, 2015, and 2020 over South Goa region has been shown in Figure 4. It also can be seen that area having less than 1m elevation consists most of the urban patches (Fig.3).

The study also exhibited those built-up areas were present in small patches in northern, central, western, and southern region.

TABLE III. INCREMENT IN THE BUILT-UP AREA DURING DIFFERENT PERIODS

Elevation (in meters)	Built-up 2009 (in sq.km)	Built-up 2015 (in sq.km)	Built-up 2020 (in sq.km)
<1	50.49	64.36	78.75
1 - 2	36.56	47.39	47.35
2 - 3	1.34	1.51	1.9
3 - 4	0.01	0.03	0.13
>4	0.05	0.11	0.46

Based on the analysis it can be stated, there is 50.49, 64.36, 78.75 sq.km built-up area was mapped during 2009, 2015, and 2020, respectively in less than 1 m. elevation zone which also shows the increment in built-up land in more prone area towards coastal flooding. Study also exhibited that there is 36.56, 47.39, 47.35 sq.km was mapped during 2009, 2015, and 2020, respectively in 1 to 2 m. elevation zone.

It can be concluded that built-up areas were found prominently in less than 2 m elevation zone and growing very fast in the same region which make it more susceptible towards the disaster. There is no such study carried out to highlight built-up patches vulnerable towards coastal flooding based on the presence of built-up area in respective elevation categories. However, they have considered several other parameters which produced significant results are socio-economic, historical shoreline change, storm surge, mean tidal range, significant wave height, sea level rise, Tsunami, Rainfall, coastal slope, population and tourist density data, and temperature [2,3,13].

V. CONCLUSION

The present study clearly suggests that a decade is sufficient to deteriorate any eco-sensitive region by extensively converting it to non-productive built-up areas. The rate at which built-up conversion has occurred in south goa is alarming [18,22]. With the impending climate change crisis, the low-lying coastal areas such as South Goa, require better planning to tackle the issues such as population immigration and land-use changes as both are the driving force of haphazard development in South Goa [10]. The developmental activities should be in synchronization with the varied topography of Goa, which consists of coastal plains, wetlands, rivers, plateaus and hills. The local community participation is pre-requisite and required along with the government to oppose the unwarranted and unnecessary conversion of vegetative areas to built-up areas in their neighborhood [3,8,22].

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