CHAPTER 2
PROFILE OF THE STUDY AREA

2.1 Introduction

Gujarat, the fifth-largest state in India by area and the tenth-largest by population, has a population comparable to that of Thailand, which ranks as the 20th most populous country in the world. The Tropic of Cancer traversing the northern boundary of Gujarat adds a unique geographical significance to the state, influencing its climate, natural landscape, and cultural practices. The state has the longest coastline in mainland India, stretching approximately 1,663 kilometers and encompassing diverse habitats, including mangroves, salt marshes, coral reefs, wetlands, and seagrasses (Patro et al., 2017). Gujarat's diverse landscape, stretching from the salt deserts of Kutch to the scrublands of the Saurashtra Peninsula, reflects remarkable resilience and adaptation. This varied terrain also includes forests ranging from dry to moist deciduous, thorn forests, and grasslands (Kushwaha et al., 2020). Its terrain, primarily composed of Deccan lavas and lava dykes, exhibits low hills and plains, particularly in the central Kutch region (Karmalkar et al., 2008). Gujarat is renowned for its diverse geography and vibrant cultural heritage, blending tradition with modernity. This amalgamation of geographical and cultural aspects renders Gujarat an intriguing subject of study across various academic disciplines. This chapter delves into the state's diverse physical and cultural elements, aiming to explain the complex relationship between the natural environment and humans within this dynamic state. It encompasses various elements, including geographical location and extent, historical evolution, physiographic divisions, climate, vegetation, rivers, geomorphology, demography, and socio-economic status.

2.2 Location and Extent

Gujarat is located along the western coast of India, situated between the latitudes of 20°6' and 24°42'N, and the longitudes of 68°10' and 74°28'E. The state shares its borders with Pakistan to the northwest, the Arabian Sea to the west, and several Indian states: Rajasthan to the north and northeast, Madhya Pradesh to the east, and Maharashtra to the south and southeast (Bandyopadhyay et al., 2016). The India-Pakistan border in Gujarat spans a total length of 508 kilometers. It begins at Sir Creek, a 96-kilometer-long tidal estuary (Mishra, 2015), extends through the Rann of Kutch, a salt marsh, and ends near Nadabet in Banaskantha district. The sea encircles the state from the southern parts to the northwest. The Gulf of

Khambhat, or the Gulf of Cambay, is located on the Arabian Sea coast. This trumpet-shaped gulf acts as a natural boundary, separating the Saurashtra Peninsula from the South Gujarat region (Nayak et al., 2015). The width of the Gulf measures 190 km between Diu and Daman, gradually narrowing down to 24 km at Khambhat. The Sabarmati, Mahi, Narmada, and Tapti are some rivers that drain into the Gulf. The Gulf of Kutch is an inlet of the Arabian Sea (Vethamony & Babu, 2010), dividing the regions of Kutch and the Saurashtra Peninsula. The Sang, Naagmati, Suraai, etc, are among the few major rivers that drain into the Gulf of Kutch. Meanwhile, the Luni River disperses into the vast salt marshes of the Rann of Kutch.

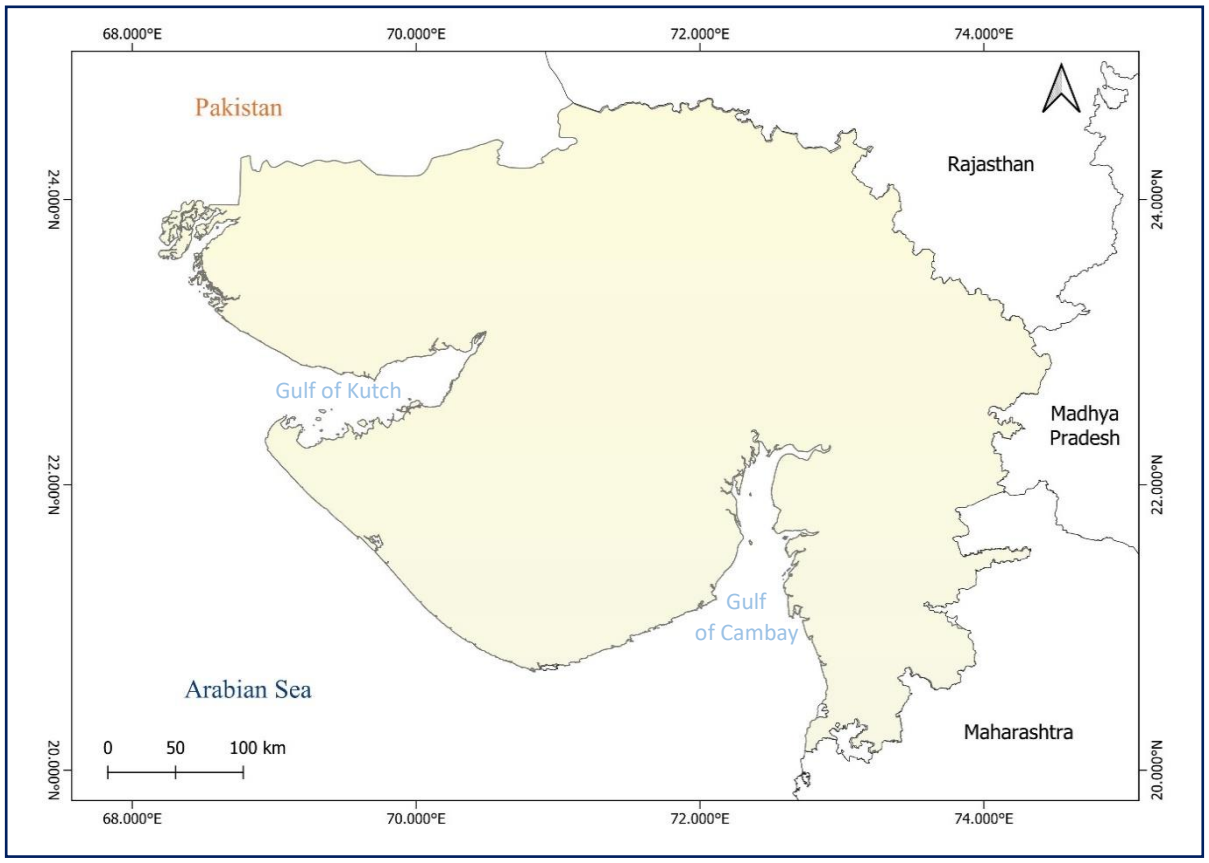

Figure 2.1 Geographical Location of Gujarat and its adjacent States.

Despite its adjacency to the Arabian Sea, Gujarat predominantly experiences an arid to semi-arid climate in most regions (Ray et al., 2008), largely influenced by its proximity to the Thar Desert in the north. Gujarat is categorized into four distinct biogeographic regions. These include the Indian Desert, covering the Kutch region, and the semi-arid zone, known as Rajwada, situated predominantly in the North, Central, and Saurashtra regions. Additionally, the Western Ghats and Coastal region along its west coast. The varied biogeographic regions in Gujarat cover six major ecosystems: forests, deserts, wetlands, coastal and marine areas, grasslands, and agricultural lands. The Greater and Little Rann of Kutch forms Gujarat's

desert region, commonly referred to as the salt marsh habitat (Saxena, 2017). Additionally, the state has the second-largest extent of mangroves in India (Kathiresan, 2018). According to Gujarat Forest Statistics for 2022-23 there is a consistent increase in mangrove cover across the state over the past two decades. The State possesses the longest coastline in the country, stretching 1,663 kilometers from Kutch in the north to Valsad in the south. Its coastline features an expansive continental shelf covering approximately 1,64,000 sq. km. These statistics represent approximately 20% of India's coastline and 33% of its continental shelf (Gujarathi-Talati et al., 2024). Additionally, the state's Exclusive Economic Zone (EEZ) encompasses 2,14,000 sq. km. With a land area of about 1,96,024 sq. km Gujarat stands as the fifth-largest state by area, contributing about 6% of India's total geographical area.

2.3 Historical Evolution

The name 'Gujarat' traces its roots to 'Gujjar Rashtra,' signifying the land of the Gujjars, a migratory tribe that settled around the 5th century BC (https://nri.gujarat.gov.in/intro.htm). The arrival of the Gujjars brought cultural dynamism and demographic changes to the region, shaping Gujarat's early history and identity. The discovery of ancient settlements dating back to the Stone Age along the banks of the Sabarmati and Mahi rivers in Gujarat provides convincing evidence of human habitation in the region during ancient times (Sarkar et al., 2020), possibly at the same time as the Indus Valley Civilization. The presence of these early settlements indicates a rich history of prehistoric human activity and cultural development in Gujarat. Gujarat is also home to several Harappan sites, including prominent ones like Lothal and Dholavira. The exploration and excavation of these sites continue to yield invaluable insights into the social, economic, and technological aspects of ancient Gujarat (Nigam et al., 2016). From ancient to medieval times, Gujarat witnessed a succession of dynasties that shaped its political and cultural landscape. The region was initially under the control of the Maurya Dynasty, led by Emperor Chandragupta Maurya, and later expanded by King Ashoka, establishing a presence in Gujarat (Kumaran, 2014). Subsequently, Gujarat came under the rule of the Sakas or Scythians, followed by the Solanki or Chaulukya dynasty, which marked the zenith of Gujarat's power and prosperity. The Solankis believed to be of Gujjar descent, presided over a golden age characterized by remarkable architectural and artistic achievements, including the renowned Sun Temple at Modhera and intricate stepwells like Adalaj and Rani ki vav (Mankodi, 2022). The Solanki Dynasty was succeeded by the Vaghela dynasty, albeit briefly, until their reign was brought to an end by the forces of Alauddin Khilji in 1297, establishing the first Muslim sultanate in Gujarat. The arrival of

Muslim rulers ushered in a new era characterized by the integration of Islamic administrative practices and the spread of Islamic influence in Gujarat (Desai, 2023). This sultanate endured until the late 16th century when Gujarat was annexed by the Mughal Empire under Akbar's reign. The Mughals governed Gujarat until the mid-18th century, after which the Marathas, under the leadership of Chhatrapati Shivaji Maharaj, seized control of the region, starting a new chapter in Gujarat's political history (Osborne, 2020). These successive dynasties not only influenced governance but also enriched Gujarat's cultural heritage, leaving behind enduring architectural marvels and traditions that remain integral to the state's identity today.

After the decline of the Maratha Empire, various European powers established bases along Gujarat's coast in the early 17th century. The British East India Company founded its initial Indian base in Surat in 1614. During the Second Anglo-Maratha War in the early 19th century, the British East India Company gained significant control over much of Gujarat (Maloni, 2016). Local rulers entered into separate peace treaties with the British, allowing them to maintain local autonomy under British sovereignty. Gujarat then became part of the Bombay Presidency, although the state of Baroda retained some level of independence (Jhala, 2019). Over two centuries of British rule, the seeds of the independence movement began to sprout throughout Gujarat and India as a whole. The struggle for independence reached its peak, culminating in India's attainment of independence in 1947. This period marked a significant turning point in Gujarat's history, transitioning from colonial rule to becoming an integral part of independent India, with its rich heritage and diverse culture continuing to play a vital role in the nation's identity and development. Following independence, efforts were made to unify the Gujarati-speaking population under a single administrative unit, which led to the Mahagujarat movement. This movement advocated for the creation of a separate state for Gujarati-speaking people. As a result, on May 1, 1960, the bilingual Bombay State was divided into two separate states: Maharashtra and Gujarat, encompassing the entire Gujarati-speaking region within the newly formed state of Gujarat (Isaka, 2015). The establishment of Gujarat as a separate state marked an important milestone in the political and cultural history of the region. After the formation of the state, Ahmedabad was initially chosen as the capital. However, as the city began to face challenges related to population density and urban congestion, the need for a more balanced development across the state became evident. In response, the idea of creating a new capital emerged. As a result, Gandhinagar was planned and developed, with its foundation laid on Aug 2, 1965, becoming the new capital of Gujarat (https://gandhinagar.nic.in/history/), named after MK Gandhi, the epitome of non-violence.

2.4 Physiographic Divisions

Gujarat exhibits substantial geographic diversity, spanning from the saline deserts of Kutch in the northwest to the lush green forest and coastal plains in the southeast. The state is divided into five physiographic regions: Saurashtra in the southwest along the Arabian Sea Coast; North Gujarat; Central Gujarat; South Gujarat; and the Kutch (Kachchh) in the northwest (State of Environment Reports Gujarat, 2012). Gujarat experiences a wide range of geographic and climatic conditions across its diverse physiographic regions. The state predominantly consists of plains, particularly in Central and North Gujarat, where vast expanses of flat terrain characterize the landscape. In contrast, South Gujarat has the highest forest density in the state, with lush green hills that are part of the Sahyadri ranges (Western Ghats). This region receives a high annual rainfall, ranging between 1,000 and 1,500 mm, fostering a rich and diverse ecosystem supported by ample rainfall. Whereas, Kutch experiences relatively low annual rainfall, ranging from 350 to 450 mm, resulting in an arid environment (Arora et al., 2013). The Kutch region features salt marshes (Rann), rising just a few meters above sea level. The presence of such varied landscapes and climatic conditions within Gujarat reflects the state's geographical complexity and environmental diversity.

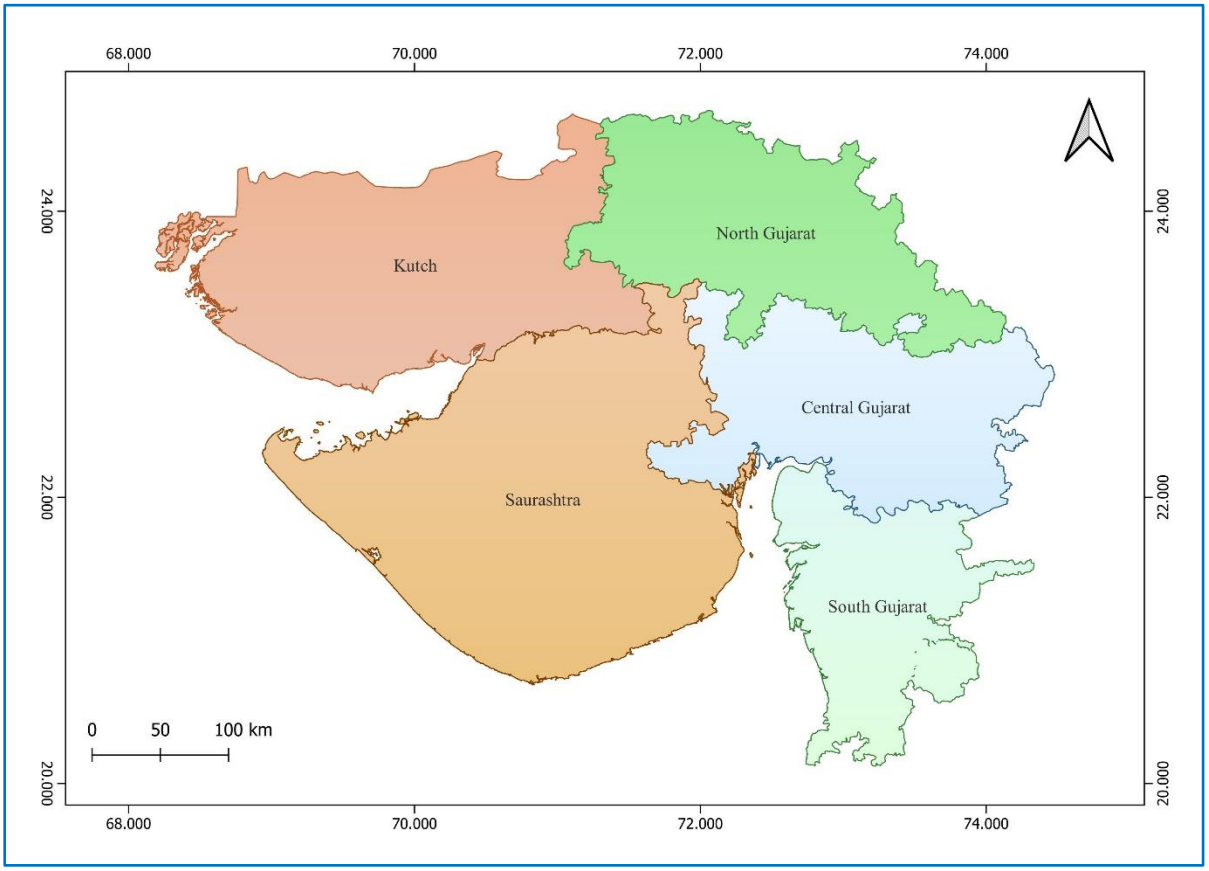

Figure 2.2 Distinct Physiographic Regions of Gujarat.

2.4.1 Central Gujarat

The districts of Ahmedabad, Gandhinagar, Anand, Kheda, Vadodara, Panchmahal, Dahod, and Chhota Udaipur belong to Central Gujarat, covering an area of approximately 34,130 sq. km. This region experiences a semi-arid climate with distinct seasons. The average annual rainfall ranges between 800 and 1,000mm, primarily received during the SWM months (Ray et al., 2008). Pre-Monsoon in Central Gujarat are characterized by scorching heat and dry conditions, with temperatures frequently exceeding 40°C. In contrast, winters are relatively mild and pleasant, with temperatures ranging from 15°C to 25°C. The semi-arid nature of the climate influences the vegetation of the region, which consists of dry deciduous forests, thorn forests, and scrublands, adapted to survive with limited water availability. The rivers in Central Gujarat, including Sabarmati and Mahi, are crucial for agriculture in the region by providing water for irrigation.

2.4.2 Kutch

Kutch, India's largest district, is characterized by its vast expanse and sparse population, largely due to its arid and challenging environmental conditions. This region receives minimal annual rainfall, making agriculture difficult and limiting settlement. The region spans an area of 45,674 sq. km., accounting for 23.27 % of the total area of the state. Around 51% of Kutch's geographical area comprises highly saline and sterile land, which includes the Greater Rann of Kutch and the Little Rann of Kutch (https://kachchh.nic.in/about-district/). The region is bordered by Pakistan to the north and northwest, with the state of Rajasthan lying to the northeast. To the east are the districts of Banaskantha and Patan, and to the south are Surendranagar and Morbi. The Gulf of Kutch and the Arabian Sea border the region to the south and southwest, respectively (Mandal et al., 2020). The distribution of rainfall is irregular, with an average annual rainfall ranging between 300 to 400 mm. Kutch has ten sub-divisions or Taluka. Additionally, Kutch is home to diverse wildlife and migratory bird species, especially around the wetlands and coastal areas (Kumar & Alam, 2023), making it a significant ecological region despite its sparse human population.

2.4.3 North Gujarat

The North Gujarat region comprises districts such as Aravalli, Mehsana, Patan, Banaskantha, Mahisagar, and Sabarkantha, covering approximately 28,910 sq. km., which accounts for 14.75% of Gujarat's total geographical area. This region is characterized by a sparse forest cover and experiences average annual rainfall ranging between 500 and 800mm. The climate

in North Gujarat varies from arid to semi-arid, with distinct seasonal patterns. Additionally, rock outcrops are notable features found in certain parts of this region, particularly in the northeastern areas (Chauhan et al., 2021).

2.4.4 Saurashtra

Saurashtra, also known as Sorath or Kathiawar, is a peninsular region of Gujarat in western India. It features a naturally saline environment and is located along the Arabian Sea (Reang et al., 2022), situated between latitudes of 20° 30′ N to 22° 30′ N and longitudes of 69° 00′ E to 72° 30′ E. The Districts of Amreli, Bhavnagar, Rajkot, Bhavnagar, Jamnagar, Junagadh, Gir Somnath, Surendranagar, Devbhoomi Dwarka, Botad, and Porbandar belong to the Saurashtra region. The region is bordered by water bodies on three sides: the Gulf of Kutch to the north, the Arabian Sea to the southwest, and the Gulf of Cambay to the southeast. The region covers an area of about 60,950 sq. km. and experiences a dry sub-humid climate with annual rainfall ranging between 500 and 800mm. The majority of soils in the Saurashtra region are classified as clayey, which refers to soils with a fine texture dominated by clay particles. The Saurashtra region features hilly areas in its southern part, including Gujarat's highest peak located atop Girnar Hills (1177m). The prominent rivers flowing through the Saurashtra region include Shetrunji, Bagod, Kalubhar, Malan, Madhuwati, and Limdino.

2.4.5 South Gujarat

South Gujarat encompasses seven districts: Surat, Bharuch, Narmada, Navsari, Dang, Valsad, and Tapi. Despite covering 12.26% of Gujarat's geographical area (24,034 sq. km.), this region is home to a significant portion, constituting 20% of the state's total population. The population density in South Gujarat is higher than the state average, with approximately 511 individuals per sq. km. compared to Gujarat's overall density of 308 per sq. km. South Gujarat is one of India's wettest regions, characterized by diverse geographical features that contribute to its unique climate. The coastal lowlands in the west contrast significantly with the Western Ghats in the east. The climate in South Gujarat varies across different areas, ranging from semi-arid conditions in the plains to a dry sub-humid climate in the hills and along the coast. This variability is reflected in the annual rainfall, which ranges from 1,200 to 1,600 mm, making South Gujarat relatively humid compared to other parts of the state. In South Gujarat, prominent rivers include Narmada, Tapi, Ambika, and Mindhola, which drain into the Arabian Sea through the Gulf of Khambhat (Singh et al., 2022). The soils generally range from fine to medium textured, varying from clayey to loamy clay in composition.

2.5 Climate

Gujarat exhibits significant variations in the spatial distribution of rainfall and temperature across its different regions (Figure 2.3, 2.5). Temperatures generally increase from the southwest to the northeast of the state, with the northwestern region, particularly Kutch, facing a higher risk of aridity and drought due to lower rainfall and higher temperatures. Conversely, rainfall patterns show an opposite trend, increasing from the northeast to the southwest (Ray et al., 2008). This spatial disparity results in the northern region of Gujarat being predominantly arid, characterized by dry conditions and limited vegetation cover. In contrast, the southern part of the state experiences higher levels of humidity, especially along the coastal areas influenced by the Arabian Sea.

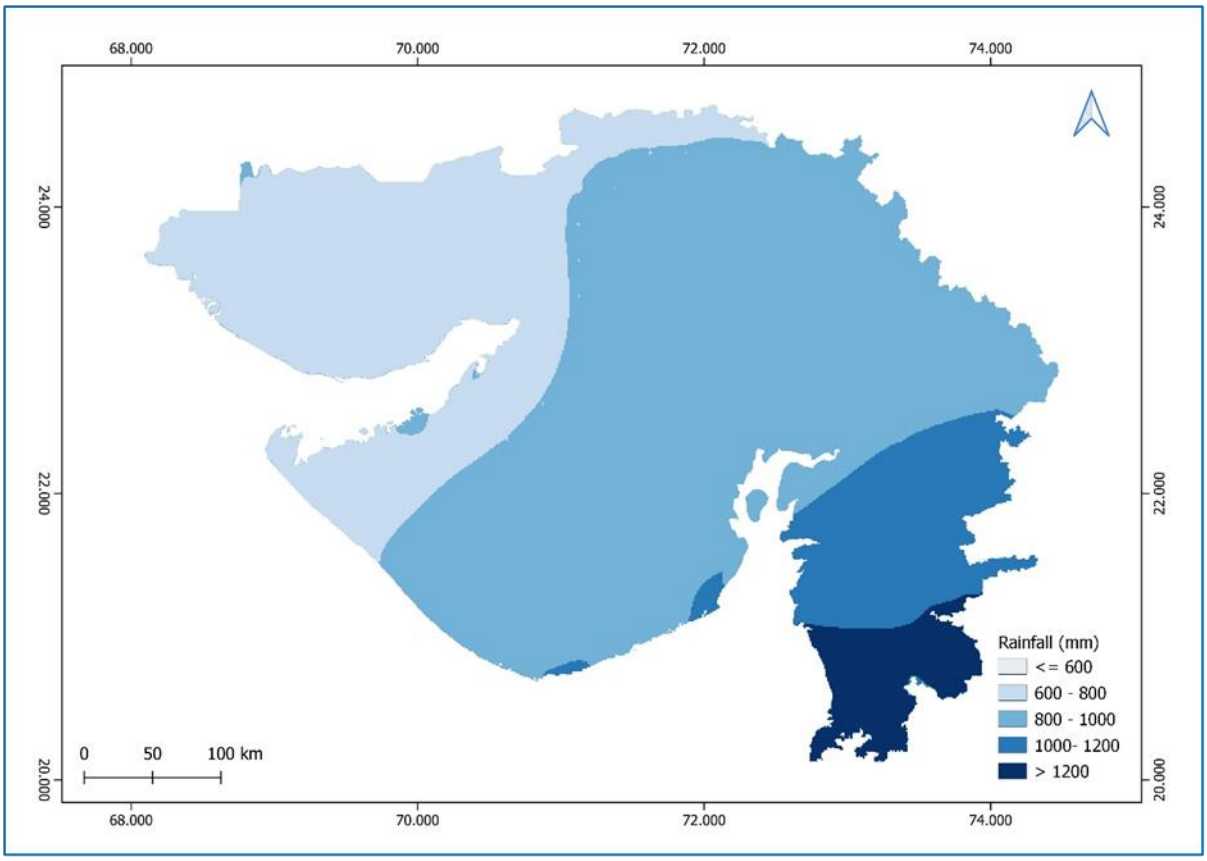

Figure 2.3 Average Annual Rainfall Distribution in Gujarat (1961-2020, mm).

The distribution of annual rainfall in Gujarat varies significantly throughout the seasons. Figure 2.4 shows that the SWM season (JJAS) accounts for the majority (96%) of the state's total rainfall. During this period, the rainfall distribution is as follows: June contributes 14.57%, July contributes 36%, August contributes 29.94%, and September contributes 15.13% of the total annual rainfall. In contrast, the Winter season (JF) and Pre-Monsoon season (MAM) together account for a mere 0.9% of the annual rainfall. The post-monsoon

season (OND) receives a moderate share of 3.3% of the annual rainfall. This seasonal pattern highlights the state's reliance on SWM rainfall, particularly during July and August when rainfall is most abundant.

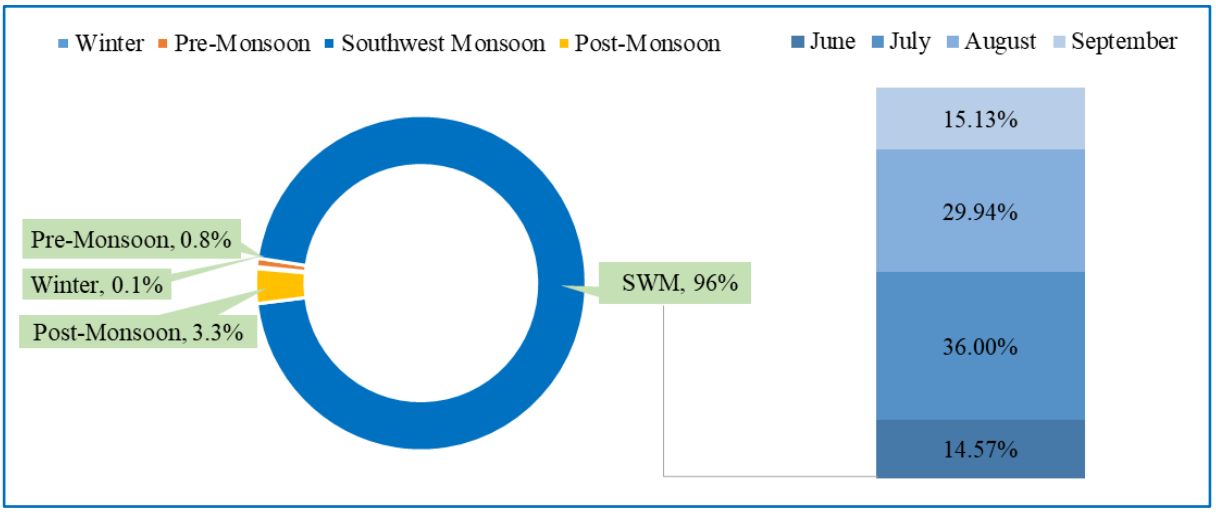

Figure 2.4 Seasonal Distribution of Rainfall in Gujarat.

Table 2.1 Average Monthly Rainfall Distribution Across Regions (1961-2020, mm)

Month/ Season	Central Gujarat	Kutch	North Gujarat	Saurashtra	South Gujarat
January	0.8	0.5	1.6	0.3	0.6
February	0.3	1.3	0.9	0.6	0.3
March	0.9	1.0	1.5	1.0	0.9
April	0.7	0.3	1.4	0.6	0.6
May	5.8	4.5	5.0	3.6	6.0
June	114.0	53.6	80.7	129.5	220.4
July	293.4	161.1	269.1	237.4	517.0
August	278.7	130.9	237.4	173.0	409.3
September	132.7	63.5	109.5	100.6	214.9
October	15.9	12.1	14.2	19.0	28.4
November	8.5	6.3	6.5	9.2	9.9
December	1.5	1.6	1.4	0.7	2.4
Winter	1.1	1.8	2.5	1.0	1.0
Pre-Monsoon	7.4	5.7	7.9	5.2	7.5
SWM	818.9	409.1	696.7	640.6	1361.6
Post-Monsoon	25.8	20.0	22.1	28.9	40.7

Gujarat is predominantly situated in arid and semi-arid climatic regions, characterized by erratic and unevenly distributed rainfall patterns, which often lead to water scarcity and drought conditions across a large portion of the state each year (Bandyopadhyay et al., 2016). Droughts are particularly prevalent in Gujarat when the SWM arrives late, departs early, or fails to bring adequate rainfall (Bandyopadhyay et al., 2016).

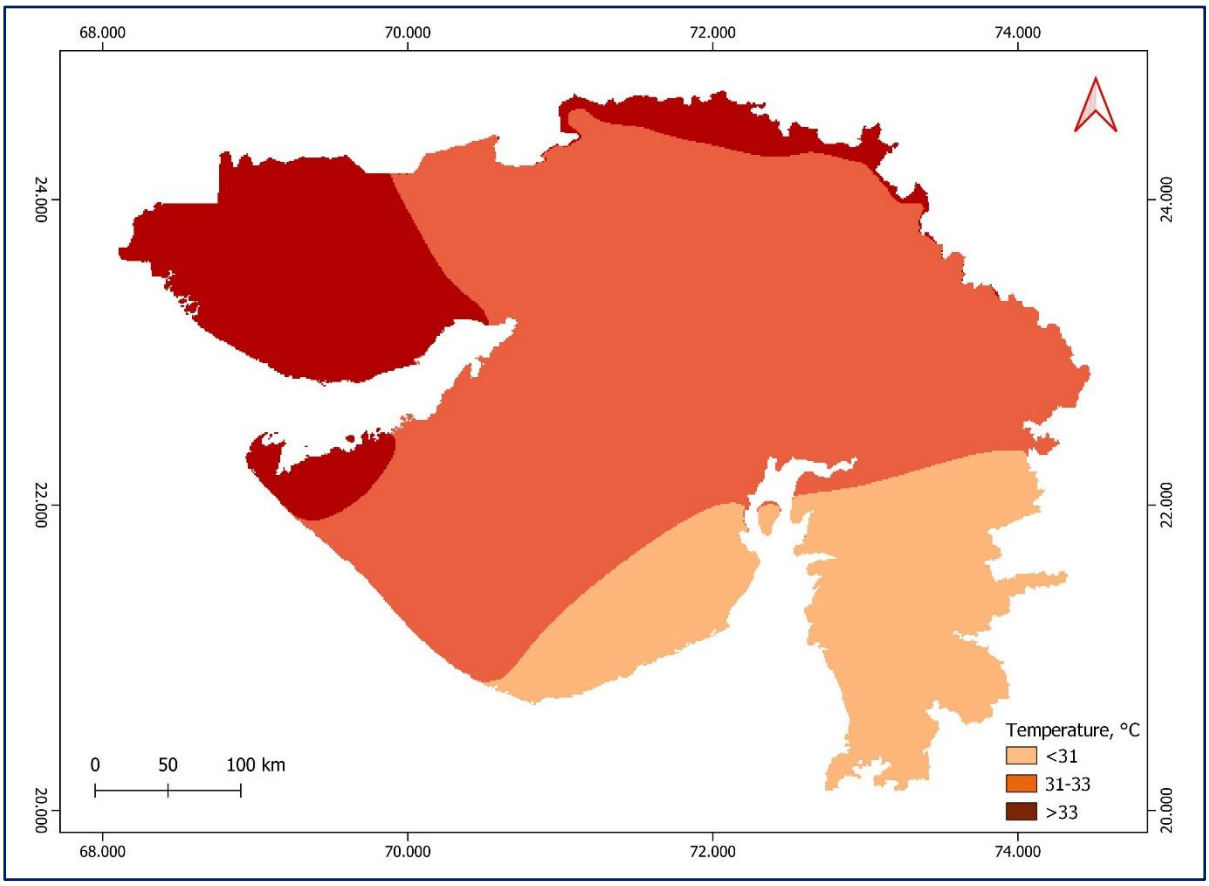

Figure 2.5 Average Temperature Distribution in Gujarat (1961-2020, °C).

The spatial distribution of temperature across Gujarat reflects the state's diverse geography and climatic zones. Generally, the northern and northwestern parts of the state experience higher average temperatures than the southern regions. Moving southward, temperatures gradually decrease. South Gujarat and Coastal Saurashtra consistently record the lowest annual average temperatures, benefiting from the moderating influence of the sea. In contrast, central Saurashtra, Central Gujarat, and certain parts of North Gujarat experience moderate annual average temperatures. This spatial variation in temperature highlights the diverse climate patterns within the state. According to Table 2.2, North Gujarat consistently experiences the lowest average T_{min} across most months, except for May and June, when South Gujarat exhibits the lowest average T_{min}. January emerges as the coldest month across all physiographic regions of Gujarat, while May stands out as the warmest month.

Table 2.2 Average Monthly Temperature Distribution Across Regions (1961-2020, °C).

Month/ Season	**Central Gujarat**		**Kutch**		**North Gujarat**		**Saurashtra**		**South Gujarat**	
	T_{min}	T_{max}	T_{min}	T_{max}	T_{min}	T_{max}	T_{min}	T_{max}	T_{min}	T_{max}
January	12.8	28.8	13.0	27.3	10.5	26.5	13.1	28.3	12.5	29.2
February	14.9	31.5	15.2	29.3	12.9	29.3	15.1	30.4	14.6	31.8
March	19.4	36.0	19.3	33.0	17.8	34.2	19.1	34.1	18.9	36.0
April	23.5	39.0	22.9	35.3	22.3	37.8	22.7	36.3	23.0	38.9
May	26.1	39.9	26.0	36.1	25.2	39.2	25.7	36.8	25.6	39.4
June	26.5	36.9	27.4	35.1	25.8	36.7	26.8	35.2	25.7	35.8
July	25.2	32.4	26.4	32.4	24.5	32.1	25.8	32.1	24.4	31.4
August	24.4	31.2	25.4	31.1	23.6	30.8	24.9	31.0	23.7	30.4
September	23.9	33.0	24.6	32.3	22.9	32.6	24.1	32.4	23.2	32.2
October	21.8	35.4	22.5	34.5	20.1	34.5	22.3	34.9	21.0	34.7
November	17.7	33.1	18.7	32.3	15.6	31.5	18.7	32.8	16.9	32.7
December	14.2	30.0	14.7	28.8	11.8	27.9	14.8	29.7	13.6	29.9
Winter	13.8	30.2	14.1	28.3	11.7	27.9	14.1	29.3	13.5	30.5
Pre-Monsoon	23.0	38.3	22.7	34.8	21.8	37.1	22.5	35.7	22.5	38.1
SWM	25.0	33.4	25.9	32.7	24.2	33.1	25.4	32.7	24.3	32.5
Post-Monsoon	17.9	32.8	18.6	31.9	15.8	31.3	18.6	32.5	17.2	32.4

The most significant temperature difference between maximum and minimum values occurs during the winter season in Gujarat, typically from January to February. This period is characterized by warm daytime temperatures of around 25°C to 30°C and much cooler nights dropping to about 10°C or below, particularly in inland areas. In contrast, during the SWM season from June to September, the temperature difference between daily maximum and minimum values is at its lowest. The presence of clouds and rainfall during this season tends to moderate temperature variations, resulting in daytime highs and nighttime lows being relatively close together. Figure 2.6 provides a detailed illustration of the relationship between temperature and rainfall in Gujarat over a 60-year average plotted monthly. The graph highlights significant patterns and variations in Gujarat's climate across the state. It shows that the highest rainfall occurs during the SWM months, particularly in July, followed by August, September, and June. This indicates that Gujarat receives a significant portion of its annual rainfall during the SWM season, which is crucial for agriculture and water

resources in the region. Additionally, Gujarat experiences varying temperatures across distinct regions. Before the onset of the SWM, particularly during the pre-monsoon months (MAM), temperatures have been observed to increase between 35°C and 45°C. In certain regions, especially during heat waves, maximum temperatures may even exceed 47°C. During the winter season, from January to February, temperatures drop to more moderate levels, ranging from around 10°C to 25°C across the state.

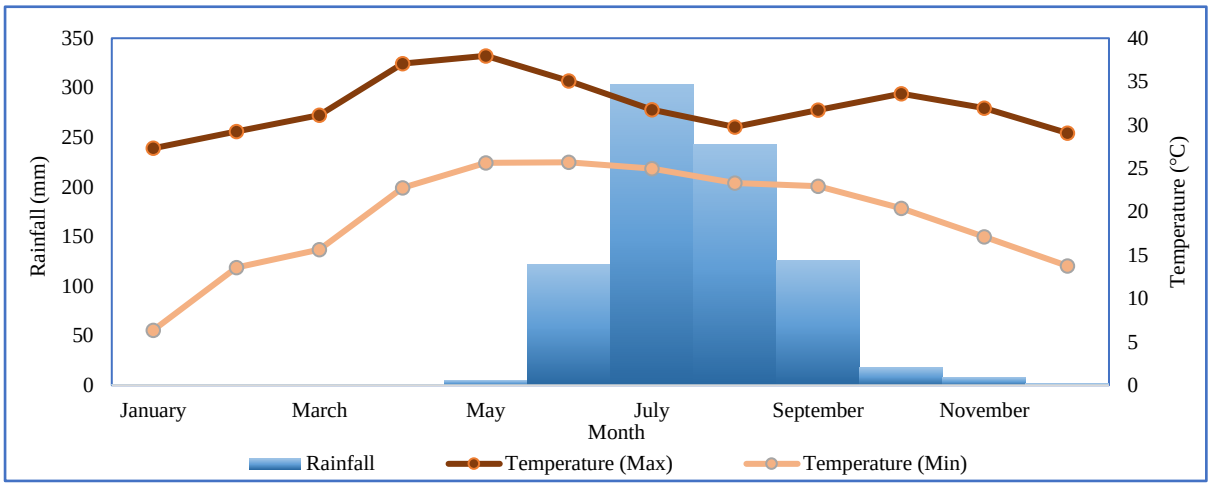

Figure 2.6 Average Monthly Distribution of Rainfall and Temperature in Gujarat (1961-2020).

2.6 Vegetation

Gujarat features a diverse range of ecosystems across its various regions. In Kachchh, Central Gujarat, and Saurashtra, expansive grasslands and scrub forests thrive, supporting unique wildlife adapted to arid environments (Kushwaha et al., 2020). Moving towards the western coast, the landscape transforms with abundant mangroves, coral reefs, and seagrasses along the shoreline (Patro et al., 2017), providing critical habitats for marine life and nesting grounds for coastal birds. To the north, Gujarat is characterized by vast saline deserts, such as the Great Rann of Kachchh, contrasting with the moist deciduous tropical forests found in South Gujarat. Additionally, hilly forests grace the South Gujarat and Saurashtra regions, adding further ecological diversity and serving as vital corridors for wildlife movement. The state encompasses four primary forest ecosystems, each characterized by distinct vegetation and ecological features. Firstly, the Tropical Moist Deciduous Forests are prominent in South Gujarat, supporting a variety of deciduous tree species, with teak being one of the important species of this ecosystem (Maisuria et al., 2022). Secondly, the Littoral and Swamp Forests are found along the coastal areas, featuring mangroves and other plant species adapted to brackish water conditions, providing essential habitats for coastal wildlife (Mahapatra et al., 2013). Moving to the Tropical Dry Deciduous Forests, these ecosystems are prevalent in

different parts of the state, with vegetation adapted to seasonal rainfall patterns. Lastly, the Northern Tropical Thorn Forests are found in areas like Kutch, known for their arid conditions. These forests are characterized by trees such as Acacia Arabica and Acacia Leucophloea, which have adapted to thrive in drought-prone and harsh climates. According to the Indian State Forest Report of 2019, Gujarat's total forest cover extends over 14,857 sq. km, accounting for 7.57% of the state's geographical area. In terms of Tree Canopy Density (TCD) classes, Gujarat comprises 377.90 sq. km of Very Dense Forest with 70% or more TCD, 5,092 sq. km of Moderately Dense Forest with 40-70% TCD, and 9,387.43 sq. km of Open Forest with 10-40% TCD. The total forested area increases to 17,851 sq. km when including Scrub Forest (<10% TCD), which covers 2,994.11 sq. km (https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-gujarat.pdf).

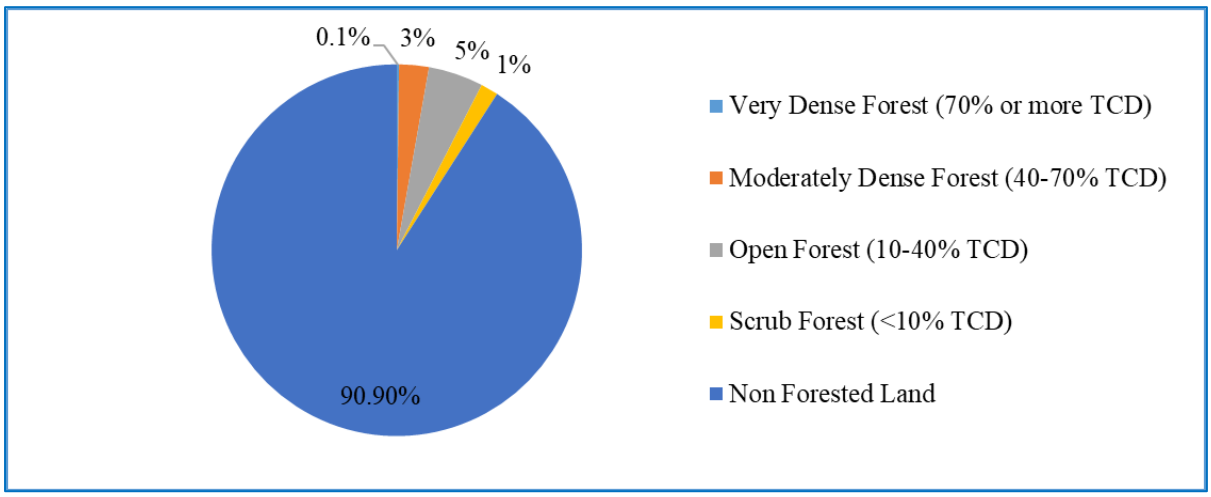

Figure 2.7 Forest Cover Distribution in Gujarat.

Source: Indian State Forest Report of 2019, Volume II, Chapter 11.8

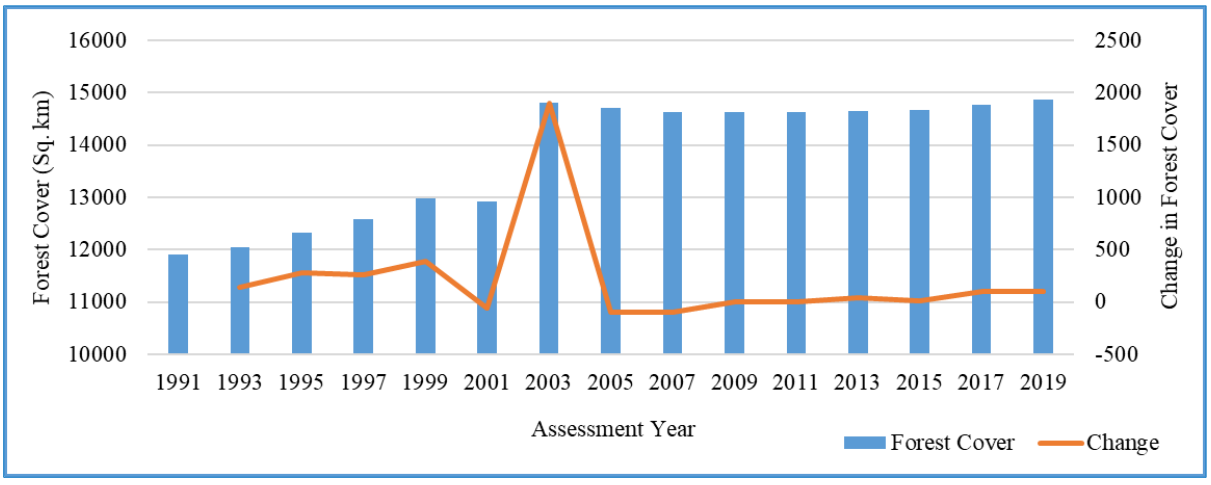

Figure 2.8 Changes in Forest Cover of Gujarat Since 1991

Source: Indian State Forest Report of 2019, Volume II, Chapter 11.8

Gujarat's recorded forest area includes 7.57% (14,857 sq. km) of forest cover and an additional 3.52% (6,912 sq. km) of tree cover, amounting to a combined 11.09% of the state's total area. The tree cover in the state has decreased by 1,112 sq. km. compared to the statistics reported in ISFR 2017, while the forest cover has increased by 100.33 sq. km. from the previous assessment. This change suggests possible shifts in land use, conservation practices, or natural ecological processes. Additionally, Gujarat has the second-largest mangrove cover in India, following West Bengal (Kathiresan, 2018). The mangrove cover in Gujarat has experienced significant growth, increasing from 911 sq. km. in 2001 to 1177.27 sq. km. by 2019. The distribution of mangroves across Gujarat is not uniform and spread in four distinct regions: Kutch (67.5%), the Gulf of Kutch (19.88%, including Jamnagar, Rajkot, Porbandar, Devbhoomi Dwarka, and areas encompassing Marine National Park), Saurashtra (5.7%), and South Gujarat (11.87%) (https://forests.gujarat.gov.in/mangrove-conserv.htm). Among these, the Kutch has the highest share of the state's total mangrove cover.

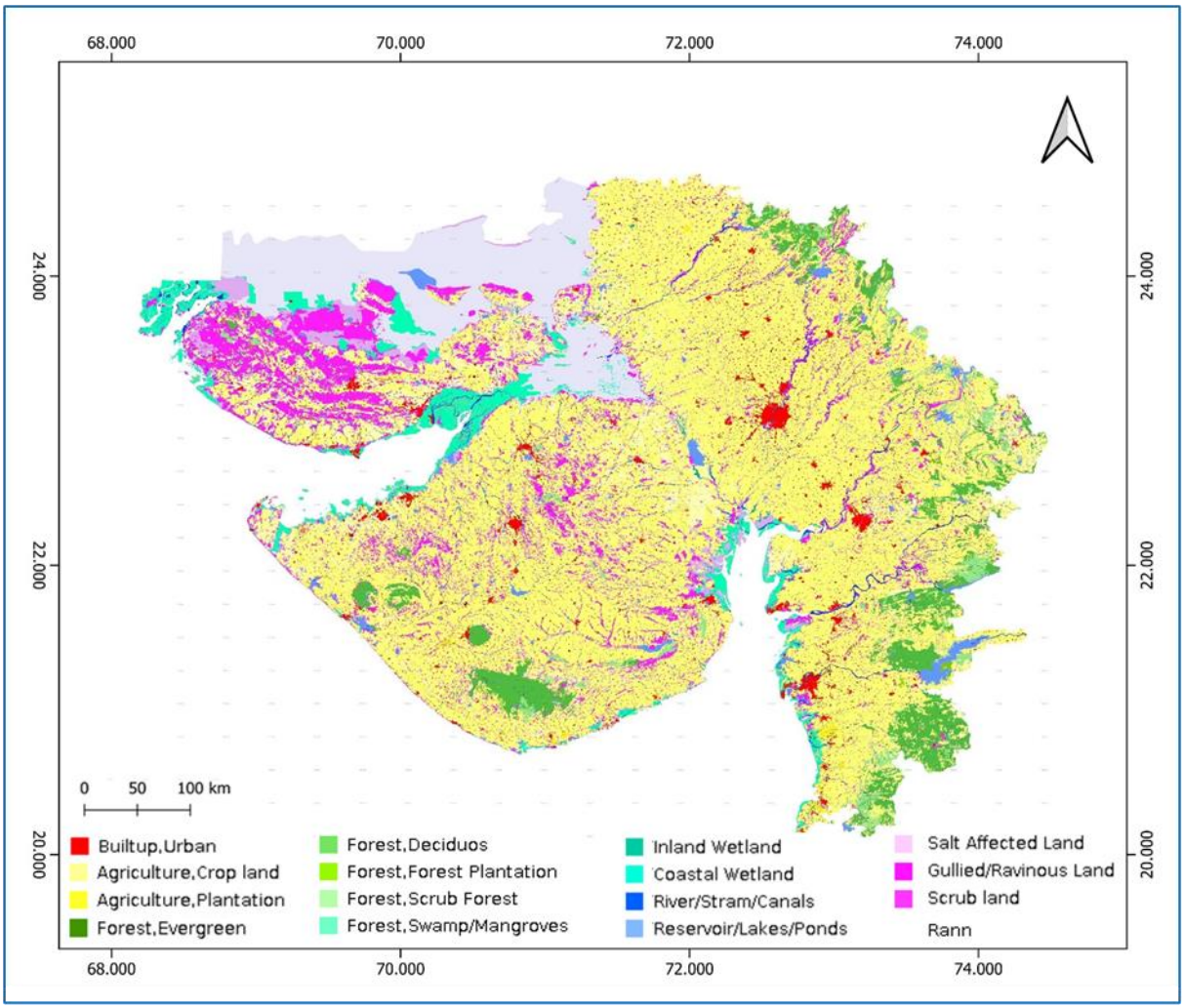

Figure 2.9 Land Use and Land Cover Map of Gujarat (2015-16), Scale 1:250,000. Source: Thematic Service, Bhuvan Platform. Prepared by NRSC, Hyderabad.

2.7 Geomorphology

Geomorphology is the study of landforms and the processes that shape the Earth's surface. Studying geomorphology facilitates understanding past climatic events, predicting future changes, and assessing human impacts on landscapes. The geomorphology of Gujarat exemplifies a rich tapestry of landforms sculpted by diverse geological processes of various origins. Evidence of tectonic activity is apparent in the Aravalli Range and the hilly terrain of the Kathiawar Peninsula (Vanik et al., 2021). Erosion and weathering have shaped rugged landscapes like the Girnar Hills in Saurashtra, showing the region's geological history. Fluvial processes from rivers like the Narmada and Tapi have formed extensive alluvial plains that support agriculture and settlements across Gujarat, particularly in Central and South Gujarat.

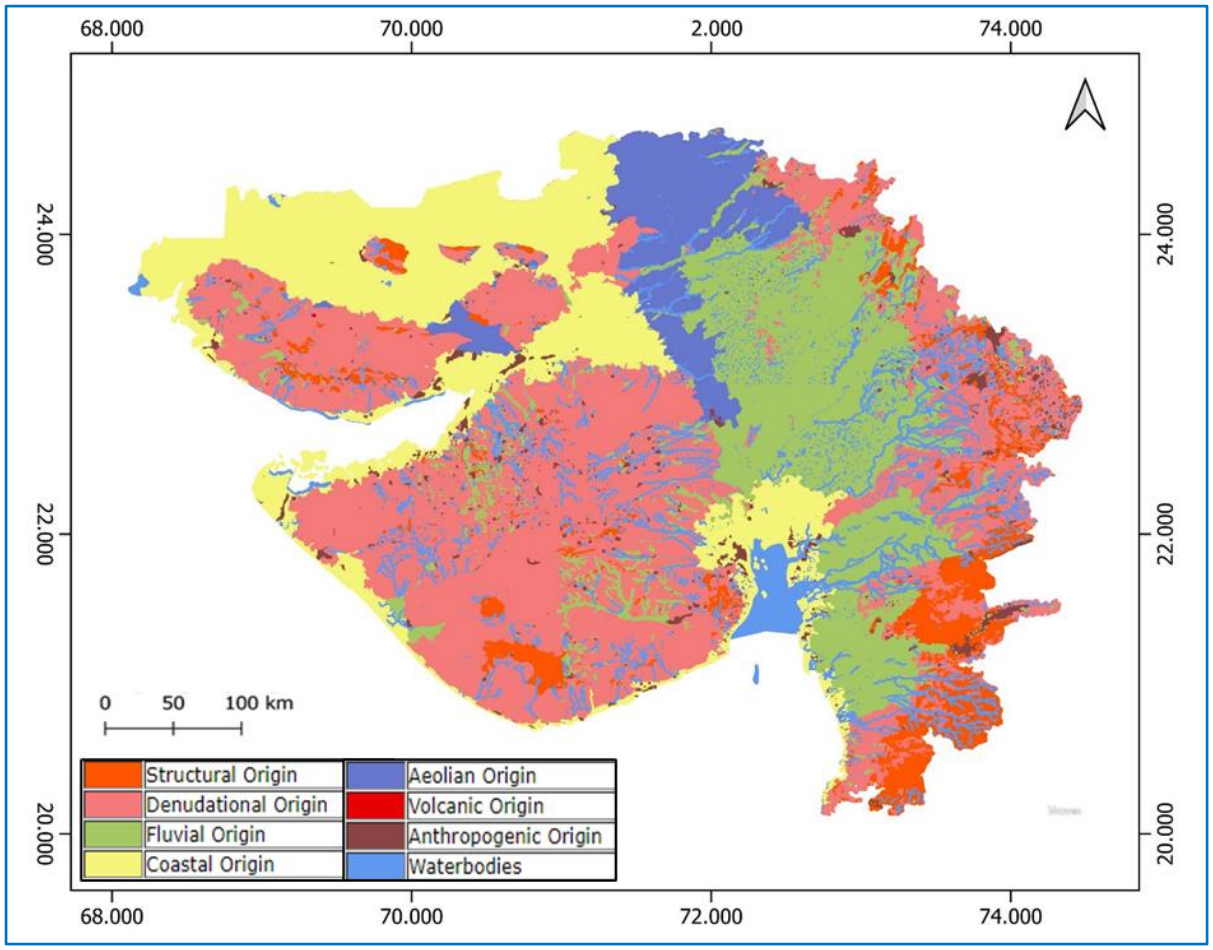

Figure 2.10 Gujarat's Geomorphology Map (2005-06) at 1:50,000 Scale Using Resourcesat-1 LISS-III. Source: Thematic Service, Bhuvan Platform. Prepared by NRSC, Hyderabad.

Along the coastline, wave action and sediment deposition have created sandy beaches, estuaries, and mangrove habitats. In the Rann of Kutch, aeolian processes have formed vast salt flats and seasonal wetlands, influencing local climate patterns. Despite limited volcanic activity, remnants of volcanic rocks and basaltic formations contribute to the geological

diversity of the state. Additionally, Human activities such as urbanization and agriculture interact with natural processes, influencing landforms, which can impact local climate dynamics and environmental conditions.

2.8 Rivers

Gujarat relies mainly on surface water for its water supply. With 185 river basins, the state's total water availability is 55,608 million m^3, of which surface water accounts for 38,100 million m^3, constituting just 2% of the country's total surface water quota (Swain et al., 2017). However, despite this relatively small percentage, Gujarat is home to 5% of the country's population. The SWM season brings a concentrated flow of rivers. Three main river groups traverse the state in different directions: the Narmada, Sabarmati, and Mahi rivers dominate the central and northern regions, while the Mithi, Khari, Bhadar, Shetrunji, and Bhogavo streams flow through Saurashtra. In the southern part of Gujarat, rivers like the Purna, Narmada, Damanganga, Tapi, and Ambika contribute to the region's water resources.

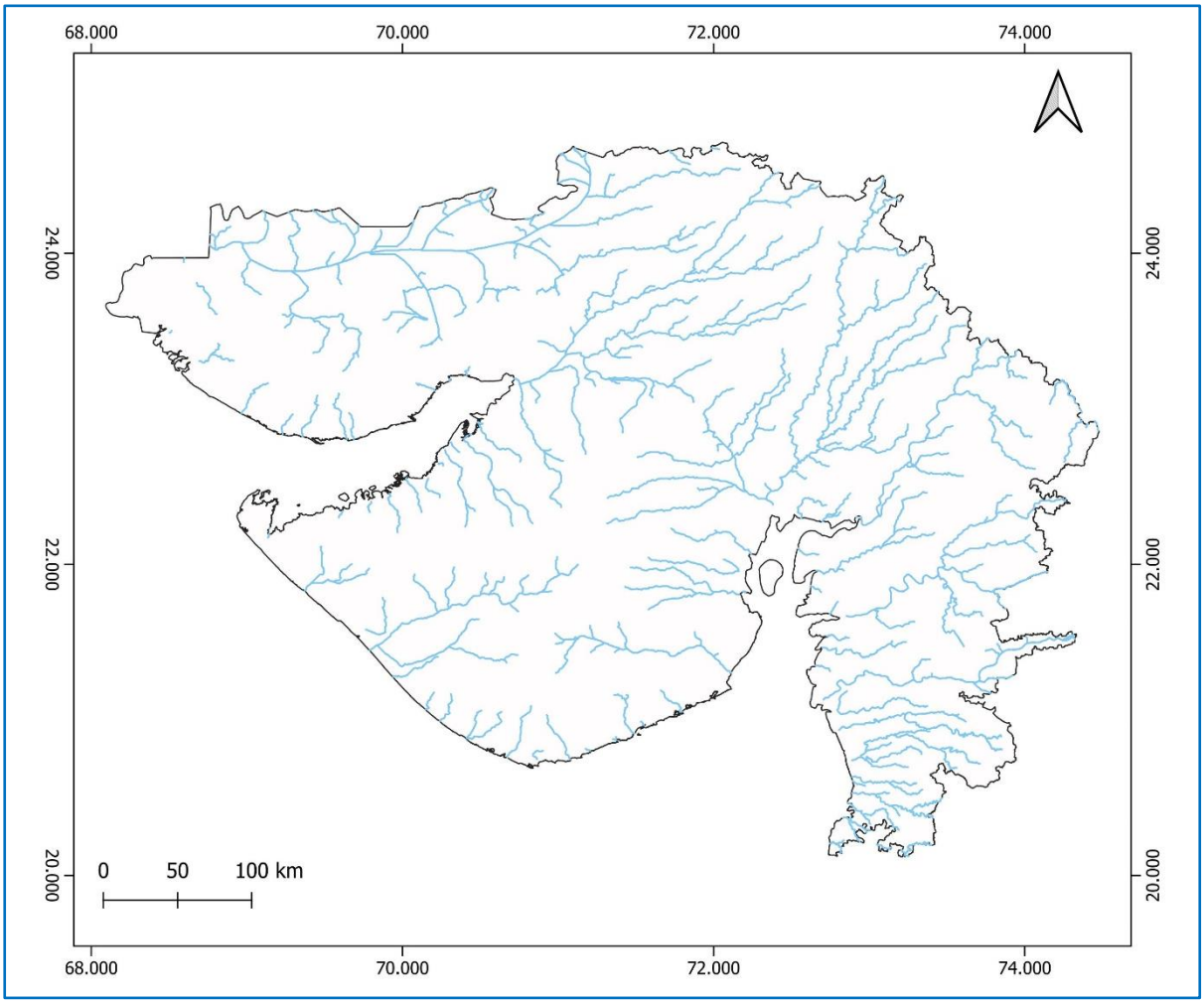

Figure 2.11 River Network of Gujarat: Streams Ranked 4th Order and Above.
Source: Lehner & Grill, 2013

2.9 Population Characteristics

Understanding population characteristics is indispensable in climate studies due to the profound influence that human demographics exert on environmental dynamics and climate change impacts. Population characteristics, including size, density, distribution, and socio-economic composition, are pivotal in shaping vulnerability and resilience to climate-related hazards. The responsibility for conducting the decadal census in India lies with the Office of the Registrar General and Census Commissioner of India, which operates under the Ministry of Home Affairs, Government of India. The last decennial population Census of India was conducted in 2011. However, the next scheduled Census for 2021 was postponed due to the COVID-19 pandemic. The 2011 Census was India's fifteenth decennial census since 1872 and the seventh consecutive census held after Independence. Census exercises in India constitute the largest administrative undertaking in the world. The population of India reached 1.21 billion in 2011, representing a 17% increase from 1.03 billion in 2001. In 2001, the population of Gujarat State was 50.6 million. According to the 2011 Census, Gujarat's population increased to 60.3 million, accounting for 4.99% of the nation's population.

2.9.1 Population Growth

Between 1961 and 2011, India's population more than doubled, increasing from around 439 million to over 1.21 billion. Initially marked by high growth rates ranging from 21% to 25% per decade during 1961-1991, driven by improved healthcare and sustained fertility rates, the rate of growth moderated in later decades. From 1991 to 2011, the growth rate reduced to around 18%, reflecting a shift towards stabilization attributed to factors like increased education and family planning awareness.

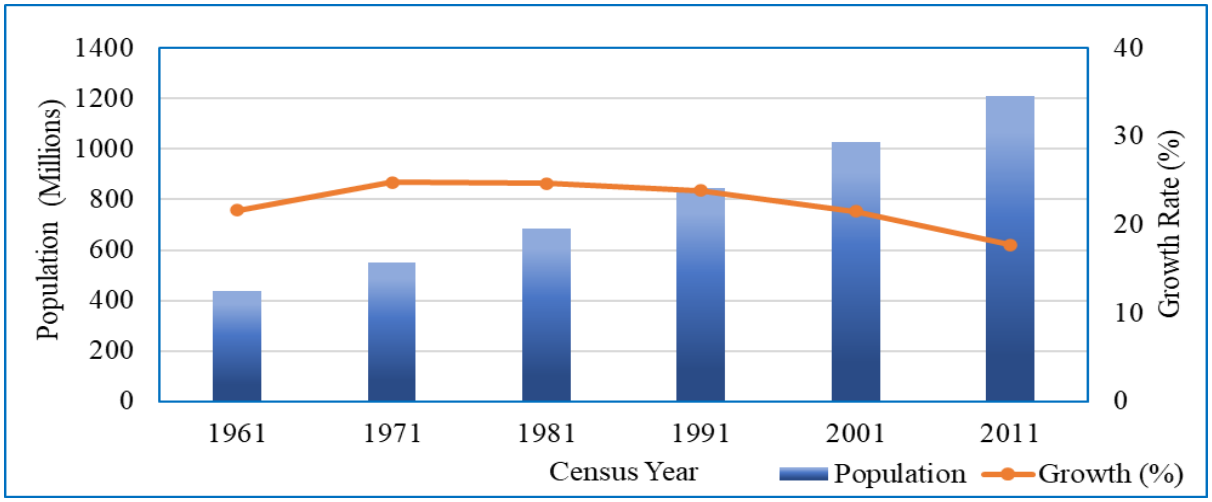

Figure 2.12 Population Growth Trends in India Over Decades.
Source- Statistical Year Book India 2022, MoSPI, Government of India.

The population growth of Gujarat increased substantially from around 20.6 million in 1961 to approximately 60.4 million in 2011, more than 3 times over this period. During the earlier decades (1961-1991), Gujarat experienced rapid population growth rates ranging from 21% to about 30% per decade. However, in the later decades (1991-2011), the growth rate moderated to about 19%.

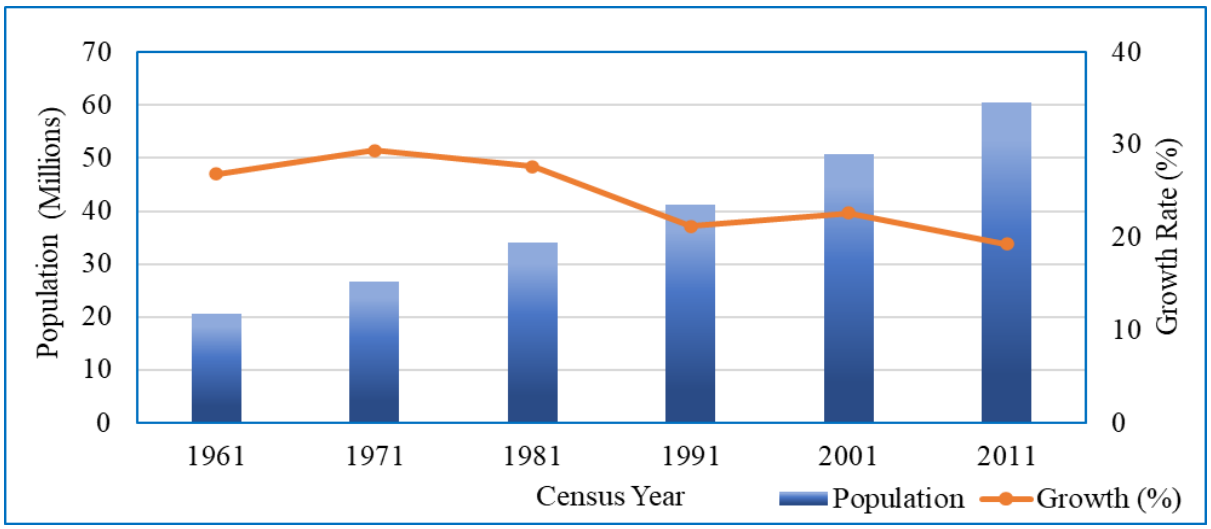

Figure 2.13 Decadal Trends in Population Growth for Gujarat.
Source- Table A-02: Decadal variation in population 1901-2011, Gujarat: Census, 2011.

2.9.2 Population Density

The population density of India and Gujarat has shown a substantial upward trend over the decades. In 1961, India's density was 143 persons per sq. km., rising to 382 persons per sq. km. by 2011. Gujarat experiences a similar trend, with density increasing from 105 persons per sq. km. in 1961 to 308 persons per sq. km. in 2011. Gujarat ranks as the fifth largest state in the area and the 10th most populous state in the nation.

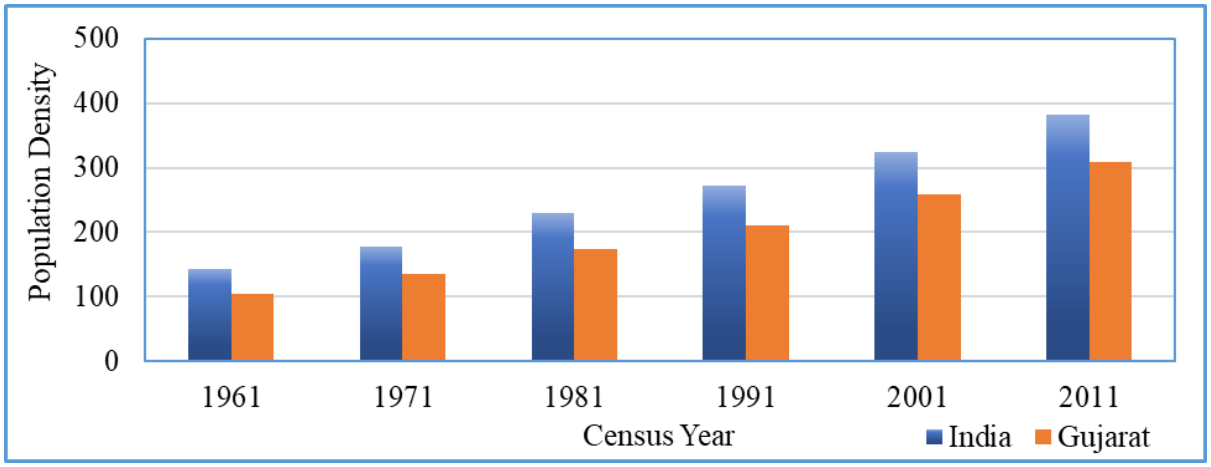

Figure 2.14 Population Density Trends in India and Gujarat Over Decades.
Source: Table A-02: Decadal variation in population 1901-2011, Gujarat: Census, 2011.

2.9.3 Sex Ratio

The Sex Ratio trends in Gujarat and India reveal intriguing patterns over the decades. In Gujarat, the Sex Ratio stood at 940 females per 1000 males in 1961 and showed relatively stable figures around the 930s in subsequent decades, declining slightly to 919 in 2011. Similarly, India's Sex Ratio was 941 in 1961, variating in the 930s range through the 1970s and 1980s, and then slightly increasing to 940 by 2011.

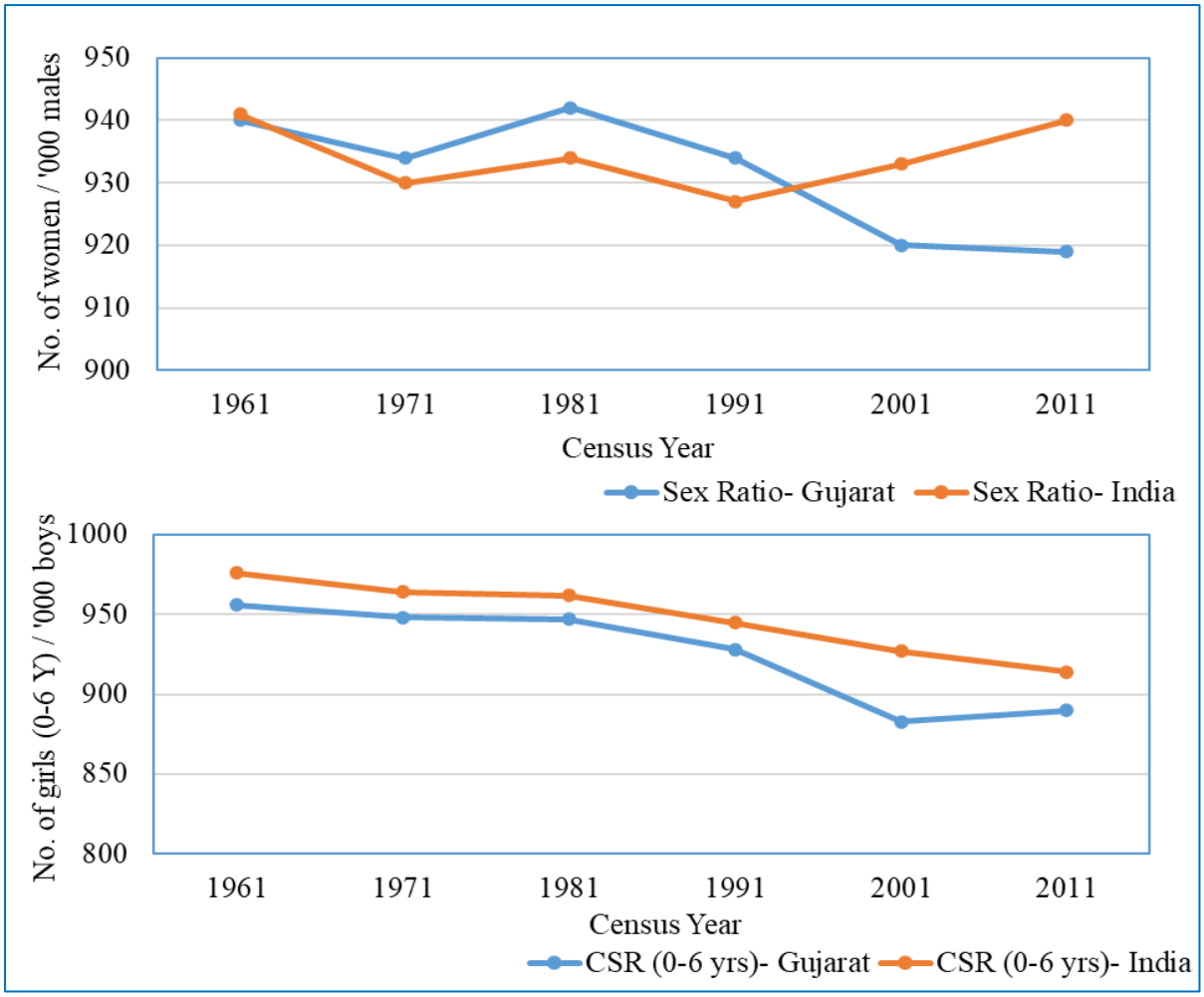

Figure 2.15 Trends in Sex Ratio and Child Sex Ratio in India and Gujarat Over Decades. Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

The Child Sex Ratio (0-6 years) trends in Gujarat and India show a decline over the decades. In Gujarat, the Child Sex Ratio was relatively high in 1961 at 956 girls per 1000 boys, remaining stable at around 940s during subsequent decades before declining to 890 by 2011. Similarly, India's Child Sex Ratio was 976 in 1961, gradually decreasing to 914 by 2011, with intermittent fluctuations during the 1970s and 1980s. The contrasting trends between Child Sex Ratio and overall Sex Ratio could indicate differing patterns of gender preference and perhaps changes in social attitudes and policies over time.

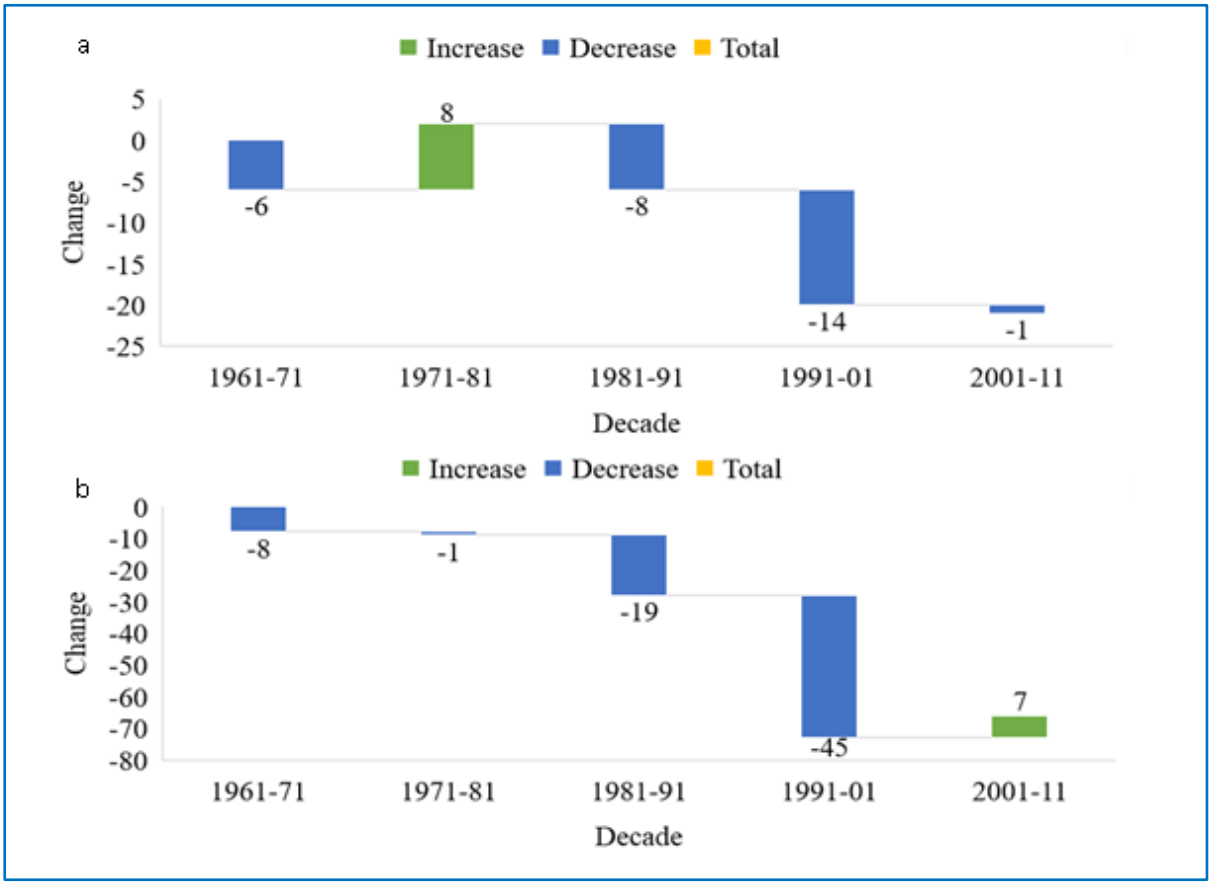

Figure 2.16 Decadal Changes in (a) Sex Ratio and (b) Child Sex Ratio for Gujarat. Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

Over the decades, a continuous decline has been observed in the Child Sex Ratio and overall Sex Ratio in Gujarat (Figure 2.10). These trends highlight the importance of continued monitoring and urgent action to address underlying factors contributing to these declines.

2.9.4 Literacy Rate

Over the decades, Gujarat and India have experienced remarkable progress in Literacy Rate, highlighting efforts to expand educational opportunities and awareness among people. In Gujarat, the overall literacy rate increased from 31.5% in 1961 to 78.03% in 2011, while India saw its overall Literacy Rate increase from 28.3% to 74.04% during the same period. Male Literacy Rate in Gujarat increased from 42.5% to 85.75% between 1961 and 2011, paralleling India's increase from 40.4% to 82.14%. These gains highlight a historical emphasis on male education and literacy initiatives. Meanwhile, the Female Literacy Rate in Gujarat improved from 19.7% to 69.68% over the decades, mirroring India's increase from 15.35% to 65.46%. Despite starting from lower levels, the growth in the Female Literacy Rate shows ongoing efforts to promote gender equality and empowerment through education, which has significant implications for their social, economic, and political participation.

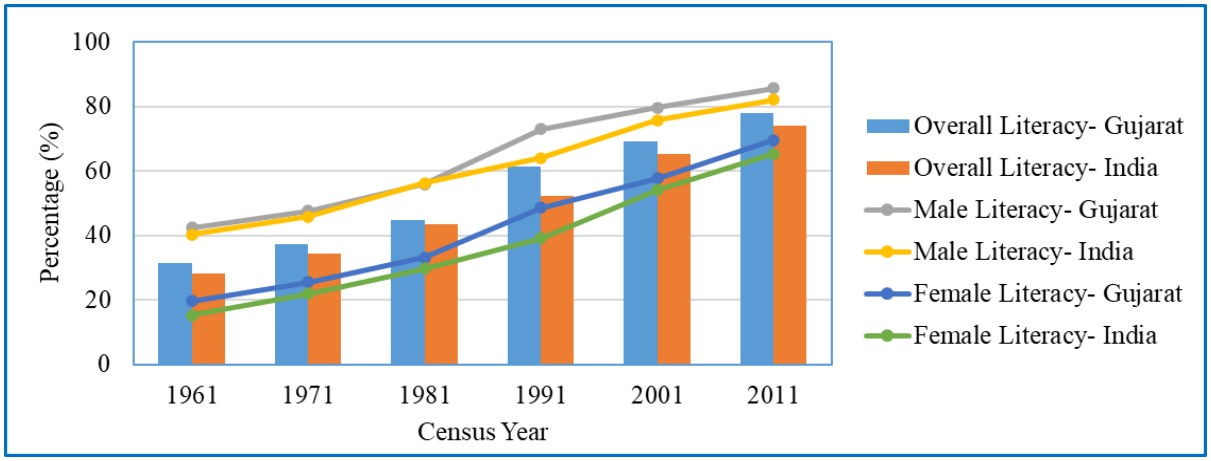

Figure 2.17 Growth of Literacy Rates in Gujarat and India Over the Decades.
Source: Decadal Population Census, India, 1961-2011.

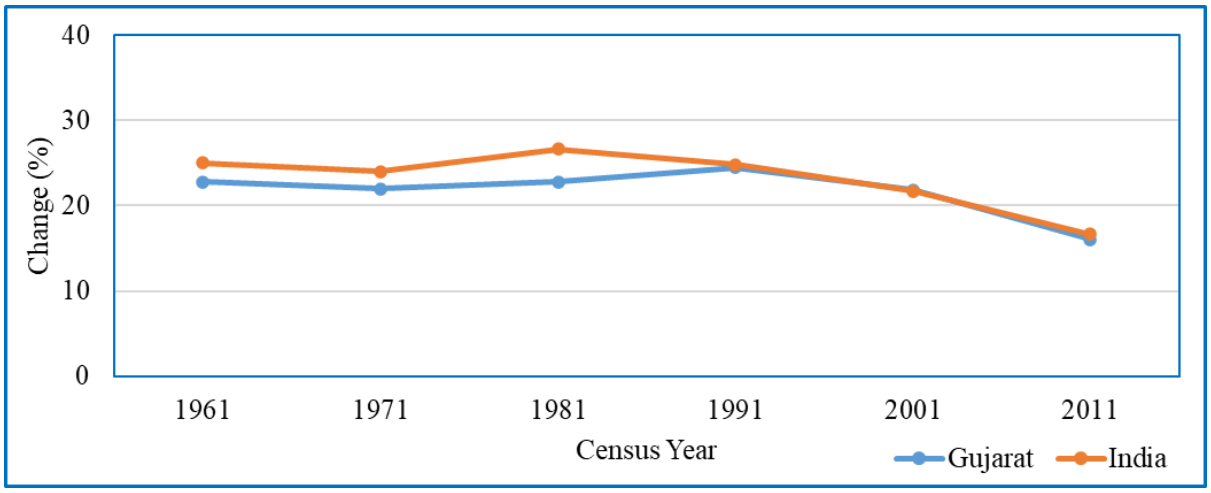

Figure 2.18 Gender Disparity in Literacy Rates Over Decades in Gujarat and India.
Source: Decadal Population Census, India, 1961-2011.

In Gujarat, the gender literacy gap was about 22.8% in 1961 and reduced to 16.07% by 2011. Similarly, India experienced a decline from 25.05% in 1961 to 16.68% in 2011. These trends signify progress towards gender parity in literacy, with both Gujarat and India reducing the gender gap in Literacy Rate over the decades.

2.9.5 Urban Demographics

The urbanization trends in Gujarat have consistently surpassed those of India as a whole over the decades, as reflected in the population statistics residing in urban areas. In 1961, Gujarat's urban population stood at 25.77%, surpassing India's 18% of urban residents. This trend continued to increase over time, with Gujarat's urbanization rate increasing to 42.6% by 2011, well ahead of India's urbanization rate of 31.16% during the same period. Projected data suggests a continuous increase in the urban population of Gujarat, showing ongoing urbanization processes and the attractiveness of urban centers for livelihood opportunities.

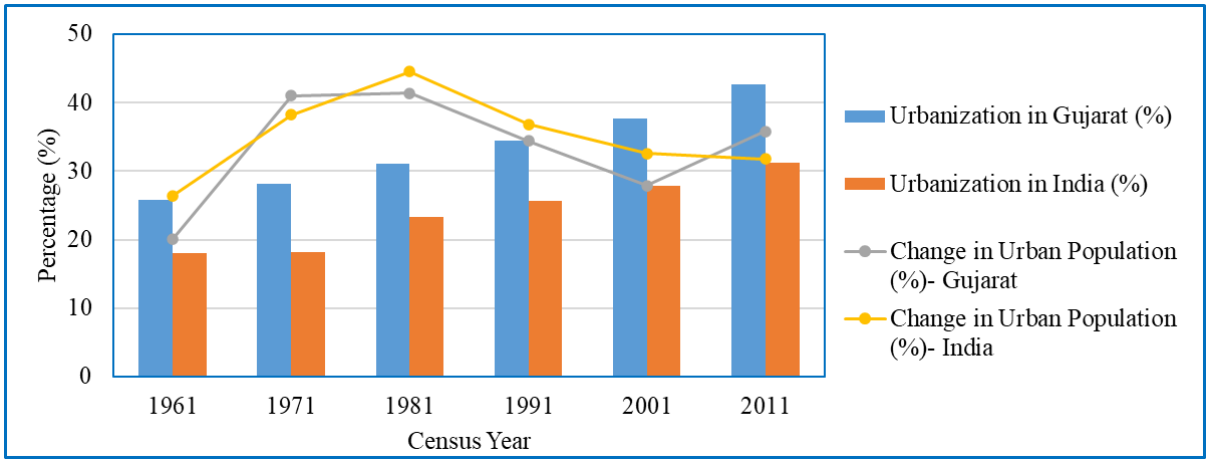

Figure 2.19 Changing Urban Demography of Gujarat and India over Decades.
Source: Decadal Population Census, India, 2011.

Additionally, Urban areas exhibit higher levels of female literacy than rural regions, with consistent improvements observed over the decades. Urban female literacy increased from 39.88% in 1961 to 82.08% in 2011, showing substantial strides in educational access and opportunities for women. In contrast, Rural female literacy increased marginally to 62.41% by 2011. However, despite advancements in Literacy Rates, the Sex Ratio in urban areas remains stagnant, around 880 females per 1,000 males since 1961. This lack of change suggests persistent gender imbalances in urban regions. In contrast, the sex ratio in rural areas has fluctuated slightly over the decades but generally remains higher than in urban areas. The disparities between urban and rural female literacy highlight the importance of tailored interventions to address urban-specific concerns and enhance educational access for women in Gujarat.

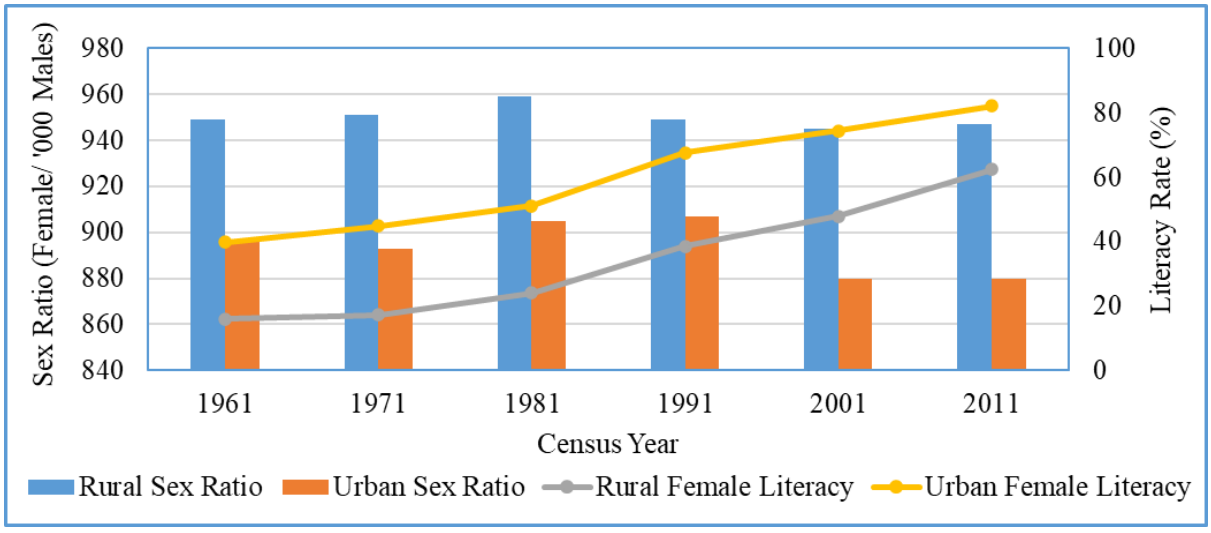

Figure 2.20 Female Literacy and Sex Ratio Across Urban and Rural Gujarat Over Decades.
Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat and Decadal Population Census, India, 2011.

2.9.6 Distribution of Population by Age Groups

The age group distribution data for rural and urban areas of Gujarat reveals intriguing demographic patterns. Rural regions tend to have higher percentages of young children, particularly in the 0-4 and 5-9 age brackets, while urban areas show a higher concentration of young adults, especially in the 20-24 and 25-29 age groups. However, as age increases, rural populations start to outnumber urban populations, particularly in the elderly categories, suggesting a potential trend of retirement migration. These findings highlight the need for targeted policies to address the diverse needs of different age groups across rural and urban Gujarat, focusing on areas such as healthcare, education, and infrastructure development.

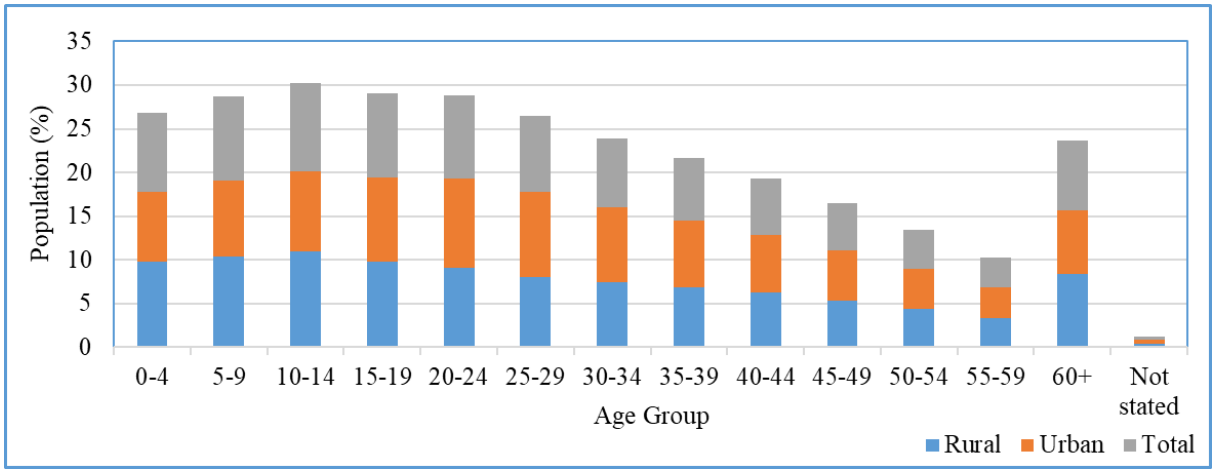

Figure 2.21 Age Group Distribution Across Rural and Urban Areas of Gujarat.
Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

2.10 Socio-Economic Profile

The socio-economic profile of Gujarat State includes a range of indicators essential for understanding its overall development. These indicators cover health, literacy, industrial development, employment, gender empowerment, workforce status, and various economic parameters. They are crucial for comprehending the state's health scenario and its relationship with socio-economic factors.

2.10.1 Income and Employment

Gujarat is a significant contributor to India's economic growth, despite its small population share. It contributes 8.36% to the National GDP and provides diverse employment opportunities, especially in manufacturing, textiles, and petrochemicals. In the fiscal year 2019-20, Per Capita Income at current market prices reached Rs. 2,13,936 showing a slight increase from Rs. 1,97,447 in the preceding financial year. Additionally, Gujarat has the

lowest unemployment rate among major states, with a 79.91% placement rate through employment exchanges (2020).

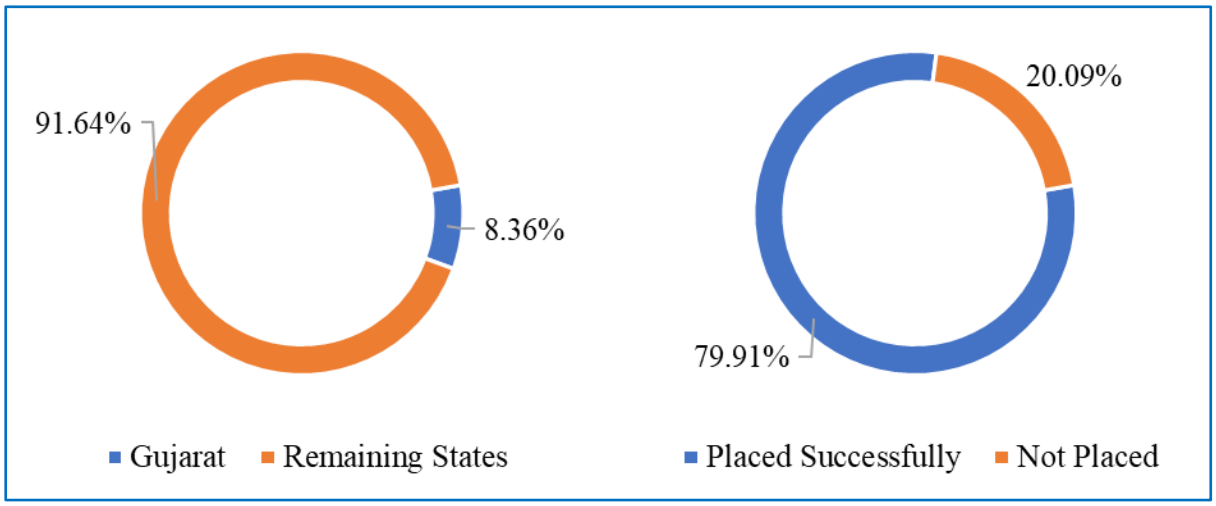

Figure 2.22 Gujarat's (a) Contribution to India's GDP, 2019-20, (b) Employment Exchange Placements as a Percentage of Total Registrations in Gujarat, 2020.
Source: Socio-Economic Review, Gujarat State, 2021-22.

2.10.2 Industrial Development

Gujarat's industrial advancement is significant, contributing 16.8% to the nation's industrial output, showing its leadership in industrial development. The state hosts various industrial clusters and SEZs, stimulating business expansion and innovation. These specialized zones focus on sectors such as automobiles, textiles, ceramics, and chemicals, facilitating collaboration and capitalizing on economies of scale. In the fiscal year 2019-20, Gujarat led the country's total exports with a share of 20.83% (Rs. 4,48,000 crores estimated).

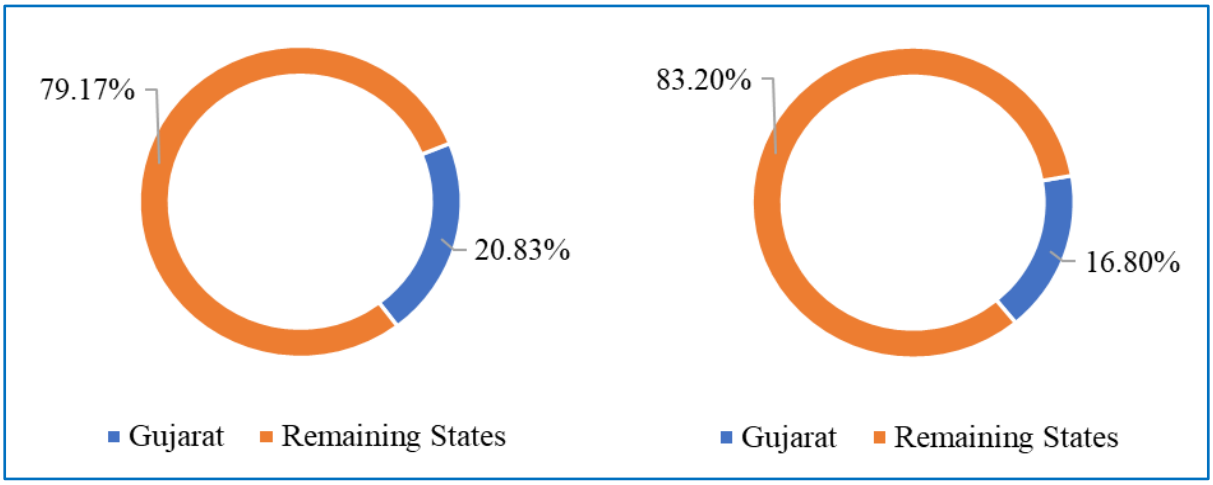

Figure 2.23 Gujarat's (a) Contribution to All-India Trade Exports, 2019-20, (b) Contribution to India's Industrial Output, 2019-20.
Source: Socio-Economic Review, Gujarat State, 2020-21.

According to the Department of Promotion of Industry and Internal Trade, Gujarat attracted FDI amounting to USD 3.4 billion between April and September 2019-20. This accounted for about 5.4% of India's total FDI inflows, emphasizing Gujarat's crucial role in drawing foreign investment. The state is promoting mega projects and innovative initiatives to foster an investor-friendly environment by harnessing its strengths as growth drivers. Gujarat has the world's largest petroleum refining hub, is a global leader in processed diamonds, and ranks as the world's 3rd-largest producer of denim, exhibiting its substantial industrial capacity.

2.10.3 Healthcare

Health indicators in Gujarat have also witnessed substantial improvement, with a concerted focus on prioritizing healthcare services to ensure the well-being of its residents. From 1961 to 2011, the Crude Birth Rate (CBR) and Crude Death Rate (CDR) in Gujarat have shown declines, reflecting demographic changes. Initially, Gujarat had a higher CBR than the national average, but from 1991 onwards, it fell below the national average, indicating effective family planning and socio-economic improvements. In contrast, Gujarat's CDR, which was slightly higher than the national average in 1961, decreased more rapidly and consistently remained below the national average from 1971 onwards. Overall, Gujarat has shown considerable progress in reducing birth and death rates, surpassing national trends, and highlighting improved quality of life and health outcomes in the state.

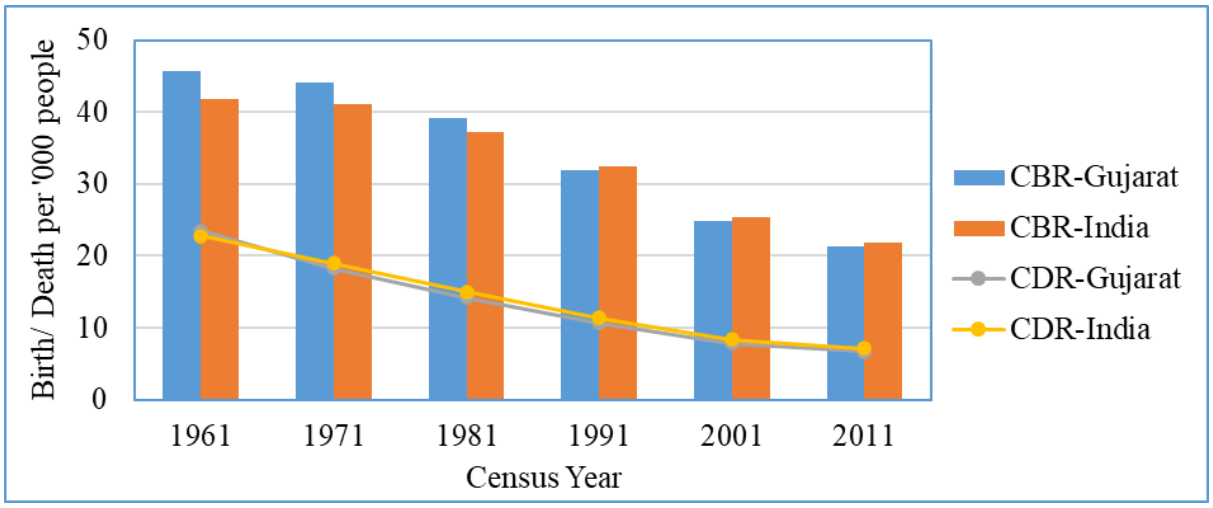

Figure 2.24 Crude Birth and Death Rates in Gujarat and India Across Decades.
Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

Additionally, the availability of health facilities in Gujarat shows a comprehensive and well-tiered healthcare infrastructure aimed at providing accessible medical services across the state. With 9,156 sub-centers, Gujarat ensures widespread primary healthcare coverage,

particularly in rural areas, offering essential services like maternal and child healthcare. The 1,342 Primary Health Centers (PHCs) further strengthen this foundation by providing more comprehensive primary care and serving as the first point of contact for medical needs. The presence of 331 Community Health Centers (CHCs) highlights a robust secondary healthcare network, offering specialized treatments and acting as referral centers for PHCs. As per Health Dossier 2021, NHSRC- Gujarat, the state has 37 Sub District/Sub Divisional Hospitals and 22 District Hospitals, which deliver advanced medical care and serve as tertiary referral centers, ensuring that even more complex health issues can be addressed within the state. This extensive network of health facilities underscores Gujarat's commitment to enhancing healthcare accessibility and quality for its population.

2.10.4 Life Expectancy at Birth

From 1961 to 2011, Gujarat experienced significant improvements in life expectancy at birth for both males and females, reflecting advancements in healthcare, nutrition, and overall living conditions. In 1961, Gujarat's life expectancy was slightly higher than the national average for both genders. However, in 1971, Gujarat fell behind India. By 1981, Gujarat had again surpassed the national average, maintaining higher life expectancy for males and females through the 1990s and early 2000s. By 2011, Gujarat's life expectancy for males (64.6 years) and females (67.7 years) was slightly lower than the national average (66.12 years for males and 68.22 years for females). Over the 50 years, life expectancy in Gujarat increased by 17 years for males and 21.7 years for females, underscoring substantial progress. However, the slight lag behind the national average in 2011 highlights the need for continued focus on health initiatives to sustain and enhance these gains.

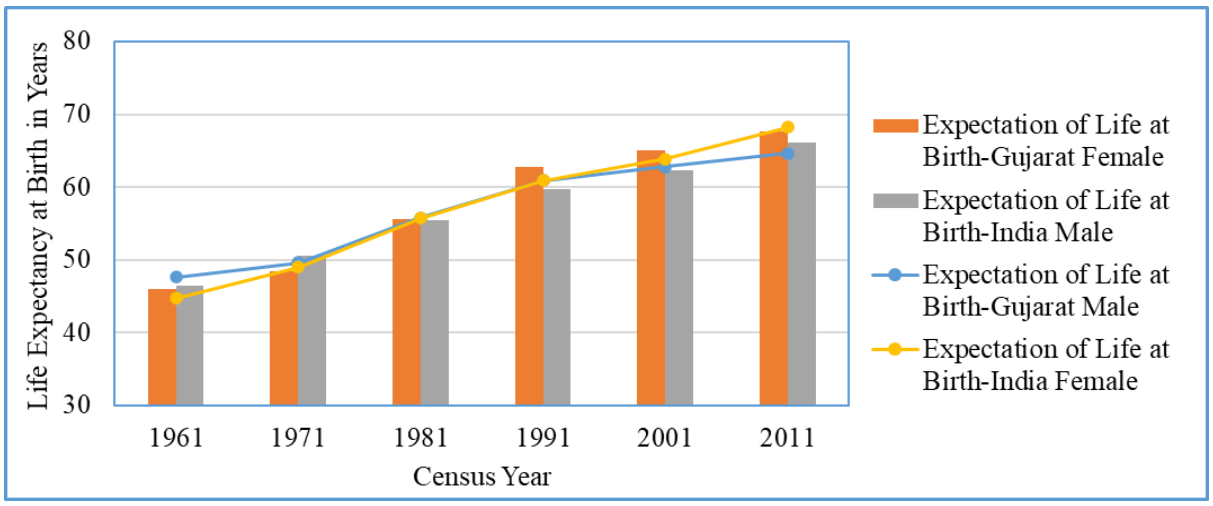

Figure 2.25 Life Expectancy at Birth in Gujarat and India overall.
Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

2.10.5 Workforce

From 1961 to 2011, the proportion of total workers in the state's population showed a consistent upward trend, increasing from 27.21% in 1961 to a peak of 41.95% in 2001, before slightly decreasing to 40.98% in 2011. This indicates a growing labour force participation over the years. Main workers, engaged in full-time employment, mirrored this upward trend until 1991, rising from 27.21% in 1961 to 34.12% in 1991. However, after 1991, the percentage of main workers started to vary, dropping to 33.7% in 2011. This suggests some variability in full-time employment opportunities or a shift in employment patterns. According to the National Classification of Occupations (1968), used in the 1971 and 1981 censuses, the 1981 census of India categorized the population based on economic activity into three groups: main workers (working 183 days or more), marginal workers (working less than 183 days), and non-workers (not engaged in any work). Since then, the proportion of Marginal workers has been increasing in the state, from 5.04% in 1981 to a peak of 8.35% in 2001, before decreasing to 7.28% in 2011. This trend indicates a growing segment of the workforce engaged in less stable or marginal employment

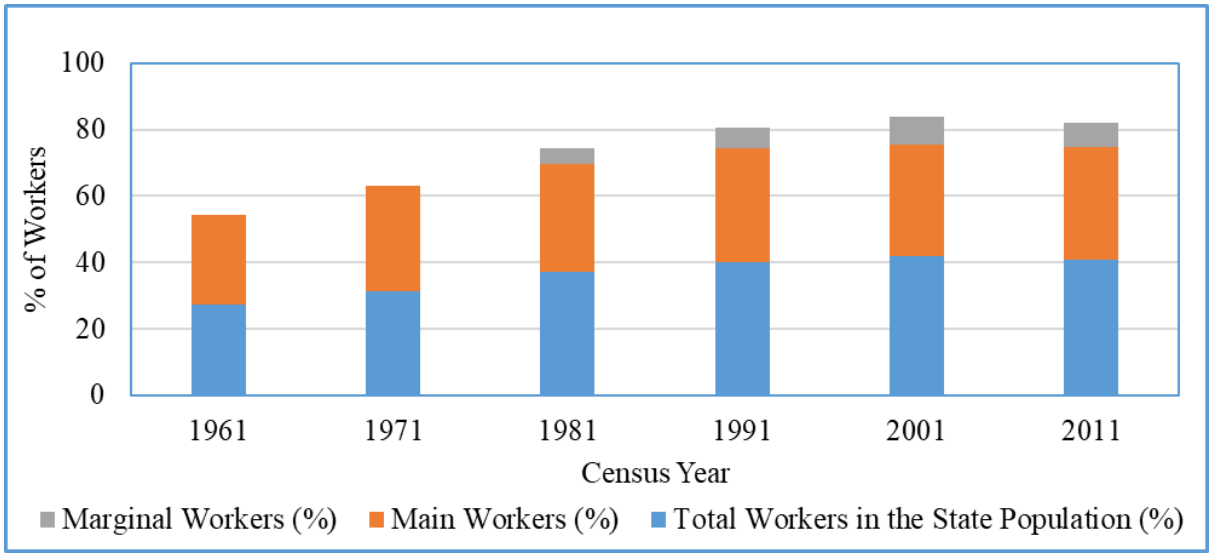

Figure 2.26 Proportion of Main and Marginal Workers in Gujarat's Workforce.
Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

The data on the classification of main workers in Gujarat from 1961 to 2011 reveals significant shifts in employment patterns. Over this period, the percentage of cultivators steadily declined from 43.12% in 1971 to 26.75% in 2011, indicating a move away from traditional farming. Similarly, agricultural labourers decreased from 22.49% in 1971 to 12.05% in 2011. Conversely, the category of "Others," which includes non-agricultural activities, saw a substantial rise, growing from 31.59% in 1971 to 59.6% in 2011. This

increase highlights a diversification of the workforce towards industrial and service sectors. Workers engaged in household industries saw a decline from 2.81% in 1971 to 1.6% in 2011. Figure 2.27 suggests a significant economic transition in Gujarat from an agriculture-based economy to a more diversified one, with a growing emphasis on non-agricultural sectors.

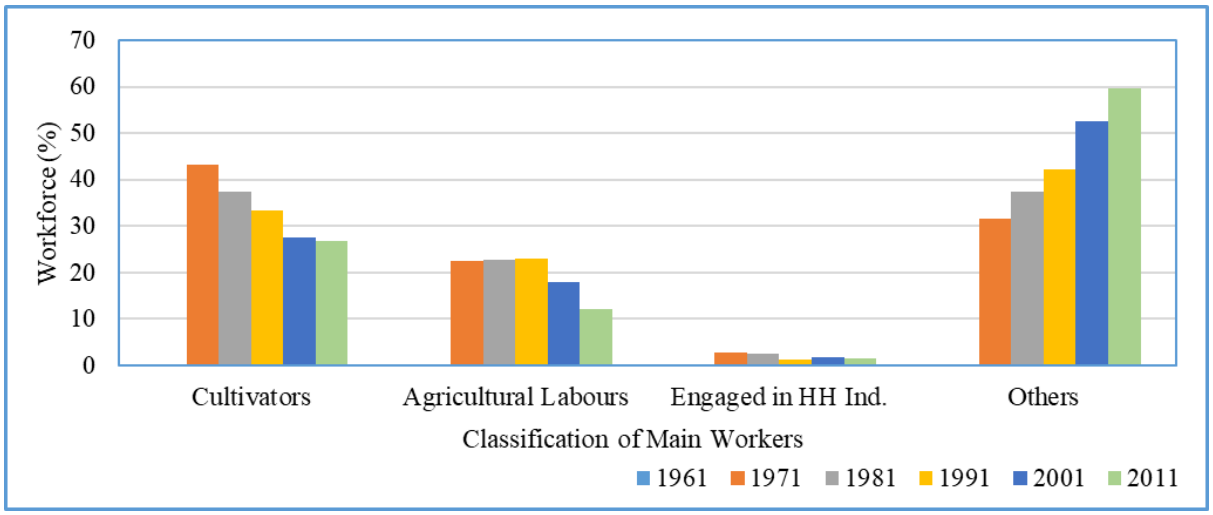

Figure 2.27 Changes in Occupation Patterns Among Main Workers Over Decades in Gujarat. Source: Health Statistics 2015-16, Health and Family Welfare Department, Gujarat.

Gujarat is making significant progress across several socio-economic indicators, including education, housing, infrastructure, and access to basic services. The state prioritizes access to quality education, evidenced by various initiatives to improve educational outcomes. Gujarat has substantially reduced primary education dropout rates and invests in higher education and skill development. Access to affordable housing and robust infrastructure supports economic activities and social connectivity. In recent decades, several schemes have been launched to enhance access to housing. These initiatives represent concerted efforts by authorities to address housing challenges and improve living conditions for citizens. In addition to basic infrastructure development, Gujarat emphasizes the expansion of mega projects. The state is advancing this by building expressways, high-speed rails, and improving bus connectivity. It prioritizes multi-lane roads for smoother transportation and leads in green energy with Mega Green Energy Parks, promoting sustainability. Gujarat's well-developed infrastructure continues to fuel progress and prosperity across diverse sectors, positioning it as a beacon of economic resilience and growth in India. The state also prioritizes essential services, aiming to improve living standards and quality of life through innovative projects such as interlinking rivers, showing its commitment to sustainable development.