

# Analysis on Decadal Variation of Reservoir Area and Perimeter with Respect to Rainfall and Population

Rajashree Lodh<sup>1,\*</sup>, Sakshi Choudhary<sup>2</sup>

## Abstract

Water is an essential element for the survival and proper functioning of all life forms on Earth. In the state of West Bengal like many other regions groundwater rivers and water canals serve as the primary sources of water. This vital resource is distributed across various sectors including agriculture households and industrial facilities following necessary treatment processes. West Bengal's climate is characterized by a tropical monsoon type in its southern parts and a humid subtropical climate in its northern mountainous regions. This climatic diversity is influenced by the state's geographical location. The Sub-Himalayan region of West Bengal receives an average annual rainfall of approximately 273 centimeters while the Gangetic region receives around 143 centimeters of rainfall. Given West Bengal's moderate annual rainfall there is a significant demand for water resources leading to the over-extraction of groundwater beyond its natural replenishment rate. This unsustainable usage pattern poses challenges for water resource management and sustainability in the state. It is crucial for the government and relevant authorities to implement measures that promote responsible water use and ensure the long-term availability of this precious resource for the well-being of all living organisms in the region. Among the many regions of India that rely heavily on efficient reservoir management and water storage, West Bengal stands out. This state, located in the eastern part of the country, experiences moderate annual rainfall. In a region where groundwater utilization is essential, the role of reservoirs becomes even more critical. In the state's quest to ensure a sustainable supply of water for its inhabitants, reservoirs play a pivotal role. To gain a deeper understanding of this complex web of water management, a comprehensive study has been undertaken in the town of Halisahar in West Bengal. The objective is to study of 100 reservoirs about their area and perimeter, nearby varying population, and rainfall every year during last decade. The yearly variation in rainfall is minimal in this area, so there appears to be no significant relationship between rainfall and the perimeter and area of a reservoir. Therefore, it can be concluded that population size is a more significant factor in determining the reservoir's perimeter and area compared to annual rainfall.

### \*Author for Correspondence

Rajashree Lodh

E-mail: rajashree.lodh@heritageit.edu.in

<sup>1</sup>Assistant Professor, Department of Civil Engineering, Heritage Institute of Technology, Kolkata, India

<sup>2</sup>Undergraduate Student, Department of Civil Engineering, Heritage Institute of Technology, Kolkata, India

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**Keywords:** Reservoir, perimeter, area, irrigation, industrialization, population, rainfall, Google Earth Pro tool, polygon, remedial measures

## INTRODUCTION

One of the countries that grapple with the intricacies of water distribution is India, a land of diverse climates, terrains, and ecosystems. Within this vast and multifaceted nation, there exists a stark contrast in the availability of water resources. Some areas face the grim specter of drought, with water resources running perilously low, while others are blessed with an abundance of this life-sustaining

liquid. Amid such disparities, communities, and authorities must wrestle with the challenges of managing and distributing this precious resource effectively. In arid regions of India, where water is a scarce and precious commodity, the specter of drought looms large. Inhabitants of these regions are all too familiar with the agony of parched lands and dwindling water sources. Crop yields are meager, and agricultural communities are left in the throes of hardship. On the other end of the spectrum, regions with copious water reserves must grapple with a different set of challenges – how to harness and manage these resources to benefit their inhabitants effectively. The sources of water in India are multifarious, with rivers, groundwater, canals, and rainfall being the primary contributors to the nation's water supply. These sources converge to create a lifeline for the people of India, forming the basis for the water reservoirs that play a pivotal role in securing the nation's socio-economic growth. Dams and reservoirs, in particular, are the unsung heroes of water management. They serve a dual purpose by harnessing the flow of rivers and contributing significantly to the welfare of the region they serve.

The importance of these dams and reservoirs cannot be overstated. They are the linchpin that ensures the water needs of the population are met. Their roles are manifold:

1. *Providing water for human consumption:* The most basic and fundamental requirement is access to clean and safe drinking water. Dams and reservoirs store and distribute water to fulfill this essential need, ensuring that people have access to the most fundamental requirement for life.
2. *Supporting industrial water needs:* In an increasingly industrialized world, water is not only a necessity for human consumption but also for various industrial processes. These reservoirs facilitate the smooth functioning of industries by supplying the water required for manufacturing and other processes.
3. *Enabling irrigation for agriculture:* Agriculture is the backbone of India's economy, and the availability of water for irrigation is crucial for the success of this sector. Dams and reservoirs enable controlled distribution of water for crop cultivation, thus contributing significantly to food security.
4. *Generating hydroelectric power:* The energy sector relies on dams and reservoirs to generate hydroelectric power. These structures capture the potential energy of water and convert it into electricity, powering homes, industries, and the nation's infrastructure.
5. *Controlling floods by managing water release:* While these reservoirs are essential for storing water, they also play a crucial role in flood management. By controlling the release of water during heavy rainfall or monsoons, they mitigate the risk of floods and protect communities downstream.

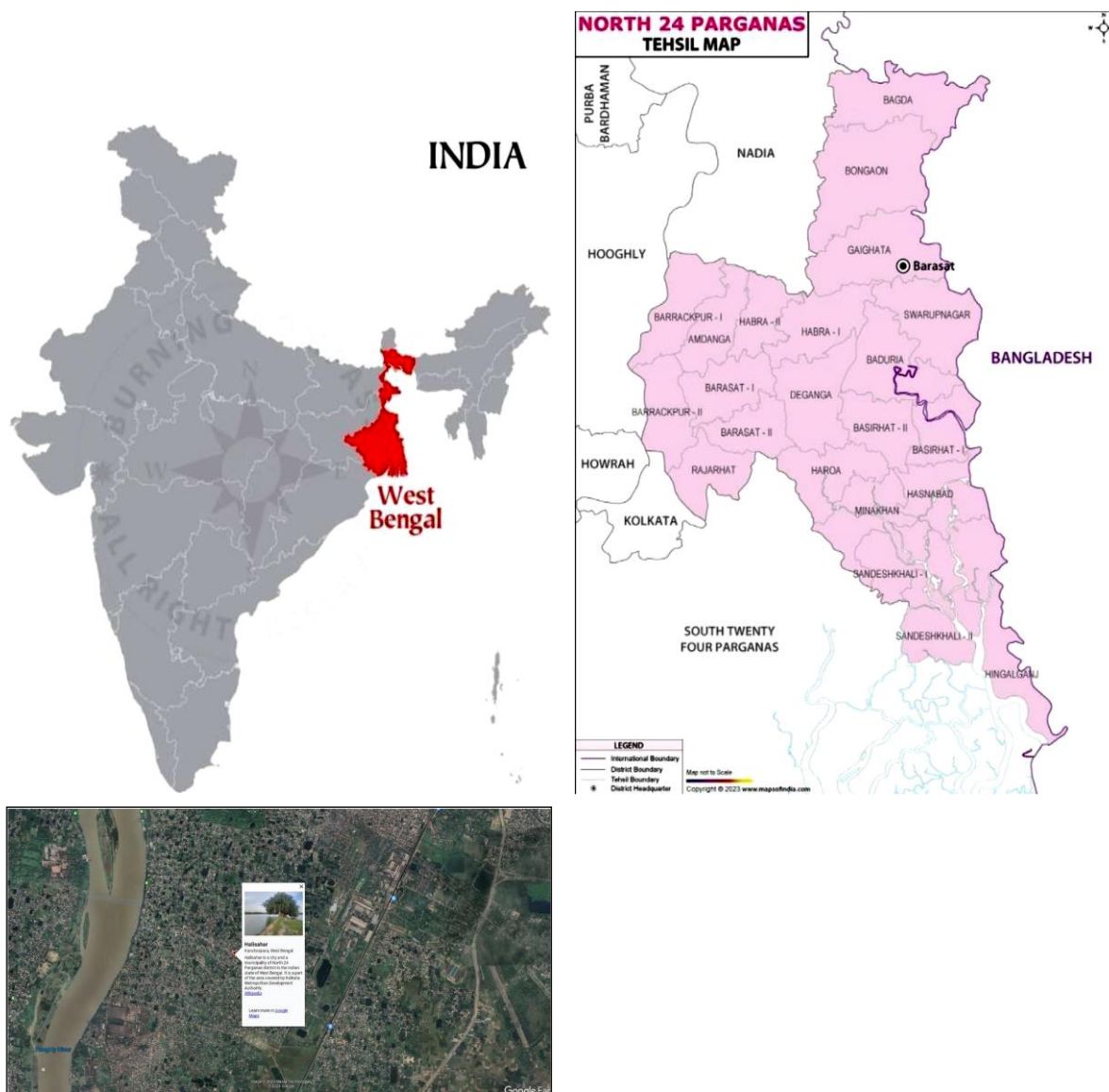
Chakraborty et al. (2021) conducted and analysed a program on the water shortage in Egra, a block of PurbaMedinipur, West Bengal, highlight a significant concern for the area. Over the past 10 years, Egra's population density has increased by 2.25% per annum, leading to a reduction of 4878 meters in the reservoir perimeter and a decrease of 30258 square meters in its area. These findings underscore the excessive water use in the region, and if the indiscriminate reservoir water extraction continues, it could result in its depletion [3]. Halder et al. (2020) researched on Shali Reservoir in West Bengal's Bankura district have been scarce over the past four decades, despite shifts in population, climate, and river morphology. This paper seeks to compile past research findings to benefit the residents of the Gangajalghati block in Bankura, emphasizing the critical role the reservoir plays in agriculture, fishing, and afforestation [8]. Chakraborty et al (2020a) showed that due to the huge amount of withdrawal of groundwater from Contai, Purba Medinipur the water quality parameters in groundwater have increased to a large extent over the years [4]. Maity et al. (17b) observed that due to excessive over extraction of groundwater; seawater intrusion was conducted in Purba Medinipur, India. On the experimental studies, they found high values of groundwater quality parameters at various locations of the district. They also suggested remedial measures to control the hazardous effect of seawater intrusion [11]. Amoakowaah et al. (2019) studied on hydro-climatic variability resulting from anthropogenic activities in Ghana's Owabi catchment from 1986 to 2015, utilizing the Soil-Water-Assessment Tool (SWAT). The model simulated historical and projected stream flow and water balance, highlighting the role of forest, topography, evapotranspiration, and surface runoff in water loss [1]. The model showcases promise for

further water quality and pollution modeling to enhance water management. Duhan and Pandey (2013) conducted a comprehensive analysis of precipitation's spatial and temporal variability across 45 districts in Madhya Pradesh, India, over 102 years (1901-2002) on an annual and seasonal basis. The application of various statistical tests facilitated the detection of trends and change points, resulting in an enhanced understanding of precipitation patterns [5]. Mall et al. (2006) discussed the global impact of climate change on freshwater resources, with a focus on India. It highlights the increasing demand for water due to urbanization, agriculture expansion, population growth, and industrialization [10]. Changes in land use, cropping patterns, and water management practices are altering India's hydrological cycle. The article emphasizes the importance of assessing water resource availability in the context of future national needs and climate change impacts for long-term development strategies. Donagh et al. [7] identified diverse water storage forms in the Neotropical Region of Argentina since 1990. The initial colonization was observed in southern lakes, and in the last decade of their research, the dinoflagellate thrived in subtropical reservoirs. Within this framework, the colonization and population development of *C. hirundinella* were examined from its first documentation in the Río Tercero Reservoir (February 1999 to February 2001). Wisser et al. [13] provided a global estimate indicating that the reduced water storage capacity in large reservoirs might influence typical human behavior. They also forecasted that rising sea levels could alter the relative freshwater reservoirs, surface water, and aquifers. Dawood et al. [6] determined that reducing evaporation involved controlling the rate at which water vapor escapes from water surfaces. Water conservation was a significant concern in areas with low rainfall and runoff. They demonstrated that evaporation from reservoirs could be significantly reduced by using polyethylene with varying densities (800, 875, and 900 kg/m<sup>3</sup>) as floating covers on cylindrical water containers with an 8 cm diameter. The optimal density of 800 kg/m<sup>3</sup> resulted in a reduction of about 57% in evaporation, based on theoretical calculations, which was considered a notable outcome. Liu et al. [9] emphasized that water application and usage are critical determinants of environmental quality and human development, aligning with UN objectives. Water scarcity is a major challenge with broad implications for global crises, including poverty, hunger, ecosystem degradation, climate change, and diminishing global peace and security. Their research focused on areas such as desalination plants, water retention (including rainwater reservoirs and reuse), wastewater reuse, and the construction of dams and reservoirs.

### Study Area

This study focuses on the examination of 100 reservoirs of varying capacities and shapes, to comprehensively assess and analyze reservoir management practices. It seeks to shed light on the intricacies of water distribution and storage in the region over ten years, aiming to provide invaluable insights into the challenges and successes of this critical aspect of West Bengal's infrastructure. Halisahar, a quaint and picturesque town in the North 24 Parganas district of West Bengal (Figure 1), embodies the essence of West Bengal's reservoir management challenges [2]. This town, with its rich history and vibrant culture, has long been reliant on the prudent management of its water resources. The reservoirs dotting the landscape of Halisahar are not mere bodies of water; they are the lifeblood of the community, serving a multitude of purposes that extend far beyond mere hydration. As the study delves deeper into the reservoirs of Halisahar, it is essential to acknowledge the sheer diversity in the capacities and shapes of these reservoirs. The research investigation was conducted in the locality of Halisahar, situated in the state of West Bengal within the administrative district of North 24 Parganas. Halisahar is geographically delineated by its proximity to Char Nandanbati, Char Kancharpara, and Kalyani in the Nadia district to the north, Kancharpara and Nanna to the east, Balibhara and Naihati to the south, and the Hooghly River to the west. As of the year 2020, the population of North 24 Parganas stood at 9,631,112 people, exhibiting an average growth rate of 18%. Halisahar, specifically located at coordinates 22.9295° N latitude and 88.4249° E longitude, was subject to the 2011 Census of India, which reported a total population of 124,939. Among this population, 65,467 individuals (52%) were males, while 59,472 (48%) were females. The count of individuals below the age of 6 years amounted to 11,138. Moreover, the number of literate individuals in Halisahar was recorded at 1,20560 representing 88.36% of the population aged over 6 years. Halisahar experiences a climate characterized by warmth and humidity, featuring short autumn and winter seasons. Notably, in the year 2018,

Halisahar encountered a particularly severe kalbaisakhi storm, with wind speeds reaching approximately 100 km/h and 51 mm of rainfall on May 13 [12]. The summer months in this delta region are marked by high humidity levels, with daytime temperatures ranging from 38°C (100°F) to 45°C (113°F). In contrast, the winter period, spanning December to January, is relatively mild, with average minimum temperatures around 19°C (66.2°F).

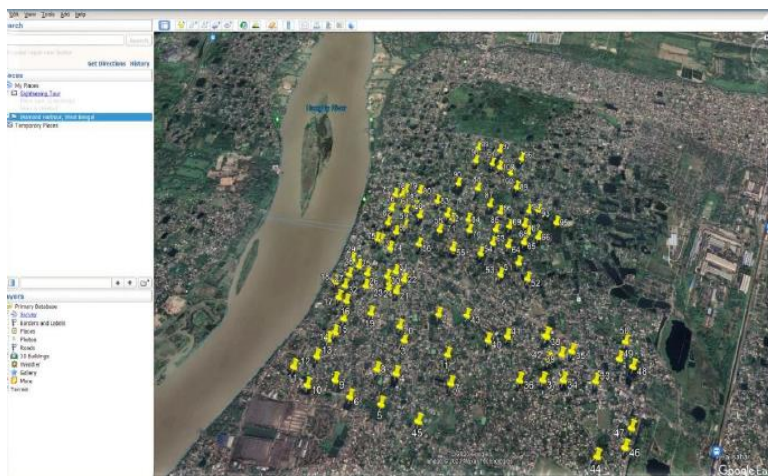


**Figure 1.** Study Area.

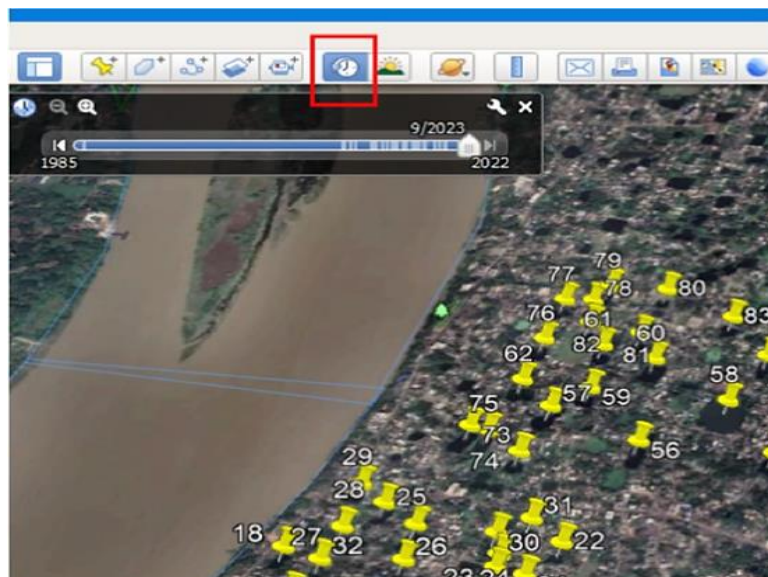
**METHODOLOGY**

This research centers on the selection of Halisahar in South Twenty-Four Parganas as the focal study area. The primary objective pursued in this study involves the determination of the cumulative area and aggregate perimeter of reservoirs spanning the preceding ten years, specifically from 2013 to 2023. The entire procedure is executed using the Google Earth Pro tool. The process commences within the Google Earth Pro tool, where the designation "Halisahar West Bengal" is entered to pinpoint the precise geographic location. Upon visualization in the satellite imagery map, the map is zoomed in to achieve the desired level of detail. Within this map, one can discern the presence of one hundred (100) natural reservoirs, each characterized by diverse shapes and situated in close proximity to vegetation. The temporal aspect of the study is facilitated through the utilization of a time slider, which allows the

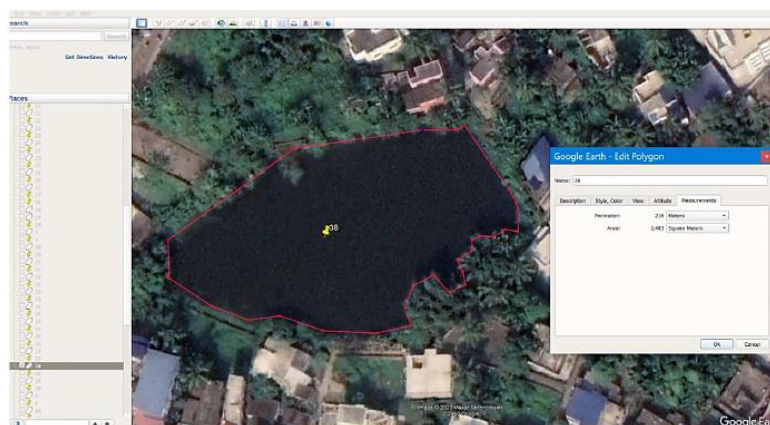
display of the current date. By reversing the slider to earlier years, it becomes evident that one hundred reservoirs have consistently existed throughout the preceding ten years. Each of these reservoirs is assigned a place marker to obtain their respective northing and easting coordinates. The meticulous creation of polygons around each individual reservoir ensues, ensuring that no portion of these bodies of water is inadvertently excluded. Following the completion of this polygon delineation process, the units for measuring perimeter and area are standardized to meters and square meters, respectively, within the measurement section of the tool. This standardized approach facilitates the calculation of the perimeter and area of each reservoir at any given moment in time. This recurring procedure is meticulously conducted each year, spanning from 2013 to 2023, for every single reservoir within the vicinity. The collective outcomes of these yearly assessments culminate to provide a comprehensive depiction of the total area and perimeter of these reservoirs, effectively encapsulating the transformations and variations over the course of the entire decade within Halisahar, located in the South Twenty-Four Parganas region of West Bengal. In terms of the specific data collection process employed in this research, a well-structured approach was meticulously followed, encompassing the following key stages: Identification and Geo tagging of the Reservoirs (Figure 2); Observation of yearly variation (Figure 3); Determination of the Collective Area and Combined Perimeter (Figure 4). The total perimeter and area of reservoirs are calculated by GOOGLE EARTH PRO tool. The values are tabulated below in Table 1.



**Figure 2.** Marked Reservoir Present in Halisahar.



**Figure 3.** Yearly Variation.



**Figure 4.** Marked Polygon for area and Perimeter Calculation.

**Table 1.** Perimeter and Area of Reservoirs.

Year	2023	2022	2021	2020	2019
Total Perimeter(m)	17096.07	17295.62	17583.31	17925.02	18352.82
Total area(m <sup>2</sup> )	199303.40	202417.33	204698.66	209153.99	213236.25

**Table 2.** Population of Halisahar.

Year	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014
Population	1,70,000	1,66,000	1,62,000	1,58,000	1,55,000	1,52,000	1,49,000	1,46,000	1,43,000	1,40,000

**Table 3.** Rainfall per year in Halisahar (2014-2023).

Year	2023	2022	2021	2020	2019	2018	2017	2016	2015	2014
Rainfall (mm)	1356.80	1041	1195	1433.30	1371.30	1265.80	1139.20	1187.60	1038.80	786.90

From above Graphs it has been observed that with the increase of population graphically in Halisahar, North 24 Paragans the area and perimeter of reservoirs decreased over the decade. It is obtained that the correlation coefficient between the decadal population of Halisahar and the total perimeter and area of reservoirs are -0.84 and -0.79 respectively. So, it can be inferred from the analysis that with the increase of population the perimeter and area of reservoirs were affected greatly. The yearly annual rainfall of North 24 Parganas is nearly 1530 mm. The yearly variation of rainfall is not much. So, no relationship between reservoir perimeter and area with rainfall can be established. So, it can be concluded that population is the major factor in the determination of reservoir perimeter and area compared to annual rainfall.

**RESULTS AND DISCUSSION**

The details of reservoirs are tabulated below. Total 100 Reservoir of different area and perimeter is selected for study; the water from reservoir is used for various purposes. From 1,62,000 in 2021 to 1,66,000 in 2022, the population of Halishar increased significantly, with an average annual growth rate of 2.41%. There are several ramifications to this quick population rise, not the least of which is increased water consumption. Reservoir water is necessary for many uses, such as household, commercial, and urban requirements. In addition to population expansion, urbanization and industrialization are other factors driving up water consumption. The current water resources are being increasingly taxed by these activities, raising questions about their sustainability and long-term availability. The need for water for production, sanitation, and everyday use increases dramatically with the growth of businesses and metropolitan areas, placing strain on reservoirs and other water sources. Inadequate rainfall in the area, according to statistics from the Indian Meteorological Department, exacerbates these problems. The yearly precipitation in 2022 was 1041 mm, which was less than the 1195 mm that fell in 2021. Because of the decreased rainfall, there is less opportunity for natural replenishment of water resources.

Dependency on reservoirs becomes even more crucial during dry spells, underscoring the fragility of Haliyar's water supply infrastructure. A comprehensive strategy is required to address these issues, one that includes conservation initiatives, sustainable water management techniques, and research into alternate water sources. Water demand can be moderated by employing tactics like rainwater gathering, effective irrigation methods, and public awareness campaigns concerning water conservation. Furthermore, by making infrastructural improvements for better water distribution and storage, Haliyar's water supply system will be more resilient to the demands of an expanding population and shifting environmental circumstances.

## CONCLUSION

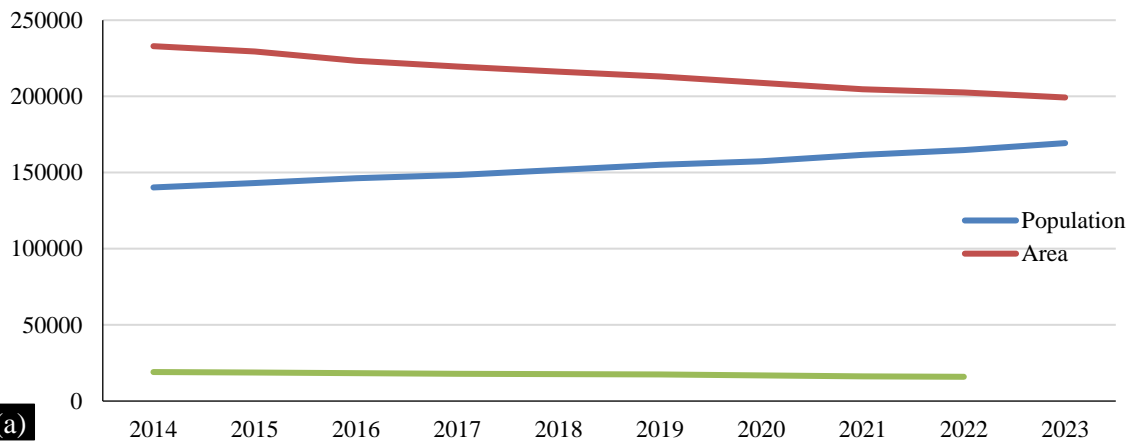
The reservoir area in Haliyar has dropped dramatically over the past ten years, by as much as 14%, according to a review of the situation there. The population is growing at a pace of roughly 2.41% year, which contrasts with the reservoir area loss, suggesting a rising demand for water supplies. More and more people are relying on groundwater sources to meet their water needs as the amount of reservoir land that is accessible decreases. But there are unique difficulties associated with this change. The large dependency on groundwater leads to a decline in the water table level. According to Gyben Herzberg's principle, this lowering of the water table can result in the intrusion of seawater into the mainland, a phenomenon known as saltwater intrusion. This compound problem exacerbates water scarcity issues and poses significant challenges for water management strategies. It becomes essential for the government to step in and impose regulations that limit water extraction operations from the reservoir in order to handle these intricate issues. These kinds of laws are necessary to protect water resources and stop future deterioration of groundwater quality. Furthermore, the people and businesses in Haliyar can adopt more conscientious water-use habits thanks to this legislation. It is essential to establish efficient water management strategies in conjunction with regulatory measures. This entails supporting water-saving measures, making investments in infrastructure for water recycling and reuse, and pushing for the use of effective irrigation methods in agriculture. Campaigns to raise public awareness of the value of conserving water and the negative effects of over-extraction can also help to develop a culture of water stewardship in the neighborhood. Moreover, government agencies, local communities, and stakeholders must work together to create integrated plans for managing water resources that give priority to sustainability and resilience in the face of environmental problems and population expansion. Through the adoption of proactive strategies and the establishment of strong frameworks for water governance, Haliyar may better manage its current water crisis and guarantee water security for coming generations.

## Remedial Measures

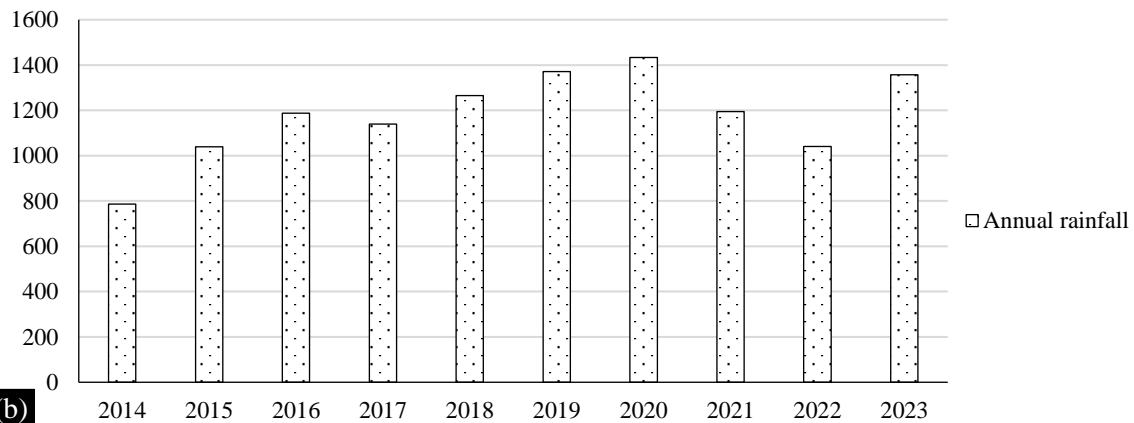
Water plays an important role in day-to-day activities of and an essential thing for the survival of mankind, and it is necessary that water should be used efficiently because usable water is limited as sea water in saline and cannot be used for various purpose and also it becomes very important to limit the withdrawal of water from the reservoir by the government Figure 5(a-c).

- Start broad public awareness efforts emphasizing the value of conserving and using water wisely. Inform people about the problems caused by saltwater seas and the finite supply of freshwater that can be used.
- Reduce the demand for freshwater by implementing water recycling and reuse systems in urban areas, agriculture, and industry. Promote the use of treated wastewater for industrial operations and irrigation, as these are non-potable uses.
- Invest in water-saving technologies such as low-flow fixtures, drip irrigation systems, and water-efficient appliances. Explore innovative desalination technologies to make seawater usable for specific purposes, reducing pressure on freshwater sources.
- Enforce stringent laws governing the removal of water from reservoirs, establishing caps in accordance with the ideas of sustainable water management. Put in place water price mechanisms to deter wasteful behaviour and encourage effective water usage.

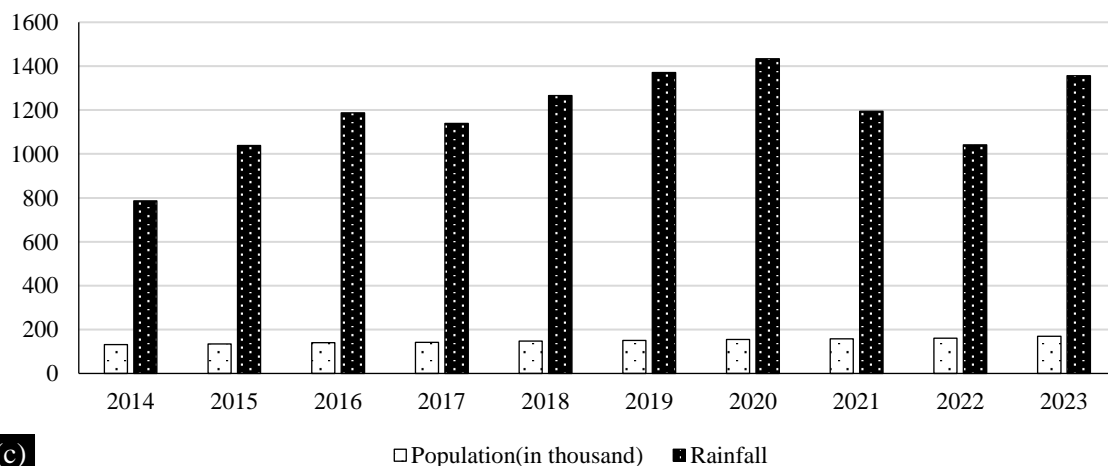
- Create and execute groundwater management strategies to stop aquifer depletion and over-extraction. Encourage the use of artificial groundwater recharge methods and rainwater collecting as recharge projects.
- Incorporate community members into local water conservation projects and programs through participation. Encourage community-driven efforts to manage water resources and provide stakeholders the authority to do so.



**(a)** Figure 5. (a) Comparative analysis between the population of Halisahar, North 24 Parganas and total perimeter and area of reservoirs between (2014-2023).



**(b)** Figure 5. (b) Variation of annual rainfall in Halisahar (2014-2023)



**(c)** Figure 5. (c) Variation of annual rainfall with change in population of Halisahar (2014-2023).

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