Original Research Article

District-Level Assessment of Water Body Areas across Different Regions of Gujarat, India

ABSTRACT

Surface water, including lakes, rivers, and wetlands, plays a vital role in agriculture, industry, and climate regulation. Rapid and accurate mapping is essential for water resource management and disaster prevention, especially during floods and droughts. This study analysed surface water distribution in Gujarat's regions; Middle Gujarat, North Gujarat, Saurashtra, South Gujarat, and Kachchh using Normalized Difference Water Index (NDWI) derived from Sentinel-2 satellite imagery on the Google Earth Engine platform for May 2020 and May 2024. The study revealed that in 2024, water bodies covered areas of 692.16 km2 (2.33%) in Middle Gujarat, 180.63 km2 (0.62%) in North Gujarat, 727.91 km2 (1.27%) in Saurashtra, 721.86 km2 (3.38%) in South Gujarat, and 4207.67 km2 (10.75%) in Kachchh. Key findings highlighted Anand, Sabarkantha, Bhavnagar, and Tapi as the districts with the largest water body areas in 2024 for Middle Gujarat, North Gujarat, Saurashtra, and South Gujarat, respectively. The highest increases in water body areas between 2020 and 2024 occurred in Anand (52.17 km2), Banaskantha (21.35 km2), Bhavnagar (32.39 km2), and Bharuch (66.08 km2) for Middle Gujarat, North Gujarat, Saurashtra and South Gujarat, respectively. Conversely, the greatest reductions were observed in Panchmahals (-7.6 km2), Aravalli (-21.58 km2), Rajkot (-30.67 km2), and Tapi (-44.54 km2) for Middle Gujarat, North Gujarat, Saurashtra and South Gujarat, respectively. Significant changes were noted in Bharuch and Tapi within South Gujarat. Furthermore, this study placed less focus on estimating water body areas in Kachchh due to the presence of marshy land and desert area. Accurate surface water mapping is crucial for sustainable resource management, planning for future needs, and supporting decisions on water allocation for agriculture, industry, and domestic purposes.

***Keywords:*** *Water body, Gujarat, NDWI, Sentinel 2, Google Earth Engine (GEE), Surface Water, Regions and Districts of Gujarat.*

1. INTRODUCTION

Water is a fundamental resource essential for sustaining life, playing a vital role in human well-being, industrial processes, livestock care, and agricultural activities (Jakovljević et al., 2019; Cheng et al., 2022). For humans, water is crucial for hydration, sanitation, and overall health, forming the foundation of daily life and public health systems (Adams et al., 2009; Horwitz et al., 2011; Howard et al., 2020). Industries rely on water for production, cooling, cleaning, and transportation, making it a critical factor in economic development and technological advancement. In livestock farming, water is indispensable for maintaining animal health, supporting metabolic functions, and ensuring high productivity. Similarly, agriculture, which feeds the growing global population, depends heavily on water for irrigation, crop growth, and soil fertility (Fereres et al., 2007; Rosegrant et al., 2009). The efficient management of water resources is paramount for ensuring food security and meeting the demands of urbanization and industrialization. However, with increasing population and climate change, water scarcity has become a significant challenge, emphasizing the need for sustainable use and conservation practices (Dolan et al., 2021; Liu et al., 2022; Jain et al., 2024). This highlights the interconnected importance of water across various sectors, reinforcing its critical role in supporting life and development.

Large-scale mapping of surface water is crucial for conserving, managing, and utilizing water resources while enhancing our understanding of the hydrologic cycle and climate change impacts. Accurate and timely spatial data support effective resource management, disaster prevention, and mitigation of floods and droughts. Remote sensing has emerged as a powerful, cost-effective tool for dynamic and continuous monitoring of water distribution patterns, offering valuable insights into spatiotemporal changes. Techniques for surface water extraction are broadly categorized into single-band image thresholding, spectral index-based identification, and image classification methods. Satellite imagery, particularly from advanced sensors like Sentinel-2 and Landsat, provides high-resolution, multi-spectral data that enable precise delineation of water bodies such as lakes, rivers, reservoirs, ponds, and wetlands (Rokni et al., 2014; Du et al., 2016; Huang et al., 2018; Jawak et al., 2015; Papa and Frappart, 2021; Cretaux et al., 2023; Tomar et al., 2023; Melnychenko and Solovey, 2024; Tola et al., 2024). These technologies facilitate effective monitoring of even remote and inaccessible water sources (Ritchie et al., 2003; Thomson, 2021; Le et al., 2023; Ibrahim et al., 2024) and distinguish water bodies from other surface features with exceptional precision (Yang et al., 2017; ED et al., 2020; Singh et al., 2020; Pena-Regueiro et al., 2020; Yilmaz et al., 2023).

Water bodies, encompassing rivers, lakes, reservoirs, wetlands, and other aquatic systems, play a vital role in sustaining ecological balance, agricultural productivity, and human livelihoods (Bassi et al., 2014; Chang et al., 2015; McCartney et al., 2015; Apostolaki et al., 2020). Accurate mapping and monitoring of these water bodies are essential for effective water resource management, urban planning, and environmental conservation (McFeeters, 1996; Kafy et al., 2021; Pampaniya et al., 2023; Tomar et al., 2023; Chatrabhuj et al., 2024; Gupta and Gupta, 2024). Remote sensing technology has emerged as a powerful tool for assessing and monitoring surface water bodies, offering a large-scale, cost-effective, and reliable approach compared to traditional ground-based methods (Slonecker et al., 2001; Huang et al., 2018; Pampaniya et al., 2018; Balas et al., 2023a and 2023b; Rahaman et al., 2023; Deng et al., 2024; Pampaniya et al., 2024; Raghul and Porchelvan, 2024; Thakor et al., 2024).

Changes in surface water bodies impact agricultural and industrial production, the environment, ecosystems, food security, and public health (Viala, 2008; Whitehead et al., 2009; Misra, 2014; Cheng et al., 2022;). Accurate knowledge of the spatial distribution, stability, and quality of surface water is essential for regional economic growth, urban planning, climate regulation, future water resource management, and environmental monitoring (Santoro et al., 2015; Pekel et al., 2016; Jakovljević et al., 2019; Dube et al., 2023).

The Normalized Difference Water Index (NDWI), introduced by McFeeters (1996), is a widely used remote sensing technique that leverages green and near-infrared (NIR) spectral bands to efficiently delineate water bodies while suppressing signals from vegetation and soil. Sentinel-2, launched by the European Space Agency (ESA), provides high-resolution (10 meters) multi-spectral imagery and crucial spectral bands (B3 and B8) for NDWI calculation, enabling precise monitoring of seasonal and interannual water body variations (Drusch et al., 2012). With its five-day revisit time, Sentinel-2 ensures consistent and updated data acquisition, making it ideal for mapping inaccessible or remote water sources. Unlike time-intensive traditional field methods, NDWI facilitates large-scale, cost-effective monitoring of hydrological patterns and water resource dynamics, which is vital for addressing climate change impacts (Gao, 1996).

This study focuses on the application of Sentinel-2 satellite data and the NDWI to quantify and assess changes in water body areas in Gujarat, India, between 2020 and 2024. Gujarat, characterized by diverse hydrological and climatic conditions, offers an ideal case study to evaluate the utility of NDWI in water body extraction. By leveraging multi-temporal satellite imagery, this research aims to provide a detailed understanding of surface water dynamics in the region, which is critical for supporting regional planning, agricultural productivity, and environmental sustainability.

2. material and methods

2.1 Study Area

Gujarat is situated on the western coast of India between 20°08'26'' N to 24°42'46'' N latitudes and 68°10'36'' E to 74°25'20'' E longitudes (Fig. 1). Gujarat shares a boundary with Rajasthan in the north east, Madhya Pradesh in the east and Maharashtra in the south and south east. it has a 1600 km long coast-line. Its northern boundary forms the international boundary with Pakistan. The Gujarat state is divided into five regions namely; North Gujarat, Middle Gujarat, Saurashtra, South Gujarat and Kachchh. Each region has its unique climate, cultural heritage, economic focus, and social characteristics, making Gujarat one of India's most varied and vibrant states. It comprises of 33 districts with a total geographical area of 1.96 lakh square kilometres.

Gujarat is home to major rivers such as Narmada, Tapi, Mahi, Sabarmati, Shetrunji, Bhadar, Damanganga, Saraswati, Vishwamitri, Hiran, Machhu, and Rukmavati. Key dams in the state include Sardar Sarovar (on the Narmada River), Ukai (on the Tapi River), Kadana (on the Mahi River), Dharoi (on the Sabarmati River), Dantiwada (on the West Banas River), Kamleshwar (on the Hiran River in the Gir Forest area), Bhadar (on the Bhadar River), Machhu (on the Machhu River), Fatehgadh (on the Ghelo River), and Ver (on the Shetrunji River). Prominent ponds include Kankaria Lake and Vastrapur Lake (Ahmedabad), Hamirsar Lake (Bhuj), Gopi Talav (Surat), Lalpari Lake and Nyari Dam Reservoir (Rajkot), Chandola Lake (Ahmedabad), and Lakhota Talav (Jamnagar). Major sarovars include Narayan Sarovar (Kutch), Sur Sagar Lake (Vadodara), Nal Sarovar (Bird Sanctuary), Sudarshan Sarovar (Junagadh), and Gomti Sarovar (Dwarka).

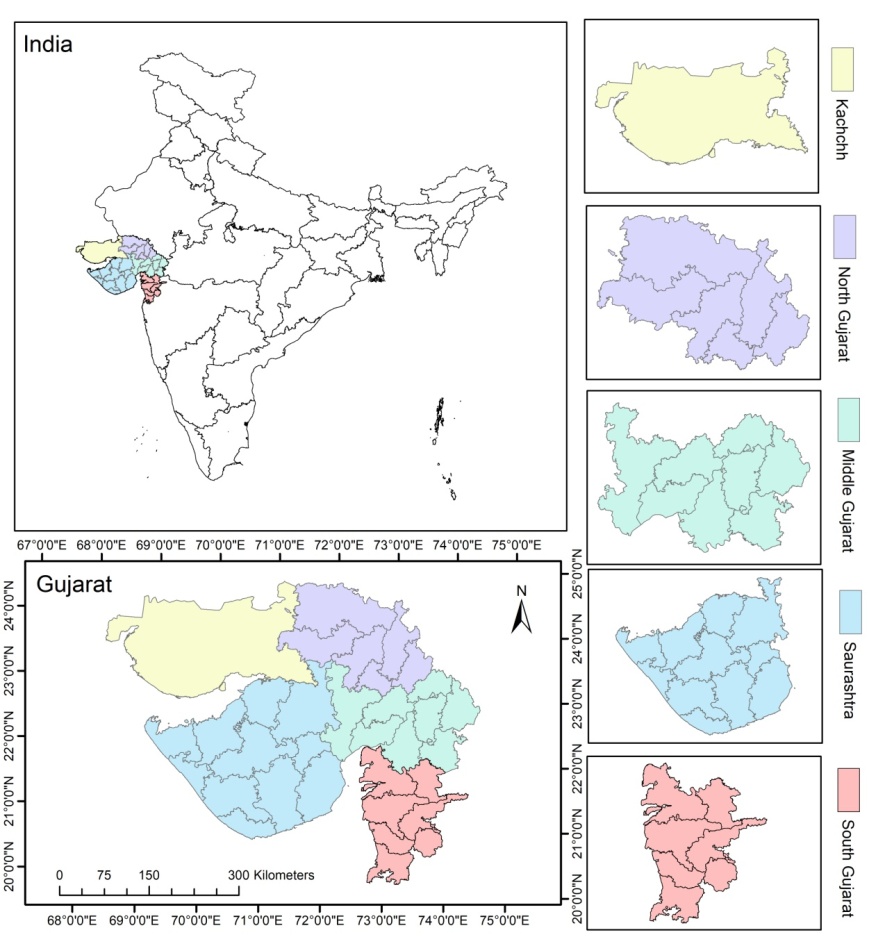


Fig.1: Geographical location of study area

**2.1.1 North Gujarat Region**

North Gujarat comprises districts like Gandhinagar, Banaskantha, Patan, Aravalli, Mehsana, and Sabarkantha. This region is characterized by semi-arid plains, with a mix of hilly terrain and fertile agricultural land. Agriculture is the backbone of north Gujarat, with crops such as potato, wheat, bajra (pearl millet), cotton, castor, mustard, maize and groundnut being widely cultivated. The region also has a significant dairy industry, especially in Banaskantha and Mehsana, which are the top milk-producing areas in India.

**2.1.2 Middle Gujarat Region**

Middle Gujarat, often called the heart of Gujarat, includes districts such as Ahmedabad, Vadodara, Anand, Kheda, Chhota Udaipur, Mahisagar, Panchmahal and Dahod. This region is known for its fertile land and substantial industrialization. Ahmedabad, the largest city in Gujarat, is an industrial and economic hub, often referred to as the "Manchester of India" due to its large textile industry. Middle Gujarat is agriculturally rich, with Anand being famous for the tobacco cultivation and the dairy cooperative movement led by Amul.

**2.1.3 Saurashtra Region**

Saurashtra, located on the Arabian Sea's western coast, encompasses districts like Rajkot, Jamnagar, Junagadh, Amreli, Bhavnagar, Botad, Devbhumi-Dwarka, Gir-Somnath, Morbi, Porbandar, and Surendranagar. It is a peninsular region characterized by coastal plains, arid lands, and rolling hills. Agriculture is essential to Saurashtra’s economy, with groundnut, cotton, pulses and sesame being major crops. The region is also known for its fishing industry due to its proximity to the sea.

**2.1.4 South Gujarat Region**

South Gujarat comprises of seven districts; Surat, Bharuch, Narmada, Navsari, Dang, Valsad, and Tapi. The region is known for its lush green landscape, fertile soil, and high rainfall due to its proximity to the Western Ghats. Agriculture and horticulture are major economic activities, with sugarcane, mango, sapota, banana and rice being prominent crops. South Gujarat's scenic beauty, including its forests, waterfalls, and hills, make it a popular destination for eco-tourism.

**2.1.5 Kachchh Region/District**

Kachchh, located in the northwestern part of Gujarat, is the largest district in India by area. Kachchh is the region as well as district in the Gujarat state. This region/district is known for its unique landscape, which includes the Great Rann of Kachchh, a vast salt marsh that transforms into a white desert during the dry season. Kachchh is relatively arid and has a sparse population, with agriculture limited to areas where irrigation is available.

**2.2 Methods**

The image data used in this study was obtained from the <https://dataspace.copernicus.eu> website using sentinel 2 data for the year of May 2020 and May 2024. By computing the difference between image bands and using a suitable threshold to separate the findings into two categories (water and non-water features), the spectral water index i.e., NDWI has been utilized to extract the surface water bodies from remotely sensed data.

Two bands B3 (green) and B8 (near-infrared) of the Sentinel-2 satellite were utilized to compute the Normalized Difference Water Index (NDWI) for May 2020 and May 2024. NDWI is a satellite-derived index designed to emphasize open water features by leveraging the combination of green and near-infrared spectral bands. The index is mathematically represented by Equation 1, as proposed by McFeeters (1996).

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Where, Green and NIR refer to the reflectance in the green and near-infrared bands of the MS data, respectively.

1. results and discussion

The region wise surface water area was extracted and discussed in detail herein

* 1. District-Wise Water Body Area in Different Region of Gujarat for The Years 2020 and 2024
     1. Middle Gujarat Region

Table 1 presents an analysis of water body changes in Middle Gujarat from 2020 to 2024, highlighting shifts in area (km²) and percentage contributions across districts. Ahmedabad experienced a significant expansion of 36.59 km2 (0.53%), reflecting rapid urbanization and infrastructure growth. Anand exhibited the largest increase at 52.17 km2 (1.71%), likely driven by industrial and agricultural development.

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| **Table 1:** Water body area by district across all regions of Gujarat state | | | | | | | | | | |
| **Regions** | **Districts** | **2020** | **2024** | | **Variation** | **Regions** | **Districts** | **2020** | **2024** | **Variation** |
| **Middle Gujarat** | Ahmedabad | 117.38\* (1.68) | 153.98 (2.21) | | 36.59 (0.53) | **Saurashtra** | Morbi | 92.78 (1.94) | 77.87 (1.63) | -14.9 (-0.31) |
| Anand | 227.13 (7.44) | 279.31 (9.14) | | 52.17 (1.71) | Devbhumi Dwarka | 104.17 (2.6) | 100.36 (2.51) | -3.81 (-0.1) |
| Chhota Udepur | 36.07 (1.08) | 29.75 (0.89) | | -6.31 (-0.19) | Jamnagar | 76.8 (1.35) | 61.66 (1.08) | -15.15 (-0.27) |
| Dahod | 24.75 (0.71) | 27.34 (0.78) | | 2.59 (0.07) | Bhavnagar | 179.62 (2.76) | 212.01 (3.25) | 32.39 (0.5) |
| Mahisagar | 85.58 (3.54) | 79.24 (3.28) | | -6.35 (-0.26) | Gir Somnath | 32.45 (1.27) | 31.59 (1.24) | -0.87 (-0.03) |
| Panchmahals | 59.37 (1.88) | 51.77 (1.64) | | -7.6 (-0.24) | Junagadh | 26.27 (0.44) | 16.67 (0.28) | -9.6 (-0.16) |
| Vadodara | 51.95 (1.32) | 49.76 (1.26) | | -2.19 (-0.06) | Amreli | 64.52 (0.92) | 62.08 (0.88) | -2.45 (-0.03) |
| Kheda | 19.59 (0.59) | 21.01 (0.63) | | 1.42 (0.04) | Porbandar | 28.44 (1.28) | 20.28 (0.91) | -8.16 (-0.37) |
| **South Gujarat** | Bharuch | 98.58 (2.08) | 164.66 (3.47) | | 66.08 (1.39) | Rajkot | 88.75 (1.2) | 58.08 (0.78) | -30.67 (-0.41) |
| Surat | 98.51 (2.36) | 113.71 (2.72) | | 15.19 (0.36) | Surendranagar | 62.25 (0.71) | 75.3 (0.85) | 13.04 (0.15) |
| Navsari | 41.84 (1.97) | 59.51 (2.8) | | 17.68 (0.83) | Botad | 9.58 (0.4) | 12.02 (0.5) | 2.44 (0.1) |
| Valsad | 32.98 (1.16) | 42.55 (1.49) | | 9.58 (0.34) | **North Gujarat** | Aravalli | 46.21 (1.53) | 24.64 (0.81) | -21.58 (-0.71) |
| Dangs | 1.74 (0.1) | 1.18 (0.07) | | -0.56 (-0.03) | Banas kantha | 24.21 (0.23) | 45.56 (0.44) | 21.35 (0.21) |
| Narmada | 104.1 (3.84) | 83.3 (3.07) | | -20.8 (-0.77) | Sabar kantha | 56.05 (1.37) | 54.16 (1.33) | -1.89 (-0.05) |
| Tapi | 301.48 (9.96) | 256.94 (8.49) | | -44.54 (-1.47) | Mahesana | 16.39 (0.39) | 19.34 (0.46) | 2.95 (0.07) |
| **Kachchh Region** | | 3460.8 (8.84) | 4207.67 (10.75) | 746.87 (1.91) | | Gandhinagar | 6.9 (0.34) | 8.56 (0.42) | 1.66 (0.08) |
| Patan | 22.3 (0.4) | 28.38 (0.51) | 6.08 (0.11) |
| \*Area in km2  Parenthesis represent Percentage | | | | | | | | | | |

Conversely, districts like Chhota Udepur and Mahisagar saw notable declines of 6.31 km2 (-0.19%) and 6.35 km2 (-0.26%), respectively, possibly due to deforestation or land degradation. Panchmahals also recorded a decrease of 7.6 km2 (-0.24%), indicative of similar environmental pressures. Vadodara exhibited a smaller decline of 2.19 km2 (-0.06%), suggesting relatively stable urban expansion. Meanwhile, Dahod and Kheda recorded modest increases of 2.59 km2 (0.07%) and 1.42 km2 (0.04%), reflecting localized growth, potentially in agriculture or small-scale development. The trends highlight the contrasting dynamics within Middle Gujarat, where urban centers such as Ahmedabad and Anand expand rapidly, while predominantly rural and tribal districts face land loss. This pattern underscores the need for sustainable urbanization, conservation of natural resources, and mitigation of land degradation. Balancing development with environmental protection remains critical to maintaining regional ecological integrity and supporting socio-economic growth in Middle Gujarat.

* + 1. North Gujarat Region

Table 1 highlights water body changes in North Gujarat from 2020 to 2024, illustrating variations in area (km2) and percentage contributions across districts. Aravalli exhibited the most substantial decline, with a reduction of 21.58 km2 (-0.71%), possibly due to agricultural shrinkage or land degradation. In contrast, Banaskantha saw a significant increase of 21.35 km2 (0.21%), reflecting growth potentially driven by expanded irrigation or industrial activities. Sabarkantha experienced a marginal decrease of 1.89 km2 (-0.05%), indicating stability with minimal changes in land use. Mahesana showed a modest rise of 2.95 km2 (0.07%), which could be attributed to urban development and agricultural intensification. Gandhinagar, the state capital, recorded a smaller increase of 1.66 km2 (0.08%), consistent with its gradual urban expansion and infrastructure development. Patan demonstrated a notable gain of 6.08 km2 (0.11%), possibly linked to increased agricultural or industrial activity. These trends highlight a contrasting pattern of water body change in North Gujarat, with urban and industrial districts like Banaskantha and Patan expanding, while Aravalli and Sabarkantha are shrinking.

* + 1. Saurashtra Region

Table 1 highlights temporal changes in water body areas across districts in the Saurashtra region between 2020 and 2024, reflecting both increases and declines in water resource distribution. Bhavnagar showed the most substantial growth in water body area, with an increase of 32.39 km2 (0.50%), likely due to improved water conservation practices, rainwater harvesting, or reservoir development. Surendranagar also experienced a notable rise of 13.04 km2 (0.15%), possibly linked to enhanced irrigation infrastructure or seasonal water storage. A minor increase of 2.44 km2 (0.10%) in Botad suggests gradual improvements in small-scale water management systems.

Conversely, significant declines were observed in several districts. Rajkot experienced the most pronounced reduction, losing 30.67 km2 (-0.41%) of its water body area, likely attributable to reduced rainfall, over-extraction of water, or sedimentation in reservoirs. Jamnagar and Morbi saw substantial decreases of 15.15 km2 (-0.27%) and 14.90 km2 (-0.31%), respectively, indicating potential water scarcity issues or encroachment on water bodies. Junagadh and Porbandar also experienced declines of 9.60 km2 (-0.16%) and 8.16 km2 (-0.37%), possibly due to groundwater depletion or agricultural expansion. Declines in Devbhoomi Dwarka (-3.81 km2, -0.10%), Gir Somnath (-0.87 km2, -0.03%), and Amreli (-2.45 km2, -0.03%) suggest localized challenges in water conservation. These trends underscore the need for strategic water resource management to address declining water body areas, particularly in districts facing significant losses, while leveraging successes in Bhavnagar and Surendranagar for sustainable water body restoration in Saurashtra.

* + 1. South Gujarat Region

Table 1 analyzes water body changes in South Gujarat from 2020 to 2024, highlighting shifts in area (km²) and percentage contributions across districts. Bharuch exhibited the most significant growth, with an increase of 66.08 km² (1.39%), likely driven by industrial expansion and urbanization. Surat followed with a rise of 15.19 km² (0.36%), reflecting sustained urban development and economic growth in one of Gujarat’s key metropolitan areas. Navsari also recorded a notable gain of 17.68 km² (0.83%), potentially due to expanding agriculture and urban settlements. Valsad experienced a moderate increase of 9.58 km² (0.34%), indicating steady growth in its mixed-use development. In contrast, Dang showed a marginal decline of 0.56 km² (-0.03%), likely reflecting minimal surface water body change in this ecologically sensitive tribal district. However, significant losses were observed in Narmada and Tapi, with reductions of 20.8 km² (-0.77%) and 44.54 km² (-1.47%), respectively. These decreases may be attributed to deforestation, land degradation, or the impacts of water-intensive activities in these regions. Tapi’s substantial decline suggests pressing concerns over sustainable land management. The contrasting patterns of growth in urbanized districts and decline in rural or ecologically sensitive areas highlight the region's development-environment trade-offs. These findings emphasize the need for balanced policies that promote economic growth while conserving natural resources and mitigating land degradation, ensuring sustainable development across South Gujarat.

* + 1. Kuchh Region/District

Table 1 highlights significant changes in the water body area of the Kachchh region between 2020 and 2024, showcasing a notable increase of 746.87 km2 (1.91%) over this period. In 2020, the total water body area was 3460.8 km2 (8.84%) of the region's geographical expanse, which grew to 4207.67 km2 (10.75%) by 2024. This substantial increase may be attributed to several factors, including enhanced water management practices, construction or expansion of reservoirs, implementation of rainwater harvesting systems, and restoration of degraded wetlands. Additionally, the increase could be linked to climatic variations, such as above-average rainfall during monsoon seasons, contributing to the replenishment of natural and artificial water bodies. However, the increase warrants further examination to confirm whether these changes represent sustainable growth or temporary seasonal variations. This result may also be attributed to the expansion of marshy land, except for the increase in surface water body area in the Kachchh region. Therefore, less emphasis was placed on estimating water body areas in Kachchh particular to this study.

* 1. Region Wise Water Body Area in Gujarat for The Years 2020 and 2024

Table 2 provides an analysis of water body area across five regions of Gujarat includes Middle Gujarat, North Gujarat, Saurashtra, South Gujarat, and Kachchh for the years 2020 and 2024, with areas expressed in square kilometers and corresponding percentages of total regional area in parentheses. Figures 2 and 3 illustrate the spatial distribution of water body areas across various regions of Gujarat for both years. Middle Gujarat exhibited an increase from 621.82 km2 (2.09%) in 2020 to 692.16 km2 (2.33%) in 2024, indicating a modest rise of 70.34 km2 (0.24%). North Gujarat's water body area grew slightly from 172.06 km2 (0.59%) to 180.63 km2 (0.62%), a marginal change of 8.57 km2 (0.03%). In Saurashtra, the water body area declined from 765.64 km2 (1.33%) in 2020 to 727.91 km2 (1.27%) in 2024, marking a reduction of 37.73 km2 (0.06%). Similarly, South Gujarat experienced an increase from 679.23 km2 (3.18%) to 721.86 km2 (3.38%), a growth of 42.63 km2 (0.20%). Kachchh region/district have already explain in above section. The observed trends suggest varied hydrological dynamics across regions, potentially influenced by climate variability, water resource management practices, and regional geographical characteristics. While some regions, like Kachchh, saw significant improvement, others, such as Saurashtra, witnessed reductions. This underscores the need for region-specific water management strategies to address ecological, agricultural, and socioeconomic challenges.

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| **Table 2:** Water body area by region in Gujarat state | | | |
| **Regions** | **2020** | **2024** | **Variation** |
| **Middle Gujarat** | 621.82\* (2.09) | 692.16 (2.33) | 70.34 (0.24) |
| **North Gujarat** | 172.06 (0.59) | 180.63 (0.62) | 8.57 (0.03) |
| **Saurashtra** | 765.64 (1.33) | 727.91 (1.27) | -37.37 (-0.06) |
| **South Gujarat** | 679.23 (3.18) | 721.86 (3.38) | 42.63 (0.20) |
| **Kachchh** | 3460.80 (8.84) | 4207.67 (10.75) | 746.87 (1.91) |
| \*Area in km2  Parenthesis represent Percentage | | | |

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| **Fig. 2:** Spatial distribution of water body areas across various regions of Gujarat in 2020 | **Fig. 3:** Spatial distribution of water body areas across various regions of Gujarat in 2024 |

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| Fig. 4: Ability of Sentinel-2 imagery to detect various water body features |

* 1. Capability of Sentinel-2 Imagery to Detect Various Features

Sentinel-2 imagery, with 10-meter resolution and 13 spectral bands, excels in mapping diverse features like vegetation, water bodies, urban areas, and soil. Its red and near-infrared bands support vegetation monitoring, while shortwave infrared bands aid in detecting water bodies, wetlands, and soil moisture. Figure 4 illustrates the capability of this satellite imagery to identify diverse features on the Earth's surface. It highlights water body features such as a reservoir, a river, and two ponds, accurately depicted alongside their corresponding ground truth locations on the Google Earth map. Overall, Sentinel-2’s combination of spectral and spatial capabilities makes it a powerful tool for natural resource management like water body monitoring and mapping using NDWI.

4. conclusion

The study aimed to estimate the water body area and its changes between 2020 and 2024 across various districts in Gujarat, India, using Normalized Difference Water Index (NDWI) derived from Sentinel-2 satellite imagery. In 2024, water bodies covered areas of 692.16 km2 (2.33%) in Middle Gujarat, 180.63 km2 (0.62%) in North Gujarat, 727.91 km2 (1.27%) in Saurashtra, 721.86 km2 (3.38%) in South Gujarat, and 4207.67 km2 (10.75%) in Kachchh. Compared to 2020, these regions saw changes of 70.34 km2 (0.24%), 8.57 km2 (0.03%), -37.37 km2 (-0.06%), 42.63 km2 (0.20%), and 746.87 km2 (1.91%), respectively. The districts with the largest water body areas in 2024 were Anand in Middle Gujarat, Sabarkantha in North Gujarat, Bhavnagar in Saurashtra, and Tapi in South Gujarat. The highest increases in water body areas from 2020 to 2024 were observed in Anand (52.17 km2, 1.71%), Banaskantha (21.35 km2, 0.21%), Bhavnagar (32.39 km2, 0.5%), and Bharuch (66.08 km2, 1.39%) for Middle Gujarat, North Gujarat, Saurashtra, and South Gujarat, respectively. Conversely, the greatest reductions were recorded in Panchmahals (-7.6 km2, -0.24%), Aravalli (-21.58 km2, -0.71%), Rajkot (-30.67 km2, -0.41%), and Tapi (-44.54 km2, -1.47%) for Middle Gujarat, North Gujarat, Saurashtra, and South Gujarat, respectively. Overall, Bharuch and Tapi in South Gujarat exhibited significant changes in water body areas over the study period. Mapping surface water is essential for effective water resource management, promoting sustainable usage, and planning for future demands. Precise mapping facilitates informed decision-making regarding water allocation for agriculture, industry, and domestic purposes. Additionally, it aids in land use planning and zoning by offering critical insights into the location of water bodies and their potential influence on land development and utilization.

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