GENESIS OF URBAN FLOOD IN BURDWAN TOWN

Thesis Submitted for the Degree of

DOCTOR OF PHILOSOPHIES (SCIENCE)

of Jadavpur University

Submitted By:

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Index No: 22/18/Geo./25

Department of Geography

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CERTIFICATE FROM THE SUPERVISOR

This is to certify that the thesis entitled "**Genesis of Urban Flood in Burdwan Town**" Submitted by Smt. **SOUMITA BANERJEE** who got her name registered on **February 06, 2018**, having **Index No: 22/18/Geo./25,** for the award of Ph. D. (Science) degree of Jadavpur University, is absolutely based on her own work under the supervision of Dr. GUPINATH BHANDARI, Associate Professor, Department of Civil Engineering, Jadavpur University and that neither this thesis nor any part of it has been submitted for either any degree / diploma or any other academic award anywhere before.

22/01/2024

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Dedicated To

MY PARENTS

Mrs. Ranjita Banerjee (Maa)

&

Mr. Sanjay Banerjee (Baba)

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- ***Published Articles/ Book Chapters*:**

I. **(Accepted on 4th January 2024) Manuscript ID GEJO-D-23-00943R2 Assessment of Solid Waste Management Practices: Study of Burdwan Town, West Bengal** by **Soumita Banerjee** and Dr. Gupinath Bhandari in Geo-Journal 0343-2521 (print) (Springer)

II. **(Accepted on 3rd December 2023) Manuscript ID RSPP-23-1285.R2 Coping with urban flooding: A community portrayal of Bardhhaman Town, West Bengal, India** by **Soumita Banerjee** and Dr. Gupinath Bhandari in journal Regional Science, Policy and Practice (ISSN:17577802) **(Publisher: John Wiley & Sons Inc.)**

III. **Tracing the everyday Sensory Heritage of Kolkata Streets'- "*Sohorer Songbedon*"** by **Soumita Banerjee** and Dr. Kunaljeet Roy, Page:1-12, Curator: The Museum Journal (Online ISSN:2151-6952; Print ISSN:0011-3069) DOI: 10.1111/cura.12582 **(Publisher: John Wiley & Sons Inc.)**

IV. **Aspects of Urban Flooding: A State of Art of Review** by **Soumita Banerjee** and Dr. Gupinath Bhandari in METSZET Journal (ISSN: 2061-2710) Volume 8 Issue 8, 2023 Page no. 200-216 (**DOI:** 10.27896/METSZET8.8/21) **(SCOPUS-UGC CARE II)**

V. **The Curious Case of Sundarbans Embankment Breaching in Indian Sundarbans: Present Status and the Way Forward** by **Soumita Banerjee** and Debajit Datta in Akhanda Sundarbans Katha-I in the combined volume of July-December,2022, edited by Nazrul Islam Mandal.

VI. **India's urban floods: Why we need to look at nature-based solutions** by **Soumita Banerjee** and Dr. Priyank Pravin Patel in the segment Natural Disaster: Down To Earth in September 2022(https://www.downtoearth.org.in/blog/natural-disasters/india-s-urban-floods-why-we-need-to-look-at-nature-based-solutions-85013)

VII. **Study on Urban Growth in Bardhhaman Municipality, Purba Bardhhaman District, West Bengal: A Metric-Based Analysis** by **Soumita Banerjee**, Dr. Gupinath Bhandari, and Dr. Ratnadeep Ray in edited book by Springer Nature Switzerland AG 2022M. I. Hassan et al. (eds.), Social Morphology, Human Welfare, and Sustainability (https://doi.org/10.1007/978-3-030-96760-4_10) (**SCOPUS Indexed)**

VIII. '**Bridging the Gap Between Sustainability and Disaster Management'**- meeting report published in EOS-AGU(American Geophysical Union) by **Soumita Banerjee** and Sujay Bandyopadhyay 17 December 2018 on IGCS Summer School 2018 on Coastal and River Hazards & Management Strategies; Aachen, Germany, 14–25 July 2018 (https://doi.org/10.1029/2018EO110987) **(Wiley)**

IX. **"Geography of Disaster Management and its Changing Approaches**" by **Soumita Banerjee** Aug 8, 2018, in Annals of Art, Culture & Humanities (E-ISSN2455-5843, ISSN-L2455-5843) **(UGC Approved Journal-according to old list)**

X. **"Urban Flooding Scenario in the City of Kolkata''** by **Soumita Banerjee** in the issue of May 2018, International Journal of Knowledge Concepts (ISSN: 2454-2415)

XI. **"Urban Expansion of the City of Kolkata Since Last 25 Years"** in March 2018 by **Soumita Banerjee** in the International Journal of Research and Analytical Reviews. E-ISSN 2348-1269, P- ISSN 2349-5138 **(UGC Approved Journal No: 43602(19)**

- ***Presented Papers in Seminars/Conferences:***

I. (Accepted Abstract for E-Poster Presentation) on **"Community- The maker turned destroyer in forming urban flood resilience: A case study of Burdwan town, West Bengal**" in the Fall meeting, 2023 by **American Geophysical Union (AGU).**

II. Oral presentation on **'Current Trends, Challenges and Future Scope in Urban Microclimatic Research: Exploring Indian Cities'** (as Presenter) organized by International Benevolent Research Foundation (IBRF), West Bengal, Institute of Scholars, and Academicians (InScA), Kolkata Confederation of Indian Universities (CIU), and New Delhi International Multidisciplinary Research Colloquium on 28-29th April 2023.

III. Oral presentation on '**Perishing of River Banka, Burdwan Town: How are the locals responsible?'** ICSSR-ERC Sponsored a two-day national seminar on self-reliance, sustainable development, and environment organized by the Department of Geography, Seram pore Girls' College on 25th-26th March 2022.

IV. Oral Presentation "**Statistical Analysis of Last 120 Years Rainfall of the District of Bardhhaman, West Bengal**" at the International Conference on "Sustainable Water

Resources Management under Changed Climate" being organized by the School of Water Resources Engineering, Jadavpur University, Kolkata, West Bengal (India) in Collaboration with Department of Geography, Women's' College Calcutta and NIT Durgapur from 13th March-15th March 2020.

V. Presented paper '**Analysis of the rainfall pattern and associated disasters since 1980 in the District of North24 Parganas, West Bengal**' in the International Seminar 'Man and Environment: Issues and Challenges' at Subarnarekha Mahavidyalaya on 13th and 14th March 2019.

VI. Presented Paper **'Statistical Analysis of Rainfall as a Component of Climatic Variability of the District of Purba Bardhhaman, West Bengal'** in XIV International Geographical Union (IGU-INDIA) International Conference, 6-8 March 2020, Burdwan University.

VII. Oral presentation on '**Multi-Decadal Analysis of Urban Land Teleconnections towards Sustainability with special reference to Bardhhaman Town'** and worked as rapporteur in the international conference 'Society and Sustainability: An Interdisciplinary Approach, conducted by the Department of Geography, Vivekananda College Kolkata and the eastern geographical society, Odisha on January 12-13, 2019.

VIII. Presented Paper on "**Geography of Disaster Management and its Changing Approach**" at a national seminar organized by *Bongio Bhugol Mancha* on 24th-25th February 2018

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I. **DAAD-IGCS** Winter School 2022 on "Sustainable Waste Management for a Circular Economy", from 21 Feb. 2022 - 4 Mar. 2022 (Virtual- Fellowship Received)

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Details of Academic Accomplishments during Period of Ph.D.

IV. **DAAD-IGCS** Summer School 2018 on "Coastal and River Hazards & Management Strategies" at RWTH Aachen University, Germany from 13 to 26th July 2018 (Fellowship and Travel Grants Received)

The above statements are true to the best of my knowledge.

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ABSTRACT

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Title of the Thesis: ***GENESIS OF URBAN FLOOD IN BURDWAN TOWN***

Submitted by: SOUMITA BANERJEE

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ABSTRACT

Floods are the most prevalent natural disasters that cause widespread devastation. As the name implies, an urban flood is the influx of massive amounts of water caused by torrential rainfall. It may occasionally be associated with extreme events such as cyclones, but the main cause is haphazard urban growth, excessive rate of concretion, the emergence of slums, expansion beyond the natural flood barrier, poorly maintained sanitation, and so on. Several scientific assessments suggest that increasing sea levels and flooding could affect over 15 million people in metropolitan areas alone by 2030. But the unfortunate and alarming part is the issue of urban flooding never got the same importance as other types of natural disasters, such as earthquakes or hurricanes, because it is typically viewed as a localized issue that affects only certain areas of a city. The situation is the worst in case of old towns like Burdwan in West Bengal, which faces flooding in many of its wards due to mostly anthropocentric causes (Excessive rate of increase of population and unplanned urbanization since last few decades, improper urban drainage system including sewage and sanitation system and ill maintenance of them, degeneration of *Banka* Khal from a navigable river to a dump site over centuries and unscientific municipal solid waste management), coupled with structural, climatological and hydrological factors. This study aims to discuss the influence of the aforementioned factors in the flooding situation, the impact of urban flooding on various socio-economic groups in the town and formulate some practical measures for this chaotic state with well-sought methodology including acknowledged geospatial procedures and proven quantitative approaches. The outcome shows that expanding urban areas, diminishing water bodies, the presence of *kutcha* (Non concreted) drains, and intensified population density have played a significant role in flooding situation. To get relief from these circumstances, the Urban Local Body that is the Municipality should keep parity in both structural and non-structural development, including appropriate Town Planning.

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Contents

List of Abbreviations

ABBREVIATION	EXPLANATION
BDA	Burdwan Development Authority
CFSR	Climate Forecast System Reanalysis
DW	Durbin Watson
IDF	Intensity-Duration-Frequency Curve
IDW	Inverse Distance Technique
InVEST-UFRM	Integrated Valuation of Ecosystem Services and Tradeoffs-Urban Flood Risk Mitigation (INVEST-UFRM)
LULC	Land Use Lad Cover
MK	Mann-Kendall
MSW	Municipal Solid Waste
NDBI	Normalized Differential Built Up Index
PCA	Principal Component Analysis
PCI	Precipitation Concentration Index
RAI	Rainfall Anomaly Index
RDI	Rainfall Deviation Index
RSI	Rainfall Seasonality Index
SNHT	Standard Normal Homogeneity Test

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This PhD dissertation is organized into seven chapters that address research problems and exploring significant research findings regarding the issues of urban flooding, its impact, and some remedial measure for Burdwan Town, Purba Bardhaman District, West Bengal.

Primarily, the *First Chapter* focuses on the need for the theoretical and practical approach for understanding the issues related to urban flooding and how it has been a major menace for most of the Indian cities. Keeping that thread, a brief introduction of the study area followed by the rationale for selecting it as the interest of study have been discussed.

The *Second Chapter* presents a thorough overview of literature on the concept, factors, consequences of urban flood (concept specific and area-specific both). It also reviews the literature related to available strategies to reduce the risk of urban flooding in a hierarchical regional order from global examples to the regional ones with special emphasis on the models used in managing urban flooding so far.

The *Third Chapter* includes very specific research gaps, objectives, further developed research questions, scope and limitations of the work and probable deliverables.

The *Fourth Chapter* deals with vivid methodology which is highly objective oriented explaining the need for opting those particular ones with the details of the framework of the field works.

The *Fifth Chapter* holds a major part of the thesis-*Results and Discussions.* For better apprehension, it is subdivided into a few parts: *5.1* deals with the multi-decadal urban landscape change and identifying the other facets related to urbanization that help to form an urban flood *5.2.* talks about the status of urban waste management where *5.3* includes the urban drainage (natural and man-made) and *5.4*. points out the cluster of factors which are mostly responsible for flooding in the study area. **(Objective-1),** *5.5* incorporates the analysis of the record of rainfall with some statistical methods *5.6*. shows the amount of run-off a particular amount of rainfall generates **(Objective-2),** Furthermore *5.*7 enlightens about the effects the urban flood leaves on the local people **(Objective-3).**

Ultimately, the investigation's results are summed up in the *Sixth chapter* based on the findings of the entire study.

Lastly, in the *final chapter* or the *Seventh chapter* the conclusion of the total study is included along with some practical guidelines for the betterment of the flooding scenario and spots light on the stakeholder's responsibility **(Objective-4).**

CHAPTER: ONE

INTRODUCTION

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INTRODUCTION

1.0. Background of the Study:

Flooding is the most common natural calamity that results in widespread destruction *(Jha et al., 2011).* **Floods are recurring occurrences that result in catastrophic losses of life, possessions, infrastructure, and public utilities.** There is mounting evidence that, on a worldwide scale, the number of individuals impacted by floods as well as the economic damages caused by flooding are increasing at a rapid rate *(Wobus et al., 2017).* The rising incidence of flood-related damages presents cause for concern*(National Disaster Management Authority Government of India, 2007).* There is variety of floods based on their places of occurrences, magnitude ,and abruptness- the broad categories can include flash flooding or massive and wide spread river flooding, but sub categories might indicate floods due to 'Urban drainage, Ground failures, Fluctuating lake levels, Coastal flooding' etc. *(Galloway et al., 2018).* Flooding that occurs in urban areas due to heavy rainfall or other natural disasters. It happens when the drainage systems in cities are unable to handle the excess water, leading to water accumulation on streets, buildings, and other infrastructure. This can endanger safety for people, damage wealth, and interfere with transit. It is a complicated phenomenon brought on by a confluence of human and natural elements. **Urban floods, as the name implies**, are caused by massive water inflows brought on by intense rainfall. While they are occasionally linked to extreme weather events like cyclones, the primary causes of urban flooding are haphazard urban centre expansion, excessive concrete construction, the emergence of slums, development outside of the natural flood barrier, inadequately maintained sanitation, and other factors. *(Tingsanchali, 2012).* According to the World Bank, **urban flooding** is defined as "the inundation of land or property in a built-up environment caused by rainfall, snowmelt, or other natural or man-made events that exceed the capacity of drainage systems or the ability of the ground to absorb water" *(World Bank, 2019). OR* The concentration of floodwaters that happens when storm water input surpasses a drainage system's capacity to either transfer or permeate water into the soil is known as urban flooding. When a drainage system cannot manage the amount of storm water entering the area, this happens. *(NIUA, 2016).*As a consequence of rapid population increase, the land use and land cover patterns of majority of the river basins have shifted significantly. Urbanization in the riverbanks is increasing,

which has numerous detrimental effects on the functioning of the river basin ecosystem. Rapid change in the hydrology and geomorphology of water bodies, as well as the degradation in their water quality, are some biggest adverse effects witnessed so *far (Shukla et al., 2013)* .Urban riverfronts in particular, give cities a way-out to cope up with all hazards related to climate change including the heat island effect and urban floods. They simultaneously promote citizens' socioeconomic well-being, social integration, and mental stability *(Shivali Jainer, 2020).* On the other hand, urban drainage systems generally perform poorly, mostly as a result of increased population and haphazard urbanization-issues like water logging; urban floods are coming out as a result of these systems' declining efficiency *(Jemberie et al., 2023).*

Some of the main reasons why cities flood are the growth of cities, changes in the temperature, and poor infrastructure *(M. Singh & Upmanyu, 2019).*As cities grow and spread, they often replace natural surfaces with ones that don't let rainwater soak into the ground, like concrete and asphalt. This, along with the fact that climate change is making extreme weather events happen more often, can cause cities to flood more often and more severely. When it rains a lot, the water has nowhere to go, so it builds up on houses, streets, and other infrastructure. This can hurt property, make it hard to get around, and put people's safety at risk. **The lack of green space and natural surfaces** in cities is another reason why floods can be bad in cities*(Ferreira et al., 2022).* As cities grow and spread, they often replace natural surfaces with ones that don't let rainwater soak into the ground, like concrete and asphalt. This, along with the fact that **climate change** is making extreme weather events happen more often, can cause cities to flood more often and more severely*(Kaisa Kosonen & Tirado, 2023).* Some status and predictions are summarized below collecting from various authentic reports.

- ‘Climate change, rising sea levels and flooding are expected to have an outsized impact on Asia where millions of people live on low-lying land near the ocean. A new report by Greenpeace East Asia looks at the risks in seven regional cities, concluding that in these metropolises alone, more than 15 million people could be affected by rising sea levels and flooding by 2030’ *(Kaisa Kosonen & Tirado, 2023)*

- 'The intensification and changing geography of disaster risks signal a new climate reality'*(UN) United Nation, 2019).*
- 'Urban climate change-related risks are increasing (including rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution) with widespread negative impacts on people (and their health, livelihoods, and assets) and on local and national economies and ecosystems (extremely high confidence, based on robust evidence, high agreement). These risks are amplified for those who live in informal settlements and in hazardous areas and either lack essential infrastructure and service'*(Gray, 2007;Revi, 2008).*Approximately, all these accounts are pointing out in the same direction and this trend is expected to worsen, in case of urban flooding as urbanization will mostly accelerate the occurring damage, while the frequency and intensity of flood events might be augmented by plenty of rainfall. Let us have a look at the factors responsible for urban floods and they are categorized in the following manner.

Table No.1.1: Factors Responsible for Urban Flooding

SL No.	Causes	Aspects
Anthropogenic Factors	Urbanization	Unplanned built-up area growth
		Land use changes
		Inefficient drainage to handle storm water
		Dumping of wastes in the urban drainage channel and make it clog
		Poor maintenance of drainage
		Building up settlements in the flood plain closer to banks
		Obstacles in flood water movement
	Concretization	Loss of green cover
		Loss of pervious surfaces
	Climate change	Change in the rainfall pattern, intensity, or temperature due to the above said factors.

	Hydro-engineering	Failure of dams, release of water without prior knowledge to the citizen.
SL No.	**Causes**	**Aspects**
Natural Factors	Climatic	Local abrupt highly intensified short-lived rainfall
		Natural disasters like cyclone

Source: Tabulate and modified after (NIUA, 2016)

Urban flooding is a significant problem affecting numerous cities throughout the globe. **However, it may not receive as much attention as other types of natural disasters, such as earthquakes or hurricanes, because it is typically viewed as a localized issue that affects only certain areas of a city** *(FEMA (Federal Emergency Managing Authority), 2013).*It is becoming a chronic issue that occurs over time, making it less noticeable and less newsworthy. The event is often viewed as a technical issue that can be resolved through engineering solutions, such as the construction of improved drainage systems or the expansion of the capacity of existing systems. Even though these solutions are significant, they do not address the root causes of urban inundation, such as climate change and urbanization.

The problems with flooding in cities in Asia and Europe are different for a number of reasons, including the level of growth in the economy, the condition of the infrastructure, social structures and ways of thinking, the drainage methods that are used, the nature and pattern of rainfall, and the effects of climate change etc. *(KSDMA & KSNDMC, 2023).* **Cities in Asia ought to encourage policies that make cities more resilient to floods.** These policies should focus on land use and environmental strategy for resiliency, as well as strengthening organizational structures and funds to reduce disaster risk and keep vulnerability and risk assessments up to date *(KSDMA & KSNDMC, 2023)*. India has a high catastrophe risk index, and urban floods have further increased that risk *(Jha, 2022).* Here is a list of Indian cities those have been flooded numerous times since the year 2000 and faced a very difficult time during the floods.

Table No.1.2: Remarkable Urban Floods in India since the Year 2000

SL No.	Year	Cities Affected
1	2000	Mumbai, Chennai, Bangalore, Kolkata, Hyderabad
2	2001	Ahmedabad, Bhubaneswar, Thane, Mumbai
3	2002	Delhi
4	2003	Delhi, Ahmedabad, Vadodara
5	2004	Chennai
6	2005	Among 10 cities all over India Mumbai was badly affected.
7	2006	The number of inundated cities hiked upto 22 where the city of Surat and Vishakhapatnam Airport was tremendously interrupted for a longer period.
8	2007	Again, the number hit at 35, among which Kolkata was tremedously affected.
9	2008	Jamshedpur, Hyderabad, Mumbai
10	2009	Delhi, Mumbai
11	2010	Delhi, Mumbai, Leh, Guwahati, Ahmedabad
12	2014	Chennai
13	2015	Jammu
14	2018	Kerala
15	2019	Malappuram and Wayanad district of Kerala
16	2020	Assam
17	2021	Bihar, Dharamshala

Source: Compiled from various sources

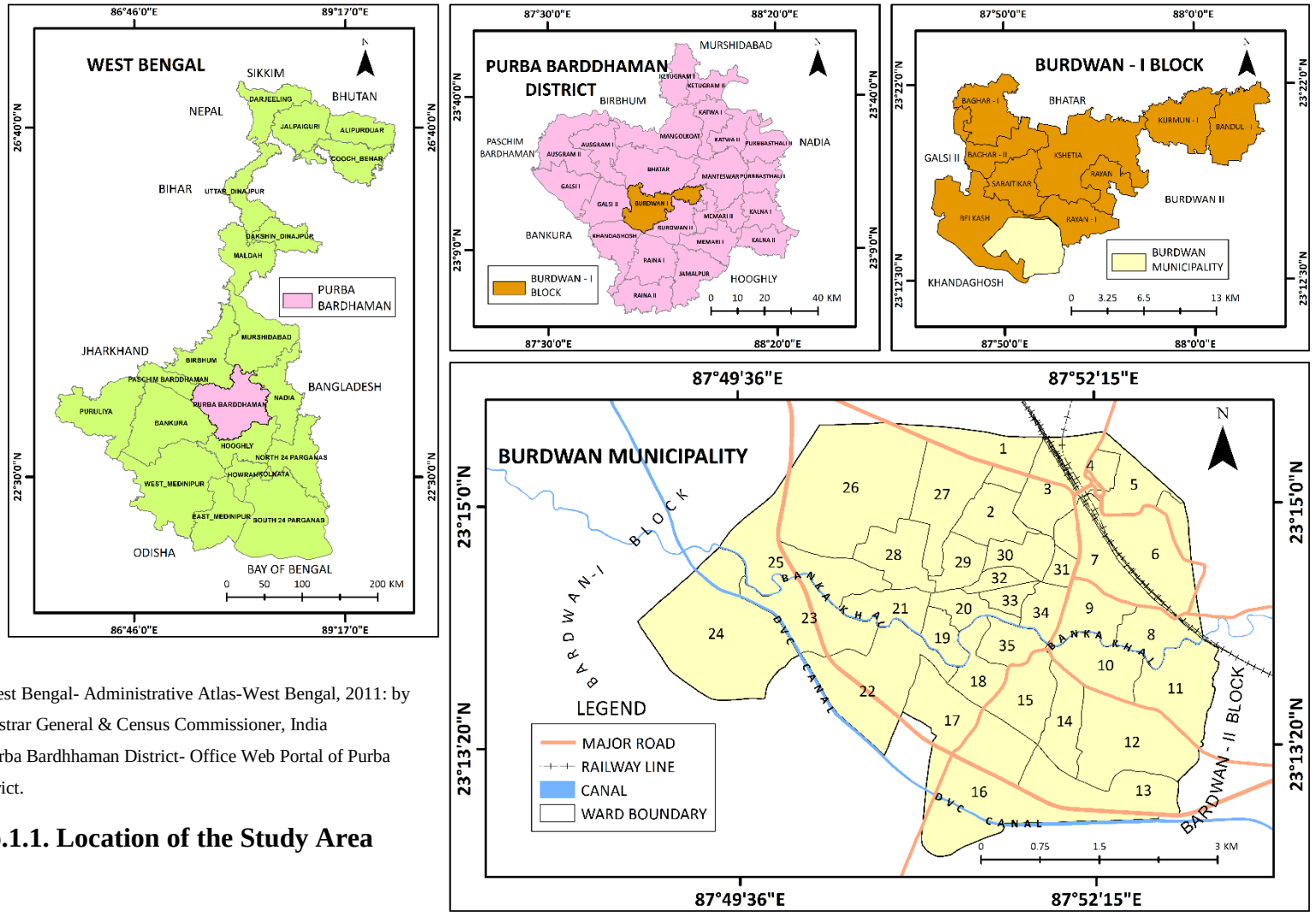
In the case of West Bengal, the years 1956, 1959, 1978, 1995, 1999, and 2000 saw the worst type of rainfall in West Bengal State, with 2000 possibly being designated as the worst year of rainfall in terms of quantity, intensity, and duration. This was all due to low pressure/depressions developed in the Bay of Bengal during those months. A huge number

of people in the state suffered for a long time as a consequence of the absence of control structures and the very high release of water in the rivers in the year 2000 *(R. Samal et al., 2014).* Whenever there was a greater cyclone formed in Bay of Bengal the cities of Kolkata and its adjacent towns get floods with the incapacitate drainage network- YASS (2021) being the recent example of this. It is quite evident from the available literatures that the number of research regarding issues of urban flooding can be found in numbers in various databases (Web of Science, Scopus) **but the study on other class-I or II Indian towns are minimal in numbers or absent.** Considering the fact and the severity of the issue, the Town of Burdwan or Burdwan is selected.

1.1.A Brief Introduction to The Study Area:

1.1.1. The Geographical Extent: The Municipality of Burdwan in Purba Burdwan District is chosen for this study because it is situated in a promising demographic location between the two major municipal corporations of Kolkata (East) and Asansol (West) and falls under the category of a medium urbanized area in the state. *(Laha, 2019).* The Burdwan Municipality is located between 87°50′E and 88°4′E longitudes, and between latitudes 23°2’N and 23°20’N. The following are this area's boundaries: To the west is Belkas Gram Panchayat; to the east are Rayan and a part of Baikunthapur II; to the south are the remaining parts of Baikunthapur II and Raina (P.S); and to the north is Belkas Panchayat. Burdwan Municipality is the sole Class I town in the East Burdwan district, in addition to being one of the six historic towns and the district seat of the previous Burdwan District. In the Burdwan district (which was split into Purba Burdwan and Paschim Burdwan in April 2017), the municipality of Burdwan was established in 1865. In 1865, there were 39,618 people living in the town, which had a total area of 21.79 square kilometers. As per the 2011 census, the population stands at 3.15 lakhs, and the total area covered by 35 wards is around 27 sq. km. *(Burdwan Municipallity, 2017).*

1.1.2. The River Scape of Burdwan Town: The town is primarily situated between the Damodar River in the southern region and the Banka River in the north-central sector. There is a wide Damodar bed areas of the town, such as the area between Sadarghat Road and Arambagh Road *(Kunal Chakraborty, 2011).*The Damodar River and its numerous paleo-channels, including Banka and Bahula, are the sources of Burdwan town.



Source:

For the map of West Bengal- Administrative Atlas-West Bengal, 2011: by Office of the Registrar General & Census Commissioner, India

For the map of Purba Bardhhaman District- Office Web Portal of Purba Bardhhaman District.

Figure No.1.1. Location of the Study Area

Geomorphologically, Burdwan town is in between Damodar, Banka, and Khari rivers *(Ganai & Sarkar, 2018).*The Banka River almost cutting the Burdwan Municipal Jurisdiction into two halves of North and South, **(Figure No.1.1)** is of no exception- it is the smallest non-perennial river originating from the Western part of the district with a length of 96 miles and a catchment of 253 sq. km, which used to be a very prominent drainage until 1960 *(P. K. Sen, 1976).* But over the decades due to construction of dams, irrigation and huge population pressure and their insensitive behavior towards the river has made it a complete dump yard at many of the places within and beyond the boundary of the Municipality and also sluggish for its velocity concerned *(P. K. Sen, 1976).* But surprisingly, the importance of Banka River as a lifeline to the town is neither very well captured in research studies nor properly documented so far. There have been quite a few Banka River Excavation plans drawn and planned before, but none of them got implemented either due to budget issues or time constraints (As per conversation with the Municipal Officials, dated 21st Nov 2022).

1.1.3. The Climate of Burdwan Town: The district of Purba Burdwan experiences 80 % of its rainfall between June and September and every year, floods might occur because of the highly intensified South-Western monsoon's seasonal rainfall. This district categorically falls into a tropical climatic zone followed by conditions of a moderate climate, with cold - dry winters, hot - humid summers, and an extended period of rainy season.

1.1.4. Urban Drainage of Burdwan Town: On the other hand, urban drainage systems generally perform poorly, mostly because of increased population and haphazard urbanization. The deficiency and incompetency of the drainage with the rapidly growing population creates severe and abrupt flooding condition (*S. Roy & Sahu, 2013).*Although this municipality does not currently have an underground sewer system, ward number 21 recently received this service. Solid garbage (such as plastic, packages, and aluminum cans) clogs most of the open surface drains. Therefore, regular flow is severely hindered. In the monsoon season, this stagnant liquid waste causes foul odors, pathogens, and urban floods *(Dutta & Mistri, 2013).* Some places of Burdwan Town are completely inundated even if it drizzles, some other places took a little longer time, but it affects every individuals

in the Municipal area as they have to commute to school, offices etc. The life of the daily wage earners like fruit sellers, flower sellers, people related to fish and diary distribution, Auto and Toto drivers, face a severe economic loss due to the flooding conditions. Not only the financial breakdown, has it caused no or less access to the civic amenities like water and electricity. In some parts of the Municipality life almost stops for a few days and others struggle.

1.2. Rationale for Selecting the Study Area:

Since all West Bengal's administrative and socioeconomic facilities are concentrated in Kolkata, the city's surrounding area has seen little urban development, and the city's overpopulation has led to a deterioration of its urban infrastructure and basic urban amenities. Burdwan, a Class-I town with a distinctive atmosphere of rich agricultural hinterland as well as historical and administrative importance of Rajas (Jamindars), can be a good example of searching for urban potentiality because the town maintains its identity despite being located between two million-cities in the East and West, Kolkata and Asansol *(Laha, 2019).*

Table No. 1.3. Rationale for Selecting the Study Area

SL No.	Nature of Factors	Causes
1.	Anthropocentric	A. Excessive rate of increase of population and unplanned urbanization since last century. **(Figure No. 1.2. to 1.4)** B. Improper urban drainage system including sewage and sanitation system and ill maintenance of them. C. Degeneration of Banka Khal from a navigable river to a dump site over centuries along with some lost courses of rivers.

2.	Structural	A. The Grand Tank Road has remodeled the town as it interrupts the natural course of water in the previous major river courses like Banka Balluka and Sapjala. B. Often the Embankments (five on the left bank of the river) hindrance the supply of water to the tributaries of river Damodar and the consequent siltation.
3.	Genetic	The Burdwan Town is 35-40 metre above the MSL and slopes down from West to East very surprisingly considering River Damodar as its West Boundaries.
4.	Hydrological	There is a very strong flood history in Lower Damodar region since last 300 years almost and the consequent inundation of Burdwan town is quite natural.
5.	Climatological	There were several huge cyclones and consequential rainfall which drowns the town in the worst possible way.

Source: For SL No. (1-3) *(Kunal Chakraborty, 2011)*, For SL No. (4-5) *(Sandipan Ghosh, 2012)*

Apart from this literature, here are some of the data facts which support the reasons for the selection of Burdwan Town as the study area presented in the parenthesis. First let us discuss the data **Satisfying Selection Criterion 1A**. (Excessive rate of increase of population and unplanned urbanization since last century)

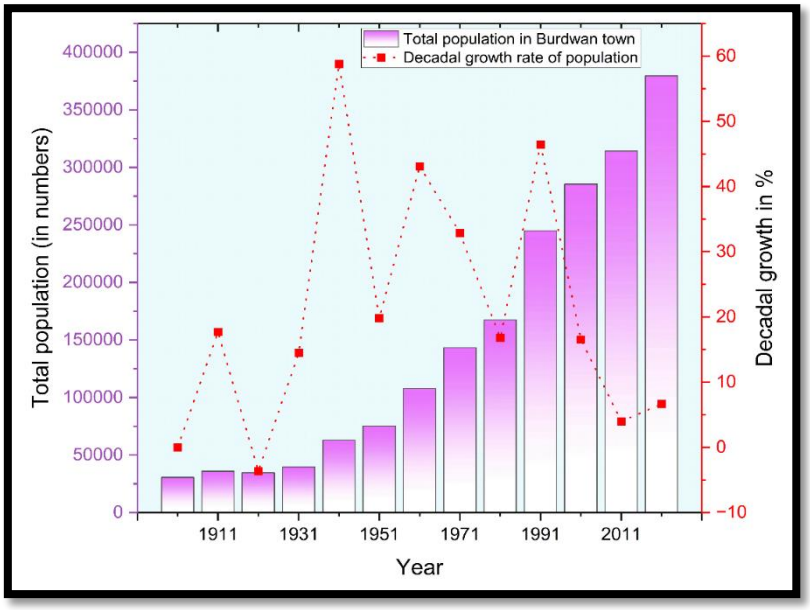


Figure No.1.2.

Growth of Population in Burdwan Town along with the Decadal Growth Rate

Source: Census of India and Data provided by Burdwan Municipality, compiled

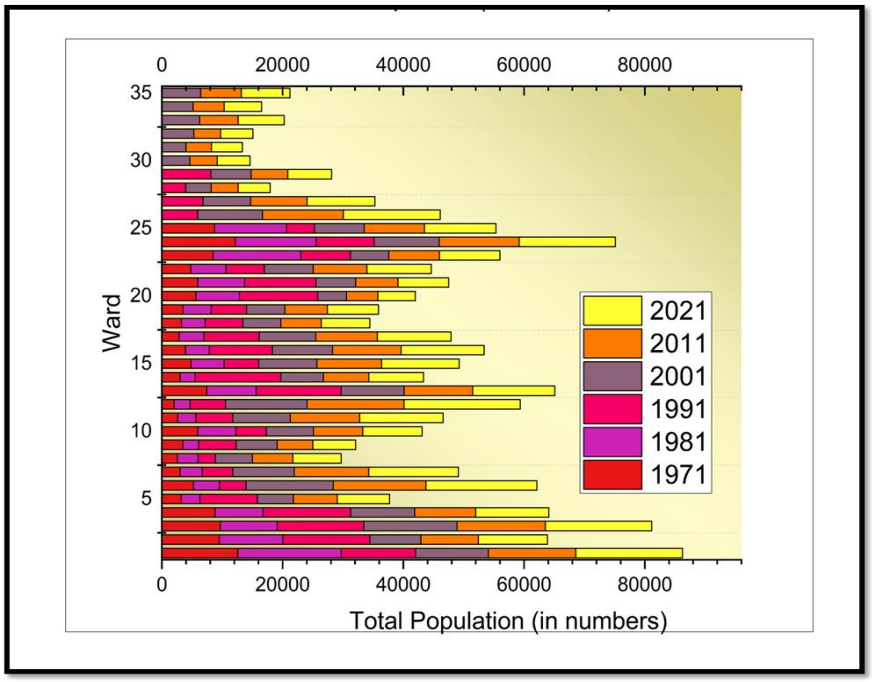


Figure No.1.3. Ward Wise Population Growth Over the Decades

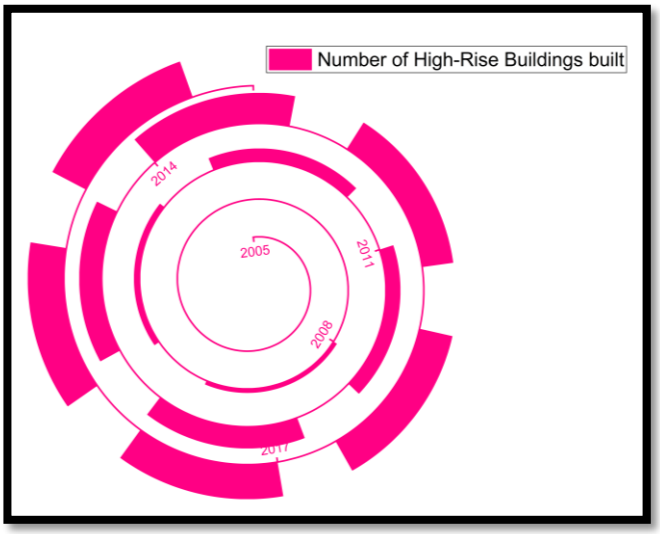


Figure No.1.4. No of High Rises in Burdwan Municipality from 2005 to 2019
Source: Census of India and Data provided by Burdwan Municipality, compiled

From Figure No.1.2 to 1.4, the population in Burdwan Town has experienced a sharp growth in terms of population since the last many decades but the last one of 2011-2021 has shown the highest hike in population even if the wards population counts. The number of high-rises even tripled from 2005 to 2019. Same applies for the slum population also- either they have emerged as a new entity in the many wards like 20,28 or they have increased manifold like in the wards 17,26.

Satisfying Selection Criterion 1B Improper urban drainage system including sewage and sanitation system and ill maintenance of them.

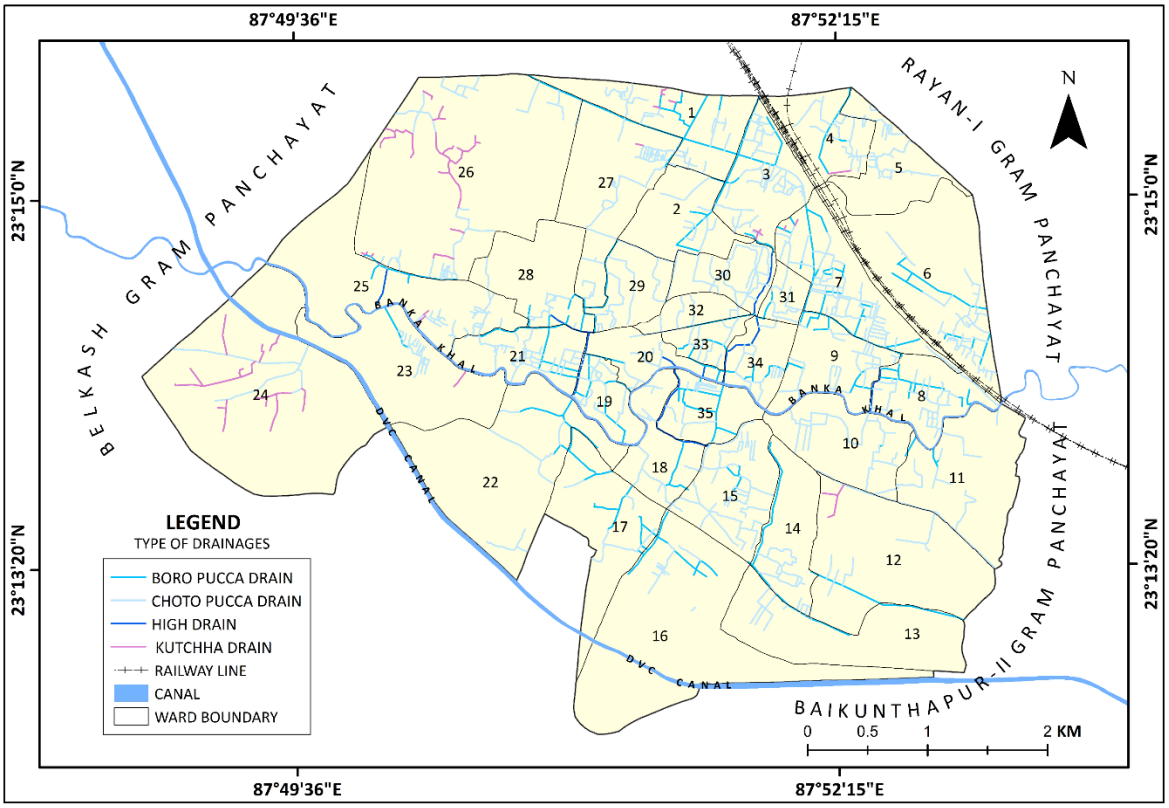
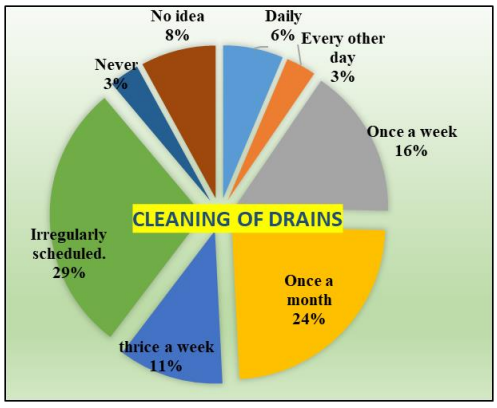


Figure No.1.5. Type of Urban Open Surface Drains in Burdwan Municipality where it confirms that in most of the places Kutcha Drains (non-concretized drains) prevail. *Source*: Base Drainage map provided by the Burdwan Municipality, 2020



While conducting the pilot survey in the beginning of the study, random respondents shared their situation regarding irregular cleaning of the drains- Hardly there are people who could report a strict maintenance of cleaning of the drains from the Municipality.

Figure No.1.6. The Opinion of The Respondents Regarding Cleaning of the Drains (*Source*: Pilot Survey,2019)

List of References:

1. Burdwan Municipallity. (2017). *Burdwan Municipality*. About Burdwan Town.
2. Dutta, S., & Mistri, B. (2013). Solid Waste Management and Sewerage Condition in Barddhaman Municipal Solid Waste Management and Sewerage Condition in Barddhaman Municipal Area , West Bengal- An Environmental Overview. In *Urban Issues in Geography* (Issue January, pp. 1–16).
3. FEMA (Federal Emergency Managing Authority). (2013). *Federal Guidelinnes for Inundation Mapping of Flood Risks Association with Dam Incidents and Failures*. https://www.fema.gov/sites/default/files/2020-08/fema_dam-safety_inundation-mapping-flood-risks.pdf
4. Ferreira, C. S. S., Potočki, K., Kapović-Solomun, M., & Kalantari, Z. (2022). Nature-Based Solutions for Flood Mitigation and Resilience in Urban Areas. *Handbook of Environmental Chemistry*, *107*(May 2021), 59–78.
5. Galloway, G., Reilly, A., Ryoo, S., Anjanette, R., Haslam, M., & Al, E. (2018). the Growing Threat of Urban Flooding: 2018. *University of Maryland College Park*, 1–44.chromeextension://efaidnbmnnnibpcajpcglclefindmkaj/https://cdr.umd.edu/sites/cdr.umd.edu/files/resource_documents/compressedurban-flooding-report-online-compressed-0319.pdf
6. Ganai, B., & Sarkar, K. (2018). Distribution of High-Rise Building and Its Relationship with Increase in Population of Burdwan Municipality , West Bengal. *International Journal of Computational Engineering Research*, *12*, 17–28.
7. Gray, V. (2007). Climate change 2007: The physical science basis summary for policymakers. *Energy and Environment*, *18*(3–4), 433–440. https://doi.org/10.1260/095830507781076194
8. Jemberie, M. A., Melesse, A. M., & Abate, B. (2023). Urban Drainage: The Challenges and Failure Assessment Using AHP, Addis Ababa, Ethiopia. *Water (Switzerland)*, *15*(5), 1–7. https://doi.org/10.3390/w15050957
9. Jha, A., Bloch, R., & Davies, J. (2011). *Five Feet High and Rising Cities and Flooding in the 21 st Century* (Issue May 2011).
10. Kaisa Kosonen, & Tirado, R. (2023). *10 things to know about the IPCC Climate Science Report* Greenspace.

https://www.greenpeace.org/international/story/58753/10-things-know-about-ipcc-climate-science-report/

11. Laha, M. (2019). Centripetal forces of urbanization in Barddhaman municipality, West Bengal. *Transactions of the Institute of Indian Geographers*, *41*(1), 33–50.
12. National Disaster Management Authority Government of India. (2007). *Floods*. Natural Hazards. https://ndma.gov.in/Natural-Hazards/Urban-Floods
13. NIUA. (2016). *Urban Flooding, Urban Climate Chnage fact sheet*. http://www.parliament.uk/documents/post/postpn289.pdf , Accessed on: 10/07/2015
14. R. Samal, N., K. Roy, P., Majumadar, M., Bhattacharya, S., & Biswasroy, M. (2014). Six Years Major Historical Urban Floods in West Bengal State in India: Comparative Analysis Using Neuro-Genetic Model. *American Journal of Water Resources*, *2*(2), 41–53. https://doi.org/10.12691/ajwr-2-2-3
15. Revi, A. (2008). Climate change risk: An adaptation and mitigation agenda for Indian cities. *Environment and Urbanization*, *20*(1), 207–229. https://doi.org/10.1177/0956247808089157
16. Roy, S., & Sahu, A. S. (2013). Effects of Urbanization on Channel Morphology: A Case Study Of Banka River in Burdwan Town, West Bengal. *Thematics Journal of Geography*, *2*(4), 31–36.
17. Sen, P. K. (1976). A Study of the Hydrological Characteristics of the Banka Basin. *Indian Journal of Power and River Valley Development*, *XXVI*(11), 353–358.
18. Shivali Jainer, S. (2020). *Learning from past mistakes: It's time to save urban rivers*. Down to Earth.
19. Shukla, S., Khire, M. V, & Gedam, S. S. (2013). Effects of Increasing Urbanization on River Basins- State of Art. *International Journal of Engineering Research & Technology*, *2*(12), 2742–2747.
20. Singh, M., & Upmanyu, V. (2019). *Urban flooding: The case of drowning cities and rising vulnerability*. Natural Disasters (Down to Earth). https://www.downtoearth.org.in/blog/natural-disasters/urban-flooding-the-case-of-drowning-cities-and-rising-vulnerability-67203
21. Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*, *32*, 25–37. https://doi.org/10.1016/j.proeng.2012.01.1233
22. (UN) United Nation. (2019). *Economic and Social Commission for Asia and the Pacific*

Ambitions Beyond Growth.

23. Wobus, C., Gutmann, E., Jones, R., Rissing, M., Mizukami, N., Lorie, M., Mahoney, H., Wood, A. W., Mills, D., & Martinich, J. (2017). Climate change impacts on flood risk and asset damages within mapped 100-year floodplains of the contiguous United States. *Natural Hazards and Earth System Sciences*, *17*(12), 2199–2211. https://doi.org/10.5194/nhess-17-2199-2017
24. World Bank. (2019). *Learning from Japan's Experience in Integrated Urban Flood Risk Management: A Series of Knowledge Notes Knowledge Note 1: Assessing and Communicating Urban Flood Risk.*

CHAPTER: TWO

REVIEW OF LITERATURE

2.0. Foreground:

A huge number of accounts related to the various facets of urban flooding have been carried out probably from the time when people are not even aware of the term itself. To give it a convenient understanding, the review of the available literature is being carried out, broadly in the following manner. The database used here is –*Web of Science (WoS), Scopus and Google Scholar.* According to the Cambridge English Dictionary, the word ***Genesis*** stands for origin. As title of my research work is concerned, it demands tracing back to the historical accounts of floods in the selected area of study. In this regard, some of the Mythological and Historical accounts are put here in details for their exemplary nature.

2.1. Mythological Archives:

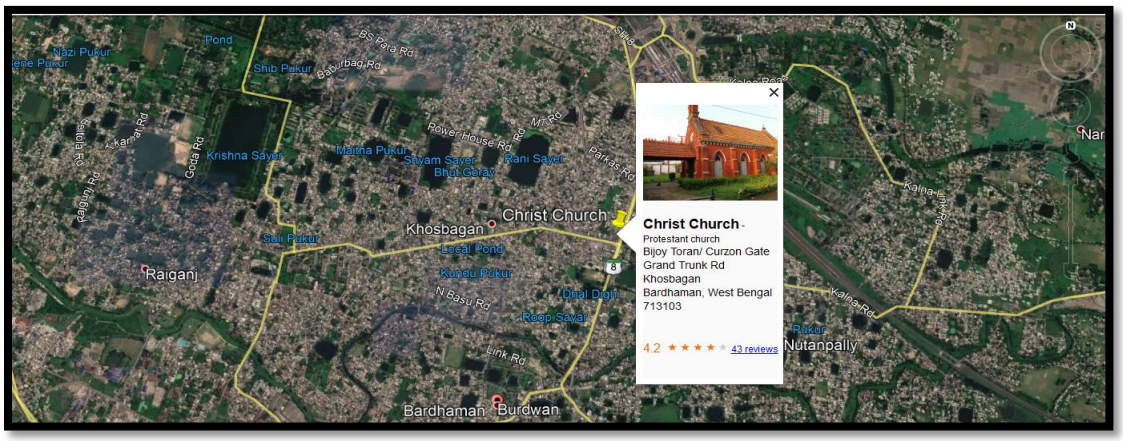
2.1.1. In the Manasa-Mangal (Part of Mangal Kavya):

In this famous folklore of Bengalis, by *Ketaki Das Kshemananda,* there are several times where the mention of the area of the Burdwan District (on its ancient nomenclatures) are found. *Hasanhati*, *Baidyapur*, *Udaypur* - these are the few places crossed when *Behula* was sailing in the wooden boat with the dead body of *Lakhinder*. All these stations were reported to have been situated on the banks of the Damodar River. The house of *Chand Saudagar, Champak Nagar* is assumed to be in the present-day position of *Kasba,* under *Galsi* Block. It has become a tourist spot also. Even there is a decaying river named *Behula* which was supposedly navigable at that point of time *(Kshemananda, 1316).*

Google Earth Image: 2.1. The Puranic places of Mangal-Kavya plotted in the proximity of *Burdwan* Municipal Area in *Purba Bardhaman* District (Retrieved on Feb,2020)

2.1.2. In the 'Kalpa Sutra':

According to Kalpa Sutra, the great Jain prophet Mahavira 42 monsoons of his ascetic life in a few places among those he spent one monsoon in ***Astikagram*** (Balbir, 2009) **.**



Google Earth Image: 2.2. Though there is not much mention about ***Astikagrama i***n the other literature, Google Earth Pro (Version 7.3.1) locates this place somewhere in the Burdwan Municipal Area. (Retrieved on Feb,2020)

2.2. Historical Accounts:

- A report on Midnapore and Burdwan cyclone **15th-16th October 1874 by W.G. Wilson** published by Bengal Secretariat Press,**1875** gives a very scientific and climatological description including hourly wind speed, rainfall, the progression of the eye of the cyclone and finally the losses. It also shows how this cyclone starting from the Bay of Bengal showed its destructive nature toward North Bengal. This book also gives an impression of the extracts of the writings of other eyewitnesses like District Superintendent of Police, Deputy Magistrate. It is an absolute treat to read such a marvelous account of disaster taken place in 1870s (Willson, 1875)
- **The Causes Symptoms and Treatment of Burdwan Fever**' or the epidemic fever of Bengal by **Dr. Gopal Chunder Roy** published **by J. A. Churchill,** New Burlington Street, Calcutta: Thacker, Spink and Co. **1876**, is basically consisted of eight chapter where in second chapter named 'Causes' and 'Symptoms' the author has given a vivid geographical description of the rivers, floods and reservoirs and

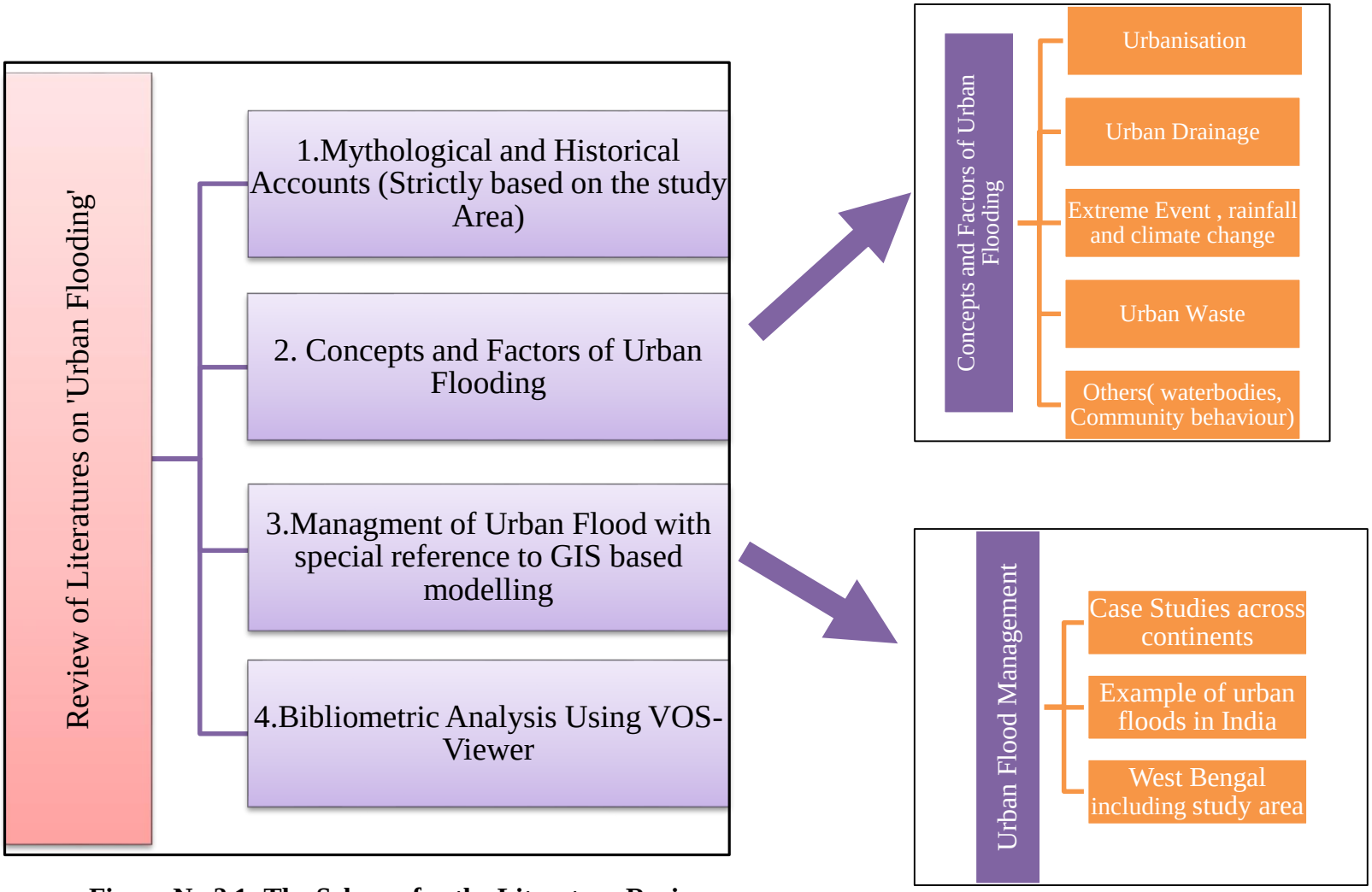


Figure No.2.1: The Scheme for the Literature Review

shown that how polluted muddy water of the river stood as one the causes for the epidemic.'"*...Several causes present themselves to our observation: (a) Naturally heavy and sometimes unnaturally heavy and unequal rain-falls (b) Inundation (c)Peculiarity of soil and its property of retaining moisture (d) Existence of tanks and unclaimed marshes and rice-fields, (e) Naturally defective drainage(f) obstructed drainage, either artificial, as by bending up the course of water channels by dams, weirs, rail roads, &c., or natural, as by the alteration in the course of rivers and silting up of their beds*."

This book is an incredibly sad narration of how once a prosperous region has gone into vain under the influence of epidemic fever *(G. C. Roy, 1876).*

- **Burdwan District Gazette, Statistics 1901-02** published by Bengal Secretariat Book Depot in the year 1905-this basically served as a data repository of late 19th century of the district Burdwan, covering from rainfall to population to wages, legislation of Municipalities to police administration, finance, stamps etc. The chapters like Climate and Population have really sited a scenario of the then climate and population in the district *(Gazetter, 1905).*
- **Bengal District Gazette of Burdwan ,1910** published by Bengal Secretariat Book Depot by **J.C.H. Peterson** covers an all the aspects of the district like a gazette does starting from its history, people to its education, local self-government. The sixth chapter named 'natural Calamities' is of the utmost importance to my work as it describes the floods of 1770,1787,1855,1909 and its devastating nature with the accounts of the losses they made in the district. This is considered as a valuable resource of the Burdwan District as it was in the 19th century *(Peterson, 1910).*
- ***Burdwan Samagra* Vol III by the famous historian Gopikanta Konar** is a collected edition by various eminent authors of their field who talked about the growth of Burdwan from the era of Jain to Mughal, its heritage to the implementation of its planned industrial town, its freedom fighters to its Democratic women Society, its development as a district of culture and heritage and some lost rivers in the lower Damodar region. There is other two volumes of these books which also strictly deal with the culture, folk history, and archaeological aspects. This book is a highly

informative and detailed one and most importantly, the story telling way of writing has made it more lucid to the readers *(Konar, 2000).*

- ***Barddhaman Jelar Itihash O Lok-o-sanskriti*** **(Vol.1) By Akkori Chattopadhyay** gives a narration of the district's history in terms of archaeological site, sites of importance where many facts are hidden as gems regarding the oldest parts of Burdwan district. Moreover, it has got old pictures which not only added some aesthetics but also are of immense help to any reader *(Chattopadhyay, 2000).*
- **Notes on the physical geography of Bengal**, from the writings and the maps of **Major James Renell by F.C Hirst published by Calcutta Secretariat Book Depot 1926**- this is an exquisite collection of **Renell's Diary 1764-1767**, Renell's description on the road in Bengal and Bihar,1778, Renell's Tables and distances from Calcutta etc. Through the principal inland navigation 1781, Renell's memoir of a map of Hindoostan or the Mogul Empire,1788 (1st Edition) and some unpublished map work of Renell which are later published by the author in 1918. The pages 79-80 give a description of the river 'Dammoodaah' and the town Burdwan which is situated 15 miles away from this river. But as far as the navigation routes are concerned it was navigable up to Burdwan and it also described 'Bonkah River' as a rainfed river. This book is a treasure when it comes to the find the literatures of Bengal rivers, but it was mostly concentrated on the river Ganges and its courses, tributaries *(O. et al., 1928).*
- Lectures on the Ancient System of Irrigation in Bengal and its application to modern problems by Sir **William Willcocks**, published by University of Calcutta,1930- it is a masterpiece describing the various ways of irrigation system existed in Bengal at that point of time and its evolution also-over flow irrigation, Zamindari irrigation system(embankment) and reclaiming the ancient irrigation system of Bengal both practically and theoretically etc. It compares the irrigation system approach with the civilization of Egypt and Babylon. It gives measurement and depth regarding 'Kana Damodar' 'Kana Nudde', the possible ways of irrigation and budgets to make these. It gives an emphasis on the river Damodar and channelizing its excess flood water. It also stated that the Burdwan Raj was the first among the productive state of India when there the old irrigation system was adopted. This book is very scientific in its nature and of course ahead of its time, but it would have been more attractive if the amount of

crop or property damages by the floods were mentioned so that it could show the loopholes of the irrigation system in a much strong way*(Willcocks, 1930).*

- **The Changing Face of Bengal: A study in Riverine Economy by Prof. Radha Kamal Mukherjee,** published by the university of Calcutta,1938 is a repository for the accounts of nature of economy specially agriculture (the then district wise), impact of flood or famine, break out of malaria, increasing population in Eastern part and decline of waterways and siltation. In the chapter' Changes in rivers and ports' he talks about the navigation and the annual discharge of the river Damodar and Saraswati and the deterioration of river Damodar and consequent decreased flow of water in the Ganges. On the top of it, it provides some old maps of Bengal since the time of 1660 by Van Dan Broucek and Asia since 1561 by Gastaldi *(Mukherjee,R.K, 1939)* .
- **Bengal Rivers and our economic Welfare by Maharaja Shri Srischandra Nandy**, published by the book company limited 1948-he shares his experience as a Minister of Irrigation of Bengal (1937-1940). in this book, there is a whole dedicated chapter on the river Damodar as 'Damodar- the river of sorrow' where he mentioned the ill effects of the previous embankments and how the floods caught the eyes of the committee where afforestation and water diversion was taken measures. He has also published the irrigation budget for the year 1936-37. He also mentioned the multipurpose river valley project for the Damodar river. (Nandy, 1948).
- **The Book 'Rivers of Bengal Delta' (1942) by S.C. Majumdar** gives a vivid description of the rivers of North, central and South along with the tidal rivers and discusses the problems related to navigation and erosion. It also mentions the role of Ganges River Commission and inter-provincial aspects of the river problems like floods *(Majumdar, 1942).*

Table.2.1: Showing the Old Maps those Have Been Studied During Literature Study

Name of the Maps (With Links)	Published by	Scale
1. The Travelogue 'Indica' of India at time of Chandra Gupta Mourya (http://www.payer.de/quellenkunde/quellen1102.htm)	Megasthenes (Schwanbeck et al., 1825)	NA

Name of the Maps (With Links)	Published by	Scale
2. An actual survey, of the provinces of Bengal, Bihar &c. (South half).1794 (https://rb.gy/mkpcgg)	Renell, James, 1742-1830 Author: Robert Laurie & James Whittle *(Rennell et al., 1794)*	1:750,000
3. Composite: Map of India. List No:6732.004 Series No:4 (https://rb.gy/vbr6xf)	Arrowsmith, Aaron(Arrowsmith, 1804)	1:1,759,575
4. Section VIII. (Bengal). Plate 29. The Edinburgh Geographical Institute. (1893). ListNo:11794.034 Series No:34(https://rb.gy/uomcfp)	Bartholomew, J. G. (John George) Archibald Constable & Co. (Burtholomew, 1893)	1:5,500,000
5. US Army Survey Map (Prepared by the Army Map Service (NSS & H), Corps. of Engineers, U.S. Army, Washington, D.C. Compiled in 1954 and 1955 from Half-Inch Series, 1: 126,720, Survey of India, 1922-43 NF45-3Series U502)	US Army *(US Army Service & Survey of India, 1922)* (http://legacy.lib.utexas.edu/maps/ams/india/nf-45-03.jpg	1:250,000

Source: Compiled by the Author from various sources (Links are given above in the table)

2.3. Concepts and factors affecting Urban Flood:

2.3.1 Concepts of Urban Flooding:

- '*Urban flooding is significantly different from rural flooding as urbanization leads to developed catchments, which increases the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. Consequently, flooding occurs very quickly due to faster flow times (in a matter of minutes)'(National Disaster Management Authority, 2017).*
- *'Urban flooding is not just "flooding that happens in an urban area." This isn't what happens when a river overflows its banks or when a hurricane drives a storm surge across a coastal neighborhood. Instead, it's caused by excessive runoff in developed areas where the water doesn't have anywhere to go. Urban flooding can be linked to a major disaster, like Hurricane Harvey and its 33 trillion gallons of rainfall. But more often it happens during more routine circumstances, appearing in the form of wet basements and sewer backups. Even small amounts of rain can overwhelm the deteriorated or inadequate infrastructure found in many neighborhoods, especially in Impoverished, neglected, and/or socioeconomically isolated urban communities'(Weber, 2019).*
- *'Urban flooding is defined as the inundation of land or property in the built environment when storm water management systems, like storm sewers, fail. Climate change is bringing increasingly heavy rains. Combining this with the increase in runoff from continued development, we find that outdated municipal drainage systems are unable to keep up. The result is more frequent and intense local flooding, destroying homes and personal property and forcing businesses to close'(FEMA (Federal Emergency Managing Authority), 2020).*

2.3.2. Factors of Urban Flooding:

If the reasons are studied it could be found that in the developing countries like India, in case of population influx, **migration** plays a huge role within the cities. This Increase in Population which results into more **inappropriate urbanization**, impermeable area, and generates very little infiltration and greater surface flow *(N & Kumar, 2020)*. Urban flooding doesn't only occur in the urban areas but also the prime cause to it is the **faulty urbanization** in the **flood plain cities** *(R. Samal et al., 2014).* Like Sarmah and Das have mentioned urban floods are more manmade in character, with fast and uncontrolled

urbanization **filling up water bodies,** blocking water courses, causing deforestation, and so on. Indeed, urbanization exacerbates floods by reducing flood-water flow, covering enormous areas of land with buildings, roads, and pavement, blocking channels, and constructing drains to guarantee that water flows into rivers quicker than it would under natural conditions. This urban expansion can lead to both **local climate change and the formation of urban heat islands,** which are some other important factors for flooding in the cities. The quantification of urban expansion through land Use and Land Cover Dynamics, Gradient analysis and urban spatial metrics can be done. Based on the result, and with the input of Digital Elevation Model, a proper flood zonation map can be figured out, like has shown in the case study of Delhi *(Gaurav et al., 2018).* The degree of Urban Sprawl can also be equated with the various entropy indices and parametric and non-parametric tests too *(Jain et al., 2016).* These measures would help to manage this irrational growth calling for a proper and scientific urban planning is needed which would take account into the design of urban growth, its causes and solutions (Rojas et al., 2017). **Hydrometeorological implications** of urbanization are always an overly complex factor**. Extreme rainfall**, on the other hand, can increase the risk and size of floods in small and urban catchments, wreaking havoc on citizens and infrastructure. The nature of the flooding is also dependent whether it is a flash flooding or pluvial flooding, or riverine or coastal floods that inundate the cities. Flooding is directly related to **high precipitation**; however, climate change, fast urbanization, and uncontrolled urban growth function as catalysts by altering the catchment's hydrological response *(P. Singh et al., 2018).*Climate change has increased the likelihood of higher precipitation both in terms of higher proportion, intensity and occurrences in the twenty-first century by more than 90 percent *(Ramachandraiah, 2011).*The exact forecasting of rainfall, be it high intensity or moderate intensity is needed to deal with the city's vulnerability. The accurate modeling and prediction of rainfall can also point out the altered-flow phenomenon which is usually found in the urban areas due to heavy storm *(Wang et al., 2019).* Non-stop precipitation (as in Mumbai in 2005 and the Gujarat flood disasters of 2005 and 2006) is projected to increase significantly over a vast region of the West and central India. This will necessitate a considerable overhaul of urban design techniques in order to incorporate flood mitigation and adaptation strategies as well as climate change mitigation and adaptation measures

(Ramachandraiah, 2011) .**The design of urban drainage** holds a pivotal role like the presence and the layout of the major drainage system (Open nallah, natural surface drains) and minor (network of underground pipes and canals) drainage system and also their competence to channelize the excess storm water*(Butler & Davies, 2020).* In Burdwan Municipality urban drainage systems generally perform poorly, mostly because of increased population and haphazard urbanization. Solid garbage (such as plastic, packages, and aluminum cans) clogs many open surface drains. Therefore, regular flow is severely hindered. In the monsoon season, this stagnant liquid waste causes foul odors, pathogens, and urban floods *(Dutta & Mistri, 2013).*Another important factor is - **Conservancy services**, by a Municipal body or a Town means conservation of urban environment in a sustainable clean manner by including the services like rubbish pickup and removal, road cleaning and sweeping, tree trimming and cutting, dead animal lifting, and so on. In one simple sentence, it is the services that make city **garbage free** *(K. N. Kumar & Goel, 2009).* The major portion of this city's conservancy services is performed by the removal and treatment of Municipal Solid Waste (MSW). On the other hand, towns and cities in the developing nations are acting as hubs of solid waste generation as an outcome of immense population growth and haphazard urbanization. Poor solid waste management (SWM) has become a burden for governments in developing Asia and Africa, as it is critical to public health, safety, and the environment. Uncollected rubbish piles in the streets, obstructed drainage channels, or deposited in watercourses constitute a significant public health risk, and unmanaged disposal of waste can harm water supplies and pose serious environmental health risks to people who live nearby. Workers in solid waste and rubbish collection confront severe occupational health and safety risks *(Ferronato & Torretta, 2019).*Thus, solid waste must be handled in a way that minimizes environmental and human health concerns, which has consequences for its storage, collection, and safe disposal. The National Action Plan for Municipal Solid Waste Management Act 2000 and Solid waste management rules,2016 (India) both put an emphasis the duty of an Urban local body to deal with the municipal solid waste management including its generation to its recycling processes *(Ministry of Environment Forest and Climate Change, 2016).* **The void between disaster occurrence and precaution is always filled with casualties** *(Oyediran & Wahab, 2023).* While numerous climate change prevention and adaptation methods have

been implemented in recent years, many have progressively concluded that developing community resilience is critical when responding to climate change, particularly urban flooding. There has been a paucity of research on **community preparedness** to urban floods, particularly among transient people, therefore more empirical investigations are needed to increase our understanding and find effective treatments *(Xu et al., 2020).*

2.4. Urban Flood Disaster Risk Reduction:

The attempts to solve the problem brought to us by the urban flooding, might date back to the time of very first civilization *(APFM, 2008).*However, other than building the traditional checks (dams, reservoirs and levees), the approach has been shifted towards building the resilience towards flooding which scientifically would hold the capacity of tackling the storm water and as well as maintaining the functionality of urban life *(Sörensen et al., 2016).* If the proposal given by is followed, there are certain strategies those can be adopted for Asian Cities like- proper management of Land Use, normalizing the concept of disaster reduction among people, building and Maintaining the structural interventions, outlining the scheme for disaster recovery programs emphasizing on the urban poor, developing a proper warning system and quick response team etc. (*Arambepola & Iglesias, 2009).* Similarly, has given stressed upon 1)Preparedness before the onset of the flood though warning system activation 2) readiness on the arrival of the flood; 3) Quick and emergency feedback; 4) Lastly, Rescue, and rehabilitation of the flood victims (Tingsanchali, 2012). But it seemed that Urban Flood management often emphasis on Engineering and Hydraulic Component so very much that it forgets to include other important dimensions like socio-economical risks (Liu, 2012). The Literature Survey for Urban Flood Management or Risk reduction has been carried out in the following manner.

2.4.1. Global Scenario (Across Continents):

A huge number of populations is at stake concerning the rising flood events and this is due to the urban development which necessitates bigger flood management as well as smaller-level adaptation measures to reduce socio- economic risk and vulnerability. This is resulting in more people emigrating, and lower-income groups are put at risk. To facilitate

urban flood resilience, inclusive strategies that combine '*bottom-up drivers of individual climate adaptation'* are required (*Koning et al., 2019).*

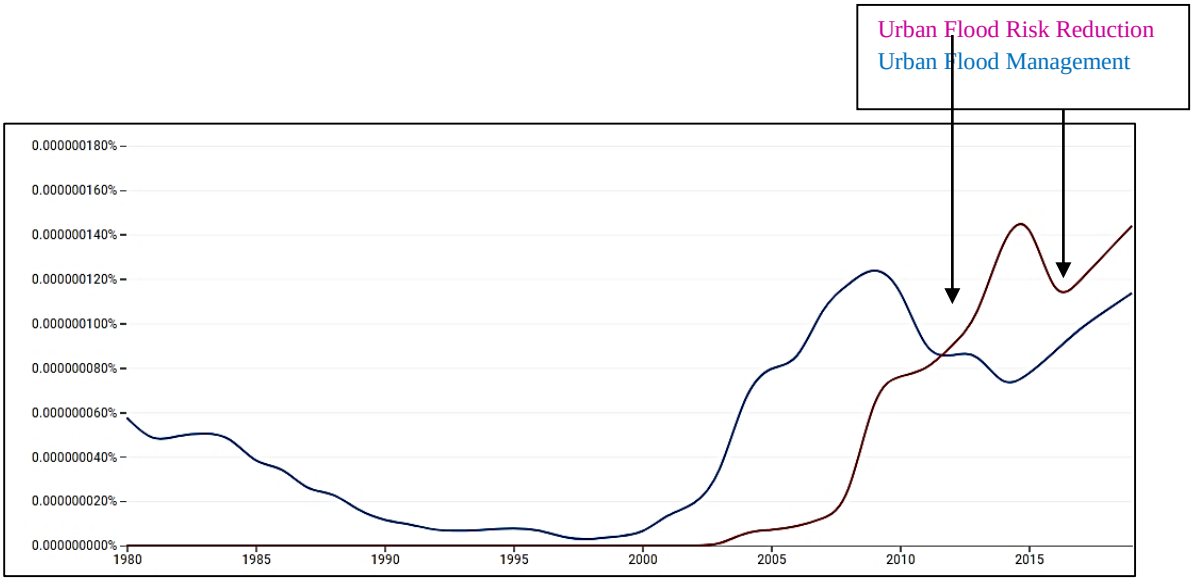


Figure No.2.2. Showing the shift the paradigm from 'Urban Flood Management' to 'Urban Flood Risk Reduction' as the number of documents containing the latter is increasing over the time.[***Google* Books *Ngram Viewer*** *where X-axis shows the year and Y-axis shows the percentages of the occurrences of the books comprising the key word 'urban flood management' more than 40 times in a specified corpus(Josund, 2017).*]

On the other hand, for the lake cities , regular lake level regulation can be a way to channelize flood water *(Chen et al., 2019).* The Greater Toronto Area has been studied using hydrological model using Digital elevation models , the census data, the streams, land use have been used as inputs to divide the area in flood zones *(Levy et al., 2007).* The STAR flood project which includes flood risks in 18 vulnerable urban areas in six European countries of England, Scotland, Belgium, France, The Netherlands, Poland, and Sweden talks about delivering the sustainable flood Management and judging the competence about the urban local bodies. Again, some categories in Structural Measures like Intensive and extensive ones, some important parts of urban drainage management, such as control strategies and principles, as well as long-term control procedures for a variety of situations in the case studies of Brazil, Argentina and Central America is discussed with the linkages and interface with the urban setups *(Tucci, 2018*). For the Nyamwamba watershed in Western Uganda ,GIS-based flood hazard index (FHI) has been formulated with the help

of Analytical Hierarchy Method that takes specially that took "*slope, flow accumulation, drainage network density, drainage channel, geology, land use/cover*" *(Kabenge et al., 2017)* .For the Eldoret Municipality of Kenya, UFRI(Urban Flood Risk Index) is created using the degree of exposure and susceptibility, obtained from mapping*(Ouma & Tateishi, 2014).*

2.4.2. Asia:

Most of the population lives in the flood prone areas and the low-lying cities and there is no sign that this trend would ever decrease, particularly in South -East Asia the rise is even steep. An increase in urban storage and managing the urban water discharge can be a way to lessen the impact of inundation *(Schultz, 2006). I*n the Tsunami affected Asia-pacific Region, the cities of Ansung of the Republic of Korea, Shanghai of China, and Yokohoma of Japan were studied as model cities where '*Appropriate and feasible flood control standards were established together with flood prevention schemes and flood regulation plans'* established, thus advocating a comprehensive approach *(Liu, 2012).* But this article has also emphasized the need for a community based early warning system which is considered as a challenge yet. The Information technology makes an important role in disseminating the education and alerts while forecasting. (Koay et al., 2016)The importance of the structural measures of flood and maintaining their standards like flood wall, flood storage areas like lakes, reservoir, underwater drainage system -are assessed in the cases of old and new urban areas of Wuhan and Ganzhou cities of China *(UNDP Project, 2017).*

Taking a case-study of a busy tourist street of Singapore, has emphasized the importance of adaptive management to deal with flooding. In terms of Flood Risk Prediction, the IPCC projections play an important role like in case of Yangtze River Basin*(Abdullah, 2020; Zhang et al., 2020).*In case of Risk management, the actual and perceived risk can be different, as shown in case of Rawalpindi, Sialkot and Muzaffargarh, Pakistan, but in the absence of the actual risk data, perceived risk ones can be an alternative for assessment *(Rana & Routray, 2016).*

2.4.3. Indian Scenario:

The comprehensive hydrological and hydraulic modelling can be a useful prop to control the current and future flooding scenario as it was proved to be helpful in case of Chennai Floods *(Andimuthu et al., 2019)*. According to this article, probably the best statistical practice is to generate an Intensity-Duration-frequency (IDF) Curve, which might be able to foresee the next occurrence of extreme events. The major feature of the Indian cities are they are incredibly populated given the lesser physical space, that is why even a little abrupt rainfall floods the city as shown by in case of Bangalore and Hyderabad Cities (*Gupta & Nair, 2011).*

In two significant Indian metropolises, Bangalore and Chennai, the difficulties associated with drainage and flood mitigation—including both structural and non-structural approaches—as well as the core issues of urban ecology have been examined. Risk management issues have been considered in the context of land use, city and population growth, wetland deterioration, and garbage disposal. The study employs remote sensing and GIS techniques to assess flood-inundated areas in the study area using a flood hazard map, the impact of flooding on people, infrastructure, and vegetation using a flood vulnerability map, and flood zones in the study area using a flood zoning map to show hazards and classify them as low, medium, and high magnitude hazards. The study area of Kottarachowki, Mangalore taluk, Dakshina Kannada district, Karnataka state, has also indicated the same *(AshwathaNarayanaM et al., 2019).*The rapid urbanization has proven fatal in case of Yamuna River basin, Delhi and therefore, flooding with greater intensity are occurring at a higher magnitude. Even with a mediocre velocity the flood can be proved fatal for a sizeable population. A proper oversight and upkeep of the old structural measures and strengthening non-structural measure can alleviate the number and the loss of flood affected people *(M. Kumar et al., 2019).* Floods in Guwahati impose a serious threat to socio-economic aspects including urban livelihood insecurity , that is why a socio-economic indicator based approach on social infrastructure and urban amenities and associated modelling of the incidents of the past events can be proven as helpful in case of further damage*(Kashyap & Mahanta, 2021).*

2.4.4. Case Studies from West Bengal:

Among other states, West Bengal happens to receive maximum precipitation in the months of September and October coupled with depressions in bay of Bengal has shown the extreme rainfall events till 2000 and has shown how the failure of structural measures associated with heavy rainfall can cause prolonged fatalities for the State*(R. Samal et al., 2014).* Developing a neuro-genetic model, the paper has identified the relationship between return period and rainfall events. The unplanned urbanization in the hazardous low-lying areas , destruction of wetlands and inadequate drainage conditions have led water logging condition of English-Bazar Municipality of Malda Town to its worst. *Chattaraj et al., 2021* has proposed a well drafted drainage plan for the town. Flood Risk Index, Flood Vulnerability Index and Flood hazard Index developed by in case of Cooch Behar basin can help towards a better management of the casualties*(Chakraborty & Mukhopadhyay, 2019).* The application of Real-Time data in flood monitoring is proposed and shown by but the data and associated processing chainage are not always available at all scales *(D. Sen, 2013).*

2.5. Flood Modelling as an Important part of Flood Risk Reduction:

… 'Flood forecasting is one of the important flood mitigation methods and is widely used in catchment flood mitigation (Zhang, 2002). Flood forecasting relies on flood forecasting models, and lots of flood forecasting models have been proposed, such as the Stanford model (Crawford et al., 1966), the Xinanjiang model (Zhao, 1977), the ARNO model (Todini, 1996), the SHE model (Abbott et al., 1986a, b), and the Liuxihe model (Chen et al., 2011), among others. The models used in catchments cannot be used directly in urban areas as there is a high density of buildings and underground pipelines that are not treated by catchment models. There are urban hydrological models which can deal with underground pipeline flow and even surface runoff flow, and determine inundation conditions, such as ILLUDAS model (Terstriep et al., 1974), SWMM model (Cole et al., 1976), TR-55 model (USDA, 1986), Inforworks model (Koudelak et al., 2008), and the STORM model (Wiles et al., 2002). These models have been widely used in urban flood planning and management, but not used so much in urban flood forecasting.'…(Jiang et al., 2015).

Table No.2.2 The Usage of Various Models Combatting The Risk For Urban Flooding

Names	**Category**	**Usage**	**Case Studies**	**Authors**
The Dynamic Spatial Model for Urban Simulations	CA (Cellular Automata) MOLAND Model	Used In Urban Growth Mapping	USA	*(Barredo Et Al., 2005)*
Hydrodynamic	SWMM And Flood Inundation and Recession Mode	Importance of Manhole in Urban Flooding Simulation	Japan	*(Gebreegziabher & Demissie, 2020)*
Multi-Criteria Decision Support Systems (MCDSS)	MCDA (Multi-Criteria Decision Analysis) Models and Techniques, With Emphasis on The Analytic Network Process (ANP)	Value judgements and technical data combined in a structured decision framework can help manage this complexity and decision load.	Italy	*(Levy Et Al., 2007)*
SWMM	SWMM	Helps To Forecast Urban Flood, But Not Precisely.	China	(*Jiang et al., 2015)*
MIKE URBAN	1D Drainage System model coupled with 2D Hydraulic Model	urban storm, flood events and urban runoff, drainage infrastructure and	Germany	*(Basnet & Bhola, 2017)*

		urban drainage modelling		
SWMM-PCSWMM	A coupled 1D-2D flood modelling approach	finds overflowing drainage nodes and prepares risk and flood inundation maps	India (Hyderabad City)	*(V. A. Rangari et al., 2018)*
(HEC-HMS) (HEC-RAS	Rainfall–runoff model	Flood concerns are modelled in two dimensions in order to create management plans that use flood risk reduction techniques to address the likelihood of future occurrences.	India (Hyderabad City)	(*Vinay Ashok Rangari et al., 2019)*

Source: Compiled by Author from Various Sources

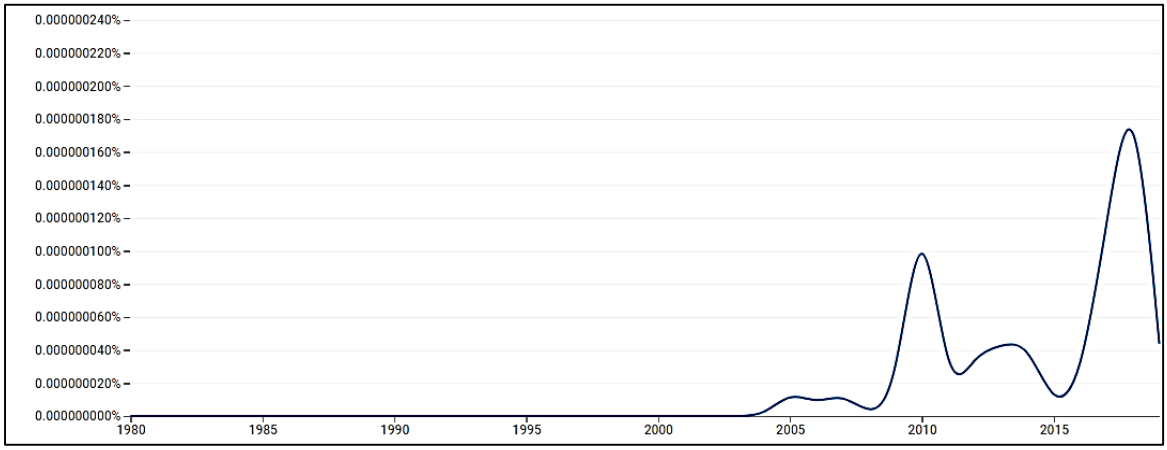


Figure No.2.3(a). Showing the Google Registered Books on Urban Flood Modelling

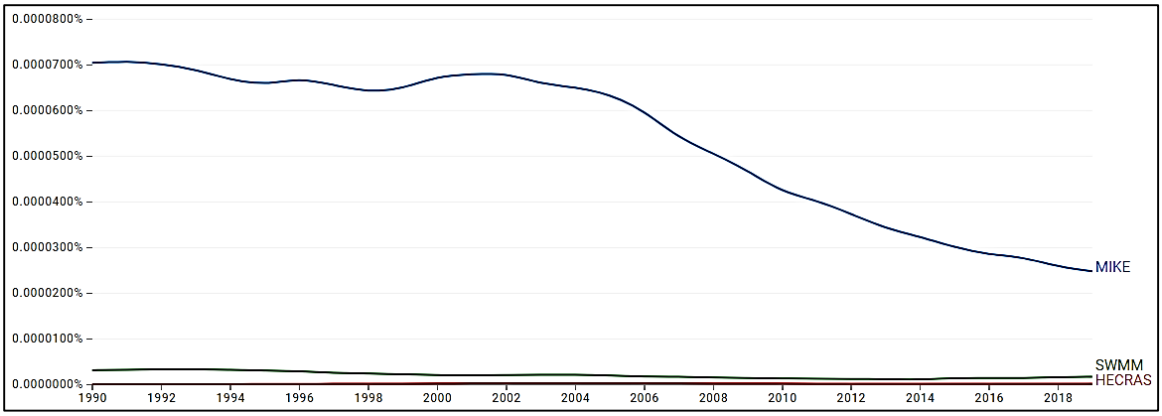


Figure No.2.3(b) showing the Usage of The Models on Urban Flood Management

For Fig. 2.3 (a) and (b)[***Google* Books *Ngram Viewer*** *where X-axis shows the year and Y-axis shows the percentages of the occurrences of the books comprising the key word 'urban flood management' and 'Urban Flood software' more than 40 times in a specified corpus.(Josund, 2017)*]

List of References:

1. Abdullah, A. F. Bin. (2020). Urban Flood Modelling. *A Methodology for Processing Raw Lidar Data to Support Urban Flood Modelling Framework*, 15–34. https://doi.org/10.1201/9781003059295-2
2. Andimuthu, R., Kandasamy, P., Mudgal, B. V., Jeganathan, A., Balu, A., & Sankar, G. (2019). Performance of urban storm drainage network under changing climate scenarios: Flood mitigation in Indian coastal city. *Scientific Reports*, *9*(1), 1–10. https://doi.org/10.1038/s41598-019-43859-3
3. Arrowsmith, A. (1804). *Composite: Map of India*. David Rumsey Map Collection.
4. AshwathaNarayanaM, K., Savanth, V. D., Madar, H. Y., Mallikarjuna, & Awati, M. (2019). Urban Flood Management at Kottarachowki, Mangalore, Karnataka, India. Using Gis And Remote Sensing: A Case Study. *International Journal of Advance Research and Innovative Ideas in Education*, *5*, 240–244.
5. Balbir, N. (2009). *Jainpedia-The Jain Universe Online*. Highlights of Jainpedia.
6. Basnet, M., & Bhola, P. K. (2017). *MIKE URBAN as a tool to model the 1D drainage system ; Case study : Kulmbach (Germany)* (Issue March).
7. Burtholomew, J. G. (1893). *Constable's Hand Atlas of India : a new series of sixty*

maps and plans ;Section VIII. (Bengal). Plate 29. David Rumsey Map Collection.

8. Butler, D., & Davies, J. (2020). Urban drainage systems. *Urban Drainage*, 37–47. https://doi.org/10.1201/b13173-6
9. Chakraborty, S., & Mukhopadhyay, S. (2019). Assessing flood risk using analytical hierarchy process (AHP) and geographical information system (GIS): application in Coochbehar district of West Bengal, India. *Natural Hazards, 99*, 247–274.
10. Chattaraj, D., Paul, B., & Sarkar, S. (2021). Integrated Multi-parametric Analytic Hierarchy Process (AHP) andGeographic Information System (GIS) based Spatial modelling forFlood and Water logging Susceptibility Mapping: A case study ofEnglish Bazar Municipality of Malda, West Bengal, India. *Natural Hazards and Earth System Sciences*, 1–20.
11. Chattopadhyay, E. (2000). *Bardhaman Jelar Itihas O Lokosanskriti* (Vol. I).
12. Chen, X., Motew, M., Booth, E., Zipper, S., Loheide, S., & Kucharik, C. (2019). Management of minimum lake levels and impacts on flood mitigation: A case study of the Yahara Watershed, Wisconsin, USA. *Journal of Hydrology*, *577*, 123920.
13. Dutta, S., & Mistri, B. (2016). *Solid Waste Management and Sewerage Condition in Barddhaman Municipal Solid Waste Management and Sewerage Condition in Barddhaman Municipal Area , West Bengal- An Environmental Overview*. *January 2016*, 1–16.
14. FEMA (Federal Emergency Managing Authority). (2020). *Types of Floods and Floodplains*.
15. Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health*, *16*(6). https://doi.org/10.3390/ijerph16061060
16. G., J. S. (1939). The Changing Face of Bengal. *Nature*, *143*(3629), 834–835. https://doi.org/10.1038/143834a0
17. Gaurav, S., Shafia, A., & Bharath, H. A. (2018). Urban growth pattern with urban flood and temperature vulnerability using {AI}: a case study of Delhi. *{IOP} Conference Series: Earth and Environmental Science*, *169*, 12092. https://doi.org/10.1088/1755-1315/169/1/012092
18. GAZETTER. (1905). *Burdwan District Gazetteer: Statistics, 1901-02*. Bengal

Secretariat Book Departmentôt.

19. Gupta, A. K., & Nair, S. S. (2011). Urban floods in Bangalore and Chennai: Risk management challenges and lessons for sustainable urban ecology. *Current Science*, *100*(11), 1638–1645.
20. Jain, M., Dimri, A. P., & Niyogi, D. (2016). Urban sprawl patterns and processes in delhi from 1977 to 2014 based on remote sensing and spatial metrics approaches. *Earth Interactions*, *20*(14). https://doi.org/10.1175/EI-D-15-0040.1
21. Jiang, L., Chen, Y., & Wang, H. (2015). Urban flood simulation based on the SWMM model. *IAHS-AISH Proceedings and Reports*, *368*, 186–191. https://doi.org/10.5194/piahs-368-186-2015
22. Josund, K. (2017). *Dating Text From Google NGrams*. 1–11.
23. Kabenge, M., Elaru, J., Wang, H., & Li, F. (2017). Characterizing flood hazard risk in data-scarce areas, using a remote sensing and GIS-based flood hazard index. *Natural Hazards*, *89*, 1369–1387.
24. Kashyap, S., & Mahanta, R. (2021). *Socioeconomic Vulnerability to Urban Floods in Guwahati, NorthEast India: An Indicator-Based Approach*.
25. Koay, S. P., Tay, L., Chan, H. Y., Jamaludin, S., Fukuoka, H., Hazarika, H., Sakai, N., & Lateh, H. (2016). Applying IT Communication Technology in Public Awareness and Education for Reducing Hazard Casualty in South East Asia Developing Countries. *Natural Hazards and Earth System Sciences*, 1–13.
26. Konar, G. (2000). *Burdwan Samagra* (V. III (ed.)).
27. Koning, K. D., Filatova, T., Need, A., & Bin, O. (2019). Avoiding or mitigating flooding : Bottom-up drivers of urban resilience to climate change in the USA. *Global Environmental Change-Human and Policy Dimensions*, *59*, 101981.
28. Kshemananda, K. Das. (1316). *Manasa Mangal*.
29. Kumar, K. N., & Goel, S. (2009). Characterization of Municipal Solid Waste (MSW) and a proposed management plan for Kharagpur, West Bengal, India. *Resources, Conservation and Recycling*, *53*(3), 166–174. https://doi.org/https://doi.org/10.1016/j.resconrec.2008.11.004
30. Kumar, M., Sharif, M., & Ahmed, S. (2019). Flood risk management strategies for national capital territory of Delhi, India. *ISH Journal of Hydraulic Engineering*, *25*,

248–259.

31. Levy, J. K., Hartmann, J., Li, K. W., An, Y., & Asgary, A. (2007). Multi-Criteria Decision Support Systems for Flood Hazard Mitigation and Emergency Response in Urban Watersheds1 JAWRA Journal of the American Water Resources Association Volume 43, Issue 2. *JAWRA Journal of the American Water Resources Association*, *43*(2), 346–358.
32. Liu, Z. (2012). Recent Progress in Urban Flood Risk Management in the Typhoon Committee Area. *Tropical Cyclone Research and Review*, *1*(1), 60–66. https://doi.org/10.6057/2012TCRR01.07
33. Majumdar, s. c. (1942). *Rivers Of The Bengal Delta*.
34. MINISTRY OF ENVIRONMENT FOREST AND CLIMATE CHANGE. (2016). Solid Waste Management Rules 2016. *MOEF, Government of India*, 787–790.
35. N, H. I. V., & Kumar, A. (2020). Causes and Impacts of Urban Floods in Indian Cities: A Review. *International Journal on Emerging Technologies 11(4):*, *11*(4), 140–147.
36. Nandy, S. (1948). *Bengal Rivers and Our Economic Welfare*. Book Company.
37. National Disaster Management Authority, G. (2017). *Urban Floods*. Natural Hazards.
38. O., C. E. A. W., Hirst, F. C., & Rennell, J. (1928). Notes on the Physical Geography of Bengal. In *The Geographical Journal* (Vol. 71, Issue 3, p. 290). https://doi.org/10.2307/1782495
39. Ouma, Y. O., & Tateishi, R. (2014). Urban flood vulnerability and risk mapping using integrated multi-parametric AHP and GIS: Methodological overview and case study assessment. *Water (Switzerland)*, *6*(6), 1515–1545. https://doi.org/10.3390/w6061515
40. Peterson, J. C. . (1910). *Bengal District Gazetteers: Burdwan*.
41. R. Samal, N., K. Roy, P., Majumadar, M., Bhattacharya, S., & Biswasroy, M. (2014). Six Years Major Historical Urban Floods in West Bengal State in India: Comparative Analysis Using Neuro-Genetic Model. *American Journal of Water Resources*, *2*(2), 41–53. https://doi.org/10.12691/ajwr-2-2-3
42. Rana, I., & Routray, J. K. (2016). Actual vis-à-vis perceived risk of flood prone urban communities in Pakistan. *International Journal of Disaster Risk Reduction*, *19*, 366–378.
43. Rangari, V. A., Gonugunta, R., Umamahesh, N. V., Patel, A. K., & Bhatt, C. M. (2018).

1D-2D Modeling of Urban Floods and Risk Map Generation for the Part of Hyderabad City. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII–5*(November), 445–450. https://doi.org/10.5194/isprs-archives-xlii-5-445-2018

44. Rangari, Vinay Ashok, Sridhar, V., Umamahesh, N. V., & Patel, A. K. (2019). Floodplain Mapping and Management of Urban Catchment Using HEC-RAS: A Case Study of Hyderabad City. *Journal of The Institution of Engineers (India): Series A*, *100*(1), 49–63. https://doi.org/10.1007/s40030-018-0345-0
45. Rennell, James, L., Robert, & Whittle, J. (1794). *David Rumsey Historical Map Collection Bengal, Bahar &c. (south)*.
46. Rojas, O., Mardones, M., Rojas, C., Martínez, C., & Flores, L. (2017). Urban Growth and Flood Disasters in the Coastal River Basin of South-Central Chile (1943–2011). *Sustainability*, *9*(2). https://doi.org/10.3390/su9020195
47. Roy, G. C. (1876). *The Causes, Symptoms and Treatment of Burdwan Fever or Epidemic Fever of Lower Bengal*.
48. Schultz, B. (2006). Flood management under rapid urbanisation and industrialisation in flood prone areas: a need for serious consideration. *Irrigation and Drainage*, *55*.
49. Schwanbeck, D., Watson, J. W. J., & McCrindle. (1825). Ancient India as described by Megasthenês and Arrian being a translation of the fragments of the Indika of Megasthenês. In *Indika of Arrian*.
50. Sen, D. (2013). Real-time rainfall monitoring and flood inundation forecasting for the city of Kolkata. *ISH Journal of Hydraulic Engineering*, *19*, 137–144.
51. Service, U. A., & India, S. of. (1922). NF.45-3 (Series-U502). In *PCL Map* (Vols. 1-AMS).
52. Singh, P., Sinha, V. S. P., Vijhani, A., & Pahuja, N. (2018). Vulnerability assessment of urban road network from urban flood. *International Journal of Disaster Risk Reduction*, *28*, 237–250. https://doi.org/https://doi.org/10.1016/j.ijdrr.2018.03.017
53. Tingsanchali, T. (2012). Urban flood disaster management. *Procedia Engineering*, *32*, 25–37. https://doi.org/10.1016/j.proeng.2012.01.1233
54. Tucci, C. E. M. (2018). Urban Flood Managemnent. *Cap-Net (APFM)*, *1372*, 1–10. https://doi.org/10.1201/9780203734582

55. UNDP Project, 00083985. (2017). Research Report on Urban Flood Risk Management Capacity. In *NDRCC\UNDP,China*.
56. Wang, X., Kinsland, G., Poudel, D., & Fenech, A. (2019). Urban flood prediction under heavy precipitation. *Journal of Hydrology*, *577*, 123984. https://doi.org/https://doi.org/10.1016/j.jhydrol.2019.123984
57. Weber, A. (2019). *What Is Urban Flooding?* NRDC.
58. Willcocks, W. (1930). *Ancient System of Irrigation in Bengal and Its Application to Modern Problems*. B.R. Publishing Corporation, 1984.
59. Willson, W. G. (1875). *Report of the Midnapore and Burdwan Cyclone of the 15th and 16th of October 1874*. Bengal Secretariat Press.
60. Xu, W., Xiang, L., & Proverbs, D. (2020). Assessing community resilience to urban flooding in multiple types of the transient population in china. *Water (Switzerland)*, *12*(10). https://doi.org/10.3390/w12102784
61. Zhang, D., Shi, X., Xu, H., Jing, Q., Pan, X., Liu, T., Wang, H., & Hou, H. (2020). A GIS-based spatial multi-index model for flood risk assessment in the Yangtze River Basin, China. *Environmental Impact Assessment Review*, *83*, 106397.

CHAPTER: THREE

OBJECTIVES AND SCOPE OF WORK

3.0. Foreground:

A research gap refers to a question or area in knowledge that has not been adequately addressed or answered through previous research studies. It is a discrepancy between the current understanding or available evidence and the knowledge or information that is still needed to advance the field. Identifying research gaps is important in guiding further research efforts and helps researchers identify topics or areas that require further investigation. On the other hand, objectives of research can explore, explain, describe, evaluate, compare and validate these research gaps *(Kothari,2004).*

3.1. Research Gap:

1. The research regarding urban floods in cities other than the metros is quite negligible in numbers.
2. There are very few area-specific publications regarding the negative impact of urbanization on the town, but a detailed mention or analysis of such problems is hard to find.
3. Consequently, the study on the impact of such problems as water logging, and flooding on the citizen's daily lives is also neglected.

3.2. Objectives:

1. To assess the **multifaceted temporal changes in the urban landscape** of Burdwan municipality since 1991.

2. To analyze **historical records of rainfall occurrence** and its control on **surface run-off generation** and urban flooding in the study area.

3. To recognize **the impact of urban flooding on the various socio-economic groups** in the municipality.

4. To formulate **some applied solutions to mitigate and manage the flooding** issue in the study area.

3.3. Research Questions:

Research Objectives are further subdivided into research questions for better understanding.

3.3.1. Objective.1:

I. How has Land use changed over the decades with special reference to urban encroachment?
II. What kinds of spatial distribution urban areas have been portraying in the last few decades along with the increase in population?
III. What are its facets?
IV. How does the urban drainage impact the flooding situation?
V. Does the temporal fluctuation of urban water bodies stress this flooding condition?
VI. What is the status of urban solid waste management, and does it influence the flooding scenario?
VII. Is there any other network for urban sewage water?
VIII. What is the causative factor/factors among so many aspects of urbanization that is most responsible?

3.3.2. Objective.2:

I. Where does the town of Burdwan stand in terms of rainfall in the district?
II. What is the existing trend and pattern of rainfall?
III. Is it short or long lived?
IV. How much run-off is generated against a certain amount of rain?
V. Do the river floods (Damodar and Banka) inundate the town?

3.3.3. Objective.3:

I. Which are the wards that get most affected?
II. What is their general perception about urban services?
III. According to them, what are the probable causes?
IV. How does their livelihood get hindered?

3.3.4. Objective.4:

I. Can it be combatted without hampering the present urban setup?

II. What could be the possible role for all the stakeholders?

3.4. Scope and Limitation of the Study:

This study might be considered as a first attempt to analyze the urban flooding scenario of the town. Unlike previous studies, it has tried to cover all the facets of urbanization that cause flood using an integrated methodology of Remote Sensing, GIS Techniques, Primary Survey, and Secondary data. Next, The Urban Run-off is calculated for the town via Integrated Valuation of Ecosystem Services and Tradeoffs-Urban Flood Risk Mitigation (INVEST-UFRM) Model, which is completely a new approach ever applied to the Municipality. The findings of the study can be of further use for any micro-level detailed analysis of the Municipality.

However, this work had got some restrictions also-The satellite data sets are all from the LANDSAT ranges, though for the year 2021 sentinel data is available, but to avoid the process of downscaling the data, all images are compiled from the LANDSAT data range thereby making the resolution coarse. The LULC Classification could be more accurate if the historical images from Google Earth Pro were still made available or if satellite images of better resolution were available on open platforms. Again, while conducting surveys some people in a particular area seem to be politically biased and also there was a temporal lag in the survey schedule due to Covid-19. The Concerned Municipality does not have any idea of the concept of urban flooding, therefore a lack in the temporal database in many urban sectors like rainfall, water logging, solid waste management, water bodies etc. is found.

3.5. Expected Deliverables:

This study will perform as an extension and improvement of pilot study in terms of identifying factors governing urban floods like urbanization and its other facets, analyzing past events of rainfall to aid the scenario through generating run-off and flood modeling, together with suggestion of alleviation scenarios to relieve flood problems. The outcome

of this study will also emphasize on the sustainable urban development by flood prone areas identification based on relief and tendency of the water inundation, precipitation intensity, developing flood resilient measures and assessing the role of stakeholders including the ULBs. (Urban Local Body).

List of References:

1. Kothari, C. (2004). Research methodology: Methods and techniques (2nd revised edition). New Delhi: New Age International (P) Limited, Publishers

CHAPTER: FOUR

METHODOLOGY

4.0. Foreground:

In order to study a research problem or subject in an organised and methodical manner, a technique is required. It is essential because it offers direction and a framework for the entire research process, which eventually improves the validity, correctness, and reliability of the results.. This chapter deals with a thorough scheme of finding the answers to the objectives by examining the spatio-temporal changes in the land use landcover identifying the facets of urban flooding along with the impact of urbanization, analysis of rainfall trend, analyzing the responses of the surveyed people and developing location-specific management recommendations. To achieve these research goals, acknowledged geospatial procedures and proven quantitative approaches were used. A comprehensive objective-specific methodological framework **(Figure No.4.1)** has been developed after reviewing considerable amount of literature including various published journal articles, book chapters, previously delivered thesis, Government Reports, Statistical Handbook, District Human Development Reports, State Annual Flood Reports, District Disaster Reduction Plan on the core concepts of urban flooding and study area both, to name a few.

4.1. Methodology opted for Objective.1 (*To assess the multifaceted temporal changes in the urban landscape of Burdwan municipality since 1991*)

4.1.1. Image Classification:

To study the temporal changes in the urban setup, the classification of LANDSAT Images has been performed since the year 1991 up to 2021 keeping the census years of India in mind. The reason for selecting 1991 as a base year is that since 1991, notable shifts have been noted in the characteristics and trends of urban expansion in India. Space in our cities is currently being reorganized in terms of both shape and function from that time, especially the middle and the small-sized towns *(Chadchan and Shankar 2012)*. The LULC change detection has followed the scheme of 2nd Cycle of LULC Classification combining Description Order-I and II given by the NRSC (National Remote Sensing Centre, India) *(Sudhakar and Rao 2010)*

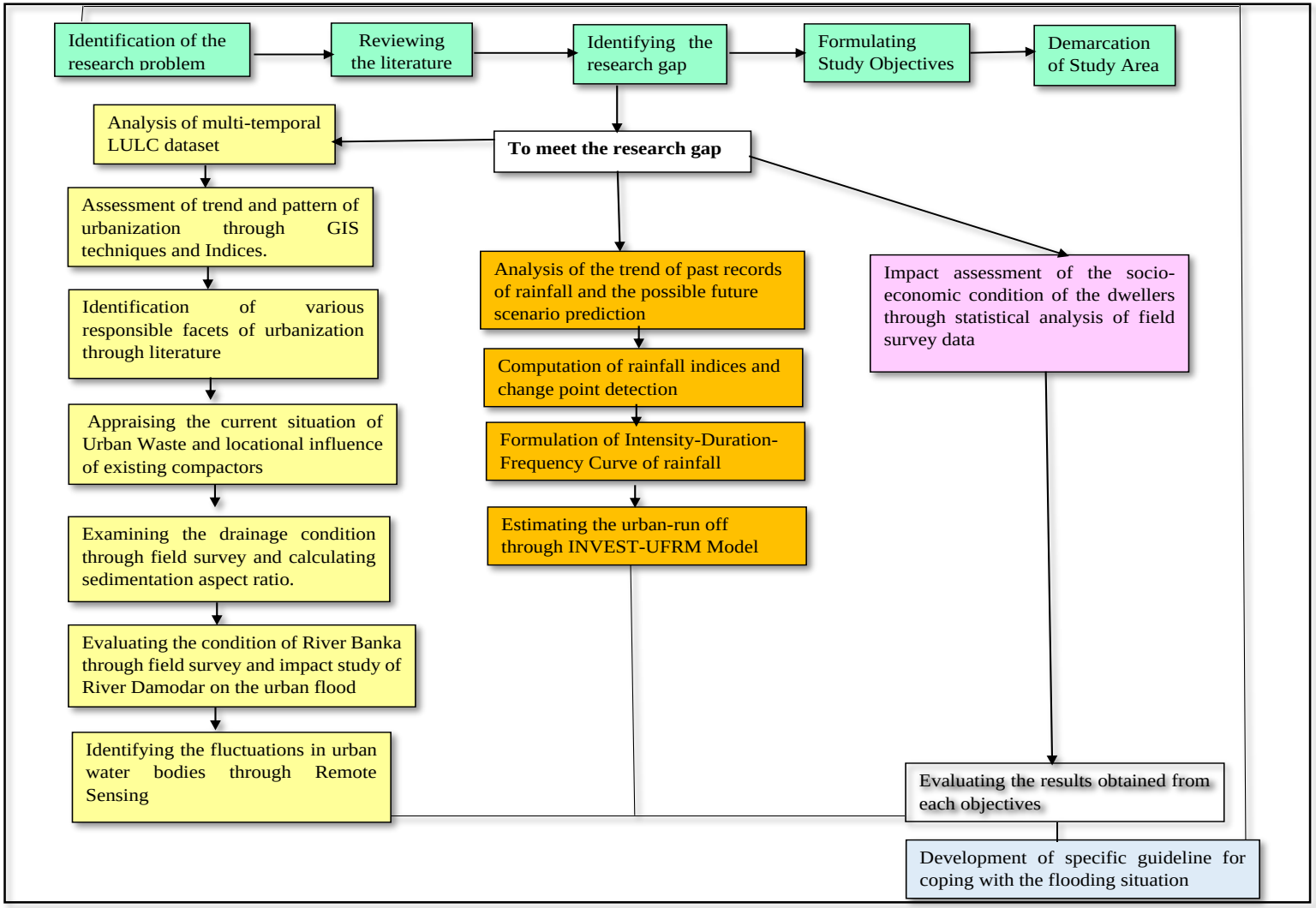


Figure No.4.1. Integrated Methodology Taken Up for this Study (*Source*: By Author)

Table No.4.1. Integrated Sources of Data along with their Links

Objectives	Sub-themes	Data Used	Links	Software Used
1	LULC Classification	Multi-temporal LANDSAT DATA from 1991 to 2021 (MSS to ETM+)	https://earthexplorer.usgs.gov/)	ERDAS_Imagine 9.2, ArcGIS 10.4
	Urban Waste	i)Data provided by the Burdwan Municipality ii)Field Survey,2022-2023		ArcGIS 10.4
	Urban Drainage	i)Field Survey,2023 ii)Data provided by the Burdwan Municipality		ArcGIS 10.4
	Urban Waterbody	i) Google Earth Pro 7.3.3 ii)Field survey,2022 iii) SoI (Survey of India)' metric topographical sheets (1:50,000) 73 M/15 and 73 M/16 for Burdwan Municipality. The open series map (1:50000) is freely available on (Survey of India (Digital), 2017) iv) Urbanization and its Facets for Principal Component Analysis	i)https://earth.google.com/web/ iii)https://onlinemaps.surveyofindia.gov.in/ iv) https://spss-64bits.en.download.it/	ArcGIS 10.4 ArcGIS 10.4 SPSS 28.0.1
2	Rainfall	CFSR-SWAT Data (1979-2014) (2001-2019)	https://swat.tamu.edu/data/cfsr	ArcGIS 10.4
	Banka	i)Field Survey (2022-2023) ii)Irrigation and Waterways Department, Govt of West Bengal	https://naturalcapitalproject.stanford.edu/software/invest-models/urban-flood-risk-mitigation	INVEST-UFRM 3.13.0 ArcGIS 10.4
	Run-Off Calculation	Retrieving information from the layers of Boundary, LULC, Rainfall Depth, and Relief.		
3	Impact Survey	Field Survey (2018, 2022,2023) and Statistical Analysis	https://www.originlab.com/origin	MS-Excel 2017 and Origin Pro,2023

According to the scheme of classification, five classes have been generated **(Table No.4.2**) where:

Table No.4.2. The LULC Classes Taken from NRSC 2nd Cycle Scheme of Classification

Description Order-1	Description Order-2
Built Up Area	Urban
Agricultural Land	Crop land, fallow
Forest	
Wetland/ Waterbodies	River/ canal and Water Bodies

Source:*(NRSC National Remote Sensing Centre 2014)*

Table No.4.3. The Details of the Satellite Images (LANDSAT) Used

Year	Date of Retrieving the Image	Path	Row	Sensors Used
1991	30.04.91	139	044	TM (Thematic Mapper)
2001	25.04.01	139	044	ETM+ (Enhanced Thematic Mapper Plus)
2011	18.04.11	139	044	ETM+ (Enhanced Thematic Mapper Plus)
2021	18.05.21	139	044	OLI (Operational Land Imager)

Source: Information gathered from LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

Land use Landcover Map preparation in ERDAS is done following the steps.

Import the image ⟶ Create training samples ⟶ Draw polygons⟶ Training data manager ⟶ Perform supervised classification ⟶ Refine classification results ⟶

Accuracy assessment⟶ Export the classified image⟶ Validate and edit the classification *(Razafinimaro et al. 2021).*

***4.1.2. Accuracy Assessment of the Classified Images*:** Accuracy assessment of land use/land cover classification is a crucial step in evaluating the reliability and quality of the classification results. It involves comparing the classified land cover map with reference

data to determine the level of agreement or disagreement between them. Here, Kappa's co-efficient matrix is used to assess the accuracy or agreement between two or more raters or classifiers. To calculate Cohen's kappa's co-efficient matrix, the observed agreement between raters is compared to the expected agreement. The formula for Cohen's kappa is:

$$\kappa = (Po - Pe) / (1 - Pe) \quad \text{.....(i)}$$

Where κ represents Cohen's kappa coefficient, Pe is the predicted agreement by chance, and Po is the observed agreement between raters. The range of Cohen's kappa coefficient is -1 to 1. A value of one denotes perfect agreement, a value of zero denotes coincidental agreement, and a value of one denotes total disagreement. *(McHugh 2012;Arumugam, Yadav, and Kinattinkar 2021).*

4.1.3.The Normalized Differential Built Up Index (NDBI):

It is a commonly used remote sensing index that quantifies the ratio of built-up (urban) areas to non-built-up (non-urban) areas in an image. It is often used to study urbanization and assess the extent of urban development within a region. The formula to calculate NDBI is as follows:

$$NDBI = (NIR - SWIR) / (NIR + SWIR) \quad \text{.....(ii)}$$

Where: NDBI = Normalized Differential Built-up Index NIR = Near-Infrared band reflectance value SWIR = Short-Wave Infrared band reflectance value.The NIR and SWIR bands are commonly obtained from satellite or aerial imagery. By subtracting the SWIR band from the NIR band and normalizing the result, the NDBI value provides an indication of the urban land cover proportion within a given area. Higher positive numbers imply more built-up areas, whereas lower negative values indicate non-built-up areas. The NDBI values can range from -1 to 1. A value that is almost equal to zero denotes a balanced distribution of both developed and undeveloped regions*(Yasin et al. 2020).*

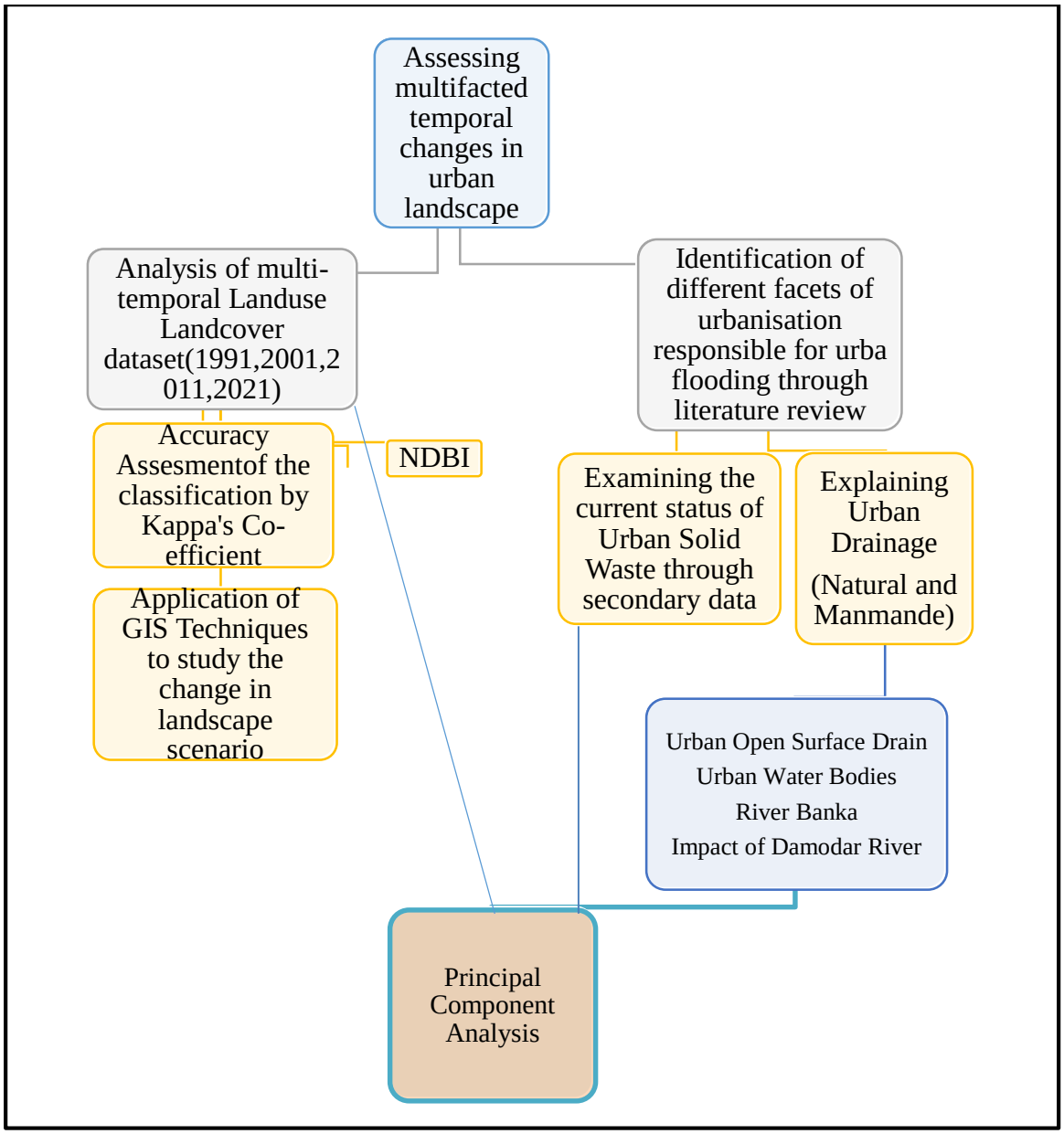


Figure No. 4.2. Methodological Framework for Objective 1

4.1.4. The Other Facets Related to Urbanization those are responsible for Urban Flooding Situation:

Now, only Urbanization cannot be held responsible only for the Urban Flooding condition. The status of urban waste, urban drainage, water bodies in the anthropogenic factors and the rainfall as a natural factor should also been investigated.*(National Disaster*

Management Authority 2017) After giving inputs of all the literature regarding the causes of urban flooding into making a word cloud the other aspects also surfaced. A word cloud is a graphic representation of text data in which the prominence or frequency of a word within the text is indicated by its size. More commonly occurring words in a word cloud are exhibited in higher letter sizes, while less often occurring words are shown in lower font sizes. *(Kalmukov 2021).* Apart from the major fact urbanization, the other responsible factors are-urban drainage, urban waste, community perceptions, extreme event and rainfall, waterbodies- which would be highlighted in the subsequent chapters.

Figure No.4.3: Word Cloud on Various Facets of Urbanization

(*Source*: https://classic.wordclouds.com/)

4.1.5. Urban Solid Waste:

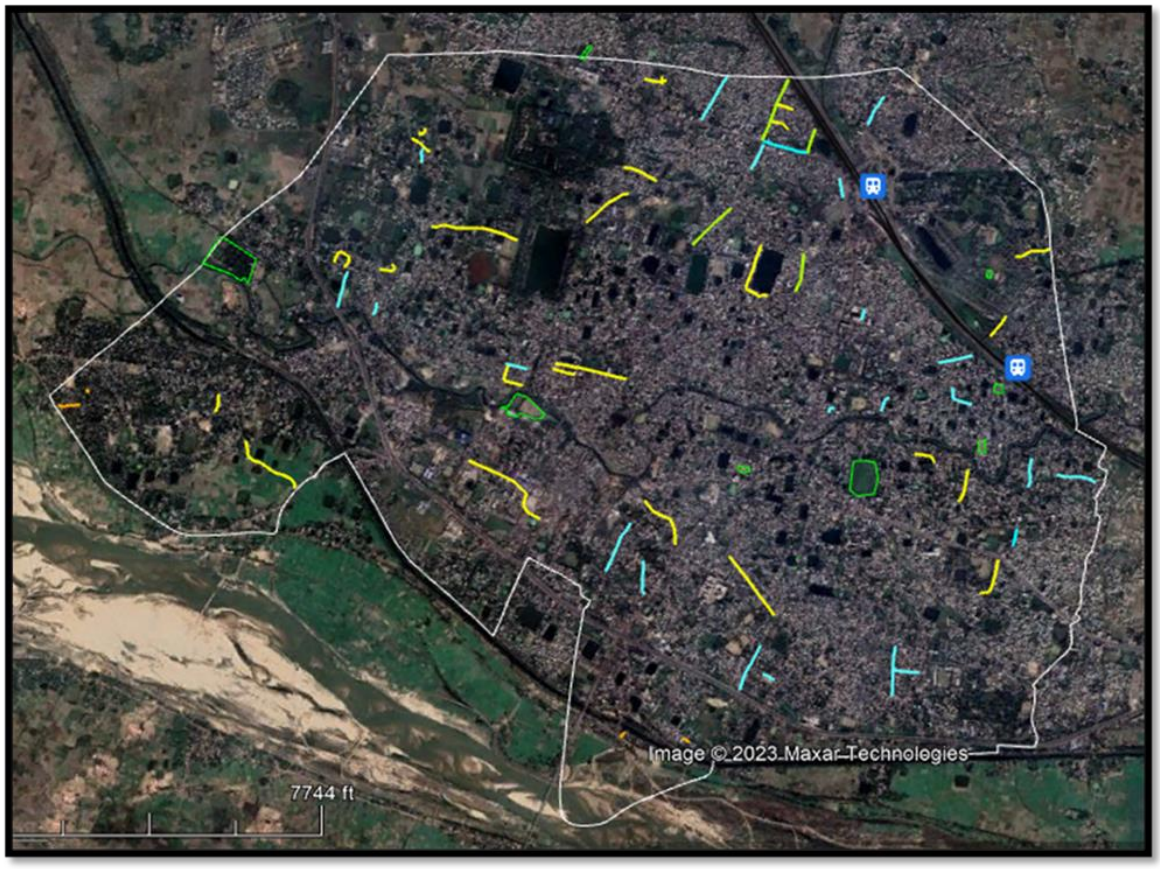
For appraising the current scenario of urban solid waste, the data provided by the Municipality regarding its generation, collection and compactors are consulted. After that they are processed in MS-Excel (2017) and ArcGIS 10.4 for network analysis.

4.1.6. Urban Drainage:

Urban Drainage includes a huge range of spectrum starting from natural to man-made. Coming first to **Urban Open Surface Drainage**, from the field observations, it was clear that whichever type of surface drain it might be they have amounted major mass of silts into them which has prohibited the water to flow properly. To assess the working

conditions of different types of drainages, some samples from each category have been selected based on certain parameters **(Google Earth Image No: 4.1.)**

- Ubiquity in the distribution of the variety of drainages so that all four types can be included.
- Proximity to Banka River or water bodies as some of the drains are supposed to be linked with them
- Vicinity to the busiest places as at times clogging of the drainages might bring up a local flood.



Google Earth Image No: 4.1. The Selected Drains from Each Category of Drainages (Source: Google Earth Pro, March,2023) [The index is given in table **4.4**]

Table No.4.4: The No of samples Taken for Urban Open Surface Drains

SL No	Type of Drains	Index	Total Number of Drainages	No of Drainage Surveyed
1	High Drain		25	4
2	Boro Pucca Drain		303	15
3	Choto Pucca Drain		1226	23
4	Kutcha Drain		56	3

Source: Calculated from the Base Map of Drainage provided by Burdwan Municipality, 2022

The Process follows:

- A measuring stick was made (a firm stick where a measuring tape was fixed)
- First, it was drowned till it touched the bottom. With the level of the watermark, the depth of water was calculated.
- After wiping, it was inserted in water till the point where sedimentation started, or the stick was blocked by the silts. With the mark of the deposition, the amount of siltation can be assumed.
- Subtracting step 3 from step 2- the actual water depth can be calculated.

Photo: 4.1. Measuring the Drainage Depth (As a result of the survey, the cross-sections of each kind of surface drain have been drawn to show the level of water, level of deposition and amount of freeboard mainly.)

4.1.6.1. Sedimentation Aspect Ratio:

In this study, the high sedimentation of the channel capacity at present was compared to determine the function value (%) sedimentation rate. The greatest cross-sectional area of the channel determines the channel capacity, and the height of the water (h) determines the channel height (H). Considering the shape of the drainage channel as rectangular, (as in most of the cities in India).

Sedimentation Aspect Rate:

$A=bH$, $A_{sed=}\ bH_{sed}$

Thus, Sedimentation rate can be measured by:

$Sed= (100- A_{sed}/A*100)$ %

Where, A= Max Cross Sectional Area, $A_{sed=}$ Sectional area due to sedimentation, b = Baseline Width, H= total channel height in m, $H_{sed=}$ Height due to Sedimentation

4.1.6.2. Calculation of Flow and Discharge of each type of Drainage:

The flow of water in an open channel is influenced by multiple elements that can cause complexity, such as the roughness of the surface, gradient inclination, and the hydraulic radius. Almost a century ago, the Manning equation was developed in an effort to simplify the key components of these elements *(Djajadi 2009).* The channel velocity, flow area, and slope all affect the Mannings equation, an empirical formula that describes uniform flow in open channels. It is equally applied for man-made channels also *(Bengtson 2017).*

$Q=VA= (1.00/n)\ AR^{2/3}\sqrt{S}$ (SI Unit)……*(iii).(A.Merry 2017)*

Where Q= flow rate, V= velocity, A= flow area, n = the friction provided by channel

lining, Manning coefficient of roughness, R the hydraulic radius, and S the channel gradient.

For calculation, the standard value for n= 0.015 for concrete, (here applied for high drain, large concretized drain, small concretized drains) and 0.025 for soil (here applied for small concretized drain)*(Djajadi 2009).*Again, to make it easier for water to flow towards the drain, basement flooring often has a slope of around 1:200 towards the drainage channel close to the wall *(Bureau of Indian Standards 1988).*

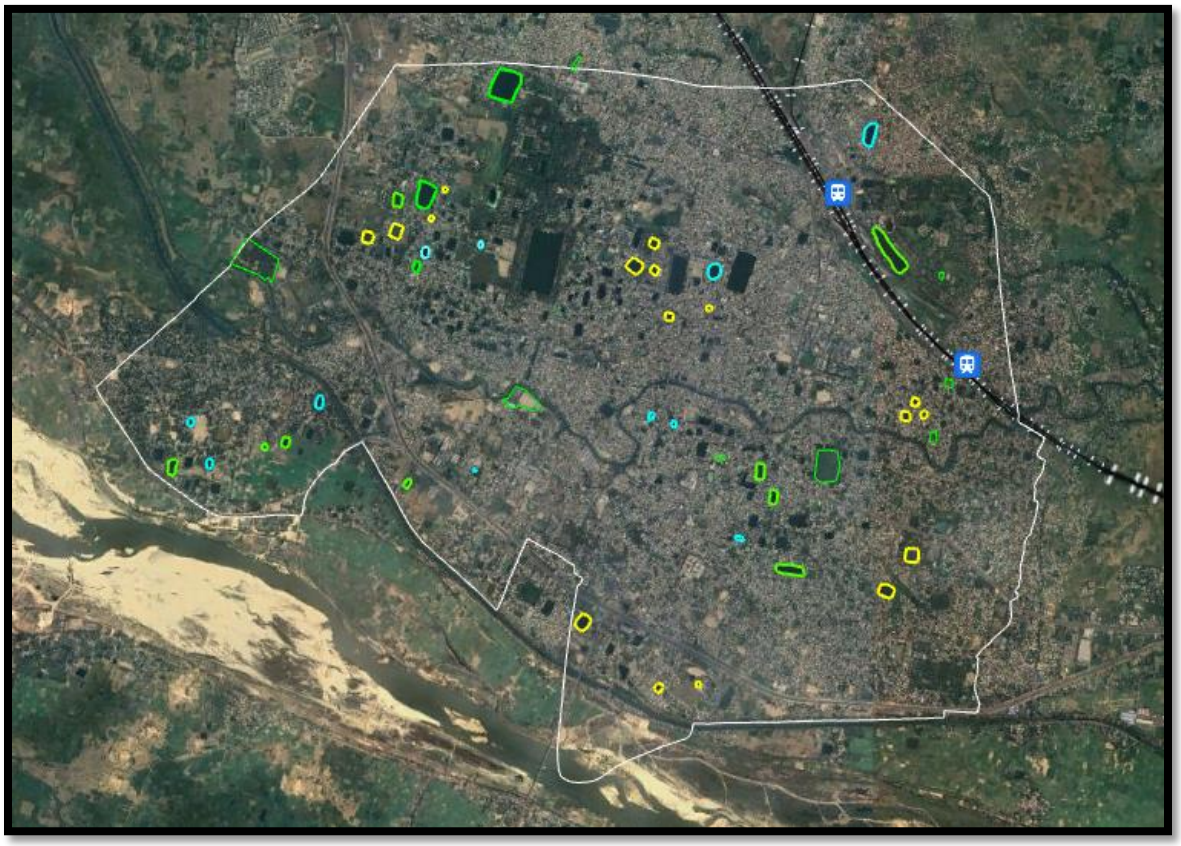
4.1.6.3. Calculation of the Number and the Approximate Water Volume of the Water Bodies:

Next coming **to Urban Water Bodies,** to demarcate the increase or decrease in the number the Google Earth Pro Images of 2010 and 2013 was compared and analyzed in ArcGIS 10.4. Thereafter, a map showing the density of water bodies is also prepared for the year 2023. For the calculation of the water volume, field works were conducted with the help of local people where the depth, length and width of the selected ponds were collected. Here, Basically the water bodies are selected based on the shape for the ease of calculations.

Photo No.4.2. A Local Brother Helping Me Out with the Field Work of the Water Bodies (Source: Primary Survey, 2023)

Table No. 4.5. The Samples Taken for Water Bodies

SL No	Shape of Water Bodies	Index	No of Water Bodies Surveyed
1	Rectangular		18
2	Oval		12
3	Square		17



Google Earth Image No.4.2. The Selected Ponds Which Have Been Surveyed. (Retrieved on October, 2023)

After selection of the water bodies, the length and width were measured by the measuring tape and verified with Google earth later. For the depth, the stuff reading was taken at the four ends of a water bodies for rectangular and square shaped ones, but the depth of the midpoint was averaged out from those numerical values. For oval shaped ones, four exact corners were presumed and then proceeded for the next steps. Now. After calculating water volume (in cubic meters) for each water body under each category, the results for water volume are averaged out.

4.1.6.4. Measurement of Water Depth of Banka River:

Coming to the Measurement of Water Depth of Banka River**,** there are 8 bridges built over Banka to connect its right and left banks within the Municipality jurisdiction. As the river water is turbid and in most of the parts it is not navigable these bridges are chosen to measure the water depth from the heights. Almost all the bridges were used for surveying except those very closely built (like the twin bridges at Birhata Clock Tower) and, because its base is concrete, causing the same amount of uniform flow everywhere at the station. Two other bridges from the Eastern and Western portions outside the Municipal boundary area have been chosen to witness if there is any discrepancy of water volume in urban and nonurban areas. Due to the height of the bridges, while measuring, a crude method of submerging brick/stone in the water with the measuring tape attached to it, is followed.

Since the creation of the dams along the left bank of the river **Damodar**, there is hardly any incident of water entering the town of Burdwan from the river unless and until there is a breaching- the records, the secondary data and the local people perceptions have confirmed this.

4.1.7. Principal Component Analysis:

To point out the most responsible factors those have taken part mostly among the urbanization and its facets, a Factor Analysis with the extraction method **Principal Component** has been run in SPSS version 28.0.1 Trial Pack. PCA in SPSS involves some major steps and principles:

The Major Steps in a PCA calculation include-

i. A correlation matrix is produced by calculating the inter-correlations between the components.
ii. The correlation matrix's inter-correlated items, or "factors," are removed to produce "principal components."
iii. For the sake of analysis and interpretation, these "factors" are flipped around*(UCLA 2021).*

The associations between the variables are displayed in the correlation matrix. These coefficients are ranging from -1 to 1, where 0 denotes no connection, -1 denotes perfect negative correlation, and 1 denotes perfect positive correlation. Once the correlation matrix is obtained, it is used to determine the principal components *(UCLA 2021).* The eigenvalues and eigenvectors of the correlation matrix are calculated, and the eigenvectors represent the directions of the principal components. The eigenvalues indicate the amount of variance explained by each principal component. Prior research has accepted an arbitrary criterion of 1.0 or higher for determining whether a factor warrants further interpretation. The rationale for the 1.0 criterion stems from the idea that a "factor" should, at minimum, account for the same proportion of common variance as it does unique variance within the construct *(IDRE Statistical Consulting 2018).* A visual tool for determining the number of "factors" to be interpreted from the extraction of the main components is a scree plot. The eigenvalues are shown against the sequence of "factors" that were taken out of the data to create a scree plot. Because the initial "factors" derived from the principal components analysis frequently exhibit the strongest inter-correlations between their respective survey item *(IDRE Statistical Consulting 2018;Beaumont 2012).*

These inter-correlated item "factors" that have been extracted are "rotated." This "rotation" happens because of the common occurrence of certain items having a strong correlation with other items on many "factors." This complicates the interpretation of the initial factor extraction. These problematic items are "rotated" onto the "factor" that has the strongest link with the "factor's" items. This mathematical "rotation" improves the interpretability of the extracted "factors," but it eliminates the interpretation of the shared variance associated with the "factor."*(UCLA 2021)*

4.2. Methodology opted for Objective.2 (*To analyze historical records of rainfall occurrence and its control on surface run-off generation and urban flooding)*

4.2.1. The Data Used for Analysis:

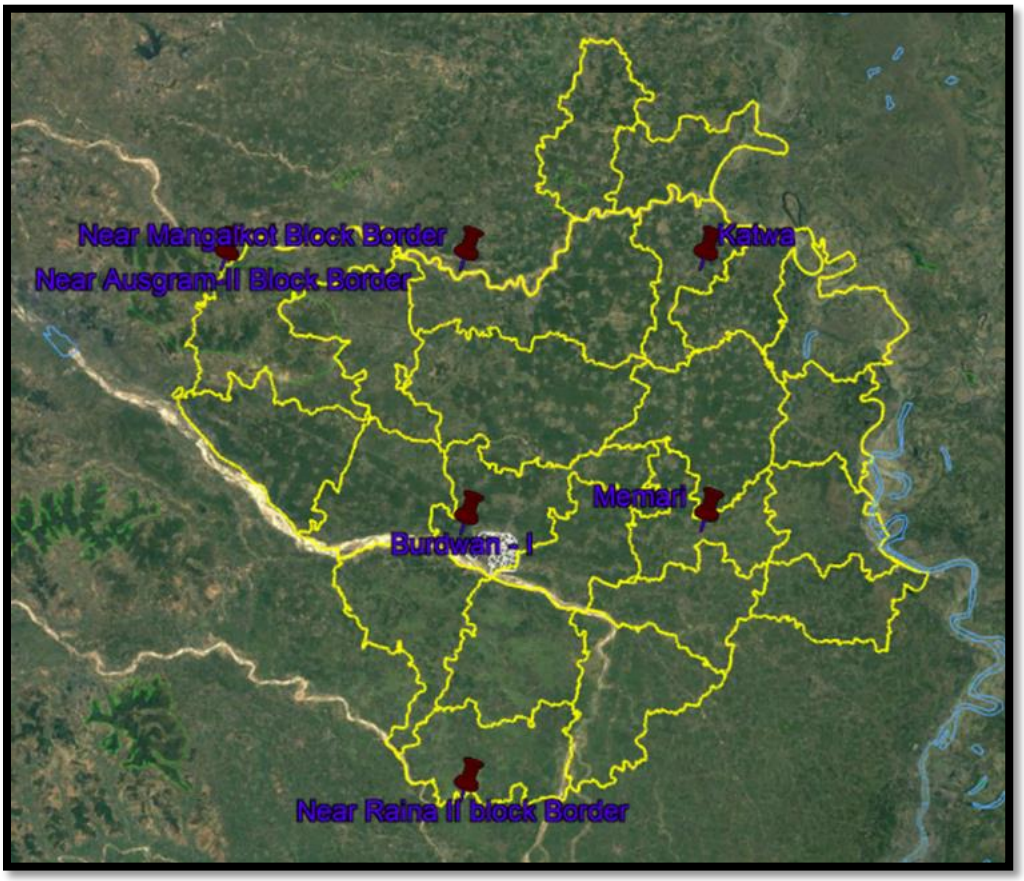
While opting for a rainfall analysis, we often lack the continuousness of daily acquired data of a particular station over a larger period. Even if sometimes the data is available either it is of restrictive usage or financially not feasible. In such scenario, for the analysis of the District Rainfall, the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) has offered a "*designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period*" (Daniel R. Fuka, 2013). It was researched that this dataset would be the best fit for small or medium-sized watershed as it is developed on the basis of 'Reanalysis' which is integrating climatic observations into the same climate model during the whole reanalysis time period aiming to help mitigate the impact of model changes on climatological figures (ECMWF, 2020) .On top of that, it is an open ware, easily available and downloadable (directly in .CSV/.XLS) format and very easy to work with. It has a resolution of 30 km, and it covers enough historical data to function climatic modeling. The results of this evidence of concept study showed that CFSR data may be successfully used in watershed models under a wide range of hydro climatic settings (Daniel R. Fuka, 2013).Accordingly, the district of Purba Burdwan has got 6 points in and around the district. The extent of 87.125 m to 22.6366 m box was drawn to locate the points and here is the outcome.

Table.No.4.6: The Points of Data Accessibility in and Around the District of Purba Bardhaman

SL No.	Longitude (in m)	Latitude (in m)	Points of Data Accessibility
1	87.8125	22.9487	*Near Raina-II Block Border*
2	88.125	23.2609	*Memari-I*
3	87.8125	23.26099	*Burdwan-I*
4	88.125	23.885	*Katwa*
5	87.8125	23.8855	*Near Mangalkot Block Border*
6	87.8125	22.6366	*Near Ausgram II Block Border*

Source: Official website of SWAT Model (https://swat.tamu.edu/data/cfsr), 2021

The station lying at SL No.3 of **Table 4.6**.is selected for analysis of the rainfall at the Municipality level. The study is carried out in two steps: a) District rainfall scenario estimation as a part of broader analysis of rainfall and b) Municipality / town rainfall profile estimation to understand the trend and pattern at the minutes level.



Google Earth Image.4.3. The Points of Data Accessibility in and around the District of Purba Bardhaman *(Source*: Google Earth Pro,2021)

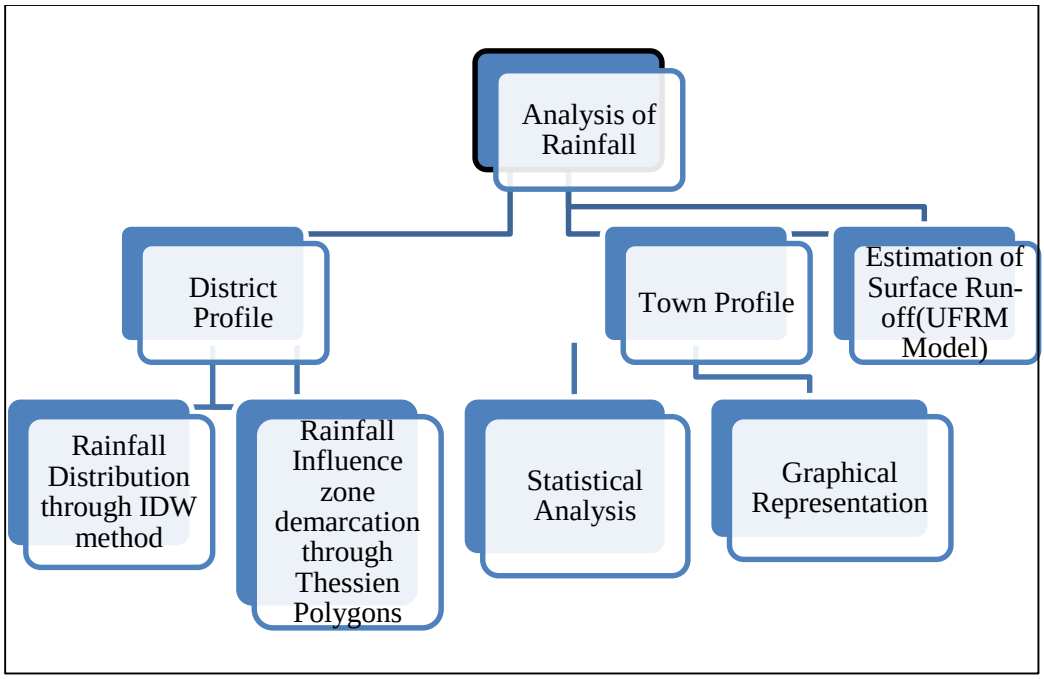


Figure No.4.4 The Methodolgical Framework for Objective.2

4.2.2. For District Rainfall Profile of Purba Bardhaman District:

4.2.2.1. Generating Spatial Distribution of Rainfall in The District:

From the six major existing data points, an interpolated surface of rainfall was generated through the method The Inverse Distance Method (IDW) makes the assumption that items that are closer together are more comparable than those that are farther apart. To forecast a value for any unmeasured site, IDW employs the measured values surrounding the prediction location *(ESRI, 2021)*. When applying inverse distance weighting (IDW), the output value for a cell is constrained by the interpolation range of values. IDW is a weighted distance average; therefore, neither the greatest nor lowest input can be bigger than the average *(PRO, 2021)*.With the help of IDW method, an Isohyet Map of Purba Bardhaman is generated, which is a type of thematic map that displays lines connecting points of equal precipitation or rainfall. These lines represent areas with the same amount of rainfall *(Jayasree and Venkatesh 2015)*.

4.2.2.2. Creation of Thiessen Polygons:

It is a technique for figuring out how important point rainfall readings are in space. Every measurement station has a perpendicular bisector erected along the lines connecting it to the surrounding stations. By joining these bisectors, a sequence of polygons with one station each are formed. The amount of precipitation measured at a station is allocated to the entire area included by the polygon (*AMS, 2012).* The average rainfall can be calculated from this equation:

$$P_{avg}=A_{i*P_i} \quad \text{(iv)}$$

Where, P_i= Precipitation recorded at the various stations

A_i= area of Thiessen polygon i

Following the generation of IDW, the rainfall values were known all over the district from that the centroids are created, based on which the block wise polygons are generated.

4.2.3. For Rainfall Profile of Town Burdwan:

For analyzing the rainfall scenario within the Municipality a few statistical tests have been performed.

4.2.3.1. Autocorrelation Test with Durbin Watson (DW) Static Test:

Autocorrelation testing in rainfall data is a statistical analysis technique used to examine the presence of correlation or patterns within the time series of rainfall measurements. This refers to the correlation between a variable and its lagged values at different time intervals. It helps in identifying temporal dependencies and patterns in rainfall data, which can be useful for climate analysis, forecasting, and understanding the underlying processes driving rainfall variability *(Huitema and Laraway 2015)*. The Durbin-Watson test is a commonly used measure for autocorrelation for its simplicity, universality, and range of applicability. This statistical test is used to find out if autocorrelation exists in a regression analysis's residuals. When the Durbin-Watson test statistic is near 2, it indicates no autocorrelation. The range of values for this statistic is 0 to 4. Positive autocorrelation, or a positive correlation between the residuals, is indicated by a value less than 2. On the other hand, a

value greater than 2 indicates negative autocorrelation, implying that the residuals are correlated in a negative manner *(King 1995)*. The formula for Durbin Watson (DW) test is:

d =\frac{\sum_{i=2} ^{n} (e_i - e_{i-1}) ^2} {\sum_{i=1} ^{n}e_i^2} ……(v)

where:

e_i represents the residuals (or errors) from the regression model, n is the number of observations in the data set. [simplified after*(Champion, Lenard, and Mills 1998)*]Here, it has been done using the software R Studio (version 4.3.2) and with the package *lmtest* and with the command *dwtest (ProgrammingR 2023).*

4.2.3.2. Change Point Detection in the Rainfall Pattern:

Change point detection models in rainfall analysis are used to identify significant changes in the pattern or behavior of rainfall data over time. Rainfall data often exhibits variability, and detecting change points helps in understanding shifts in precipitation patterns, which could be due to various factors like climate change, local environmental alterations, or other external influences. Several approaches exist for change point detection in rainfall data that involves models involves statistical analysis, time series analysis, or machine learning techniques on historical rainfall data to pinpoint significant shifts (*Arif et al. 2017)*.The Statistical Models use statistical measures to identify changes in the mean, variance, or other statistical properties of rainfall data like Pettitt's test, Buishand range test, and Standard Normal Homogeneity Test (SNHT). Here, for detecting the changes in the rainfall data these three tests have been performed *(Dhorde and Zarenistanak 2013).*

- **Pettitt's Test: (Pettitt,1979)**

The Pettitt test is a statistical test used to detect abrupt changes or shifts in a time series data. It is commonly used in environmental and climate studies to identify significant changes in variables such as temperature, rainfall, or pollutant levels. The test calculates a test statistic based on the ranks of the data and compares it to a critical value to determine if there is evidence of a change point *(Hakuba et al. 2013).* The Pettitt test can be useful in analyzing trends and detecting sudden shifts in data over time. The Pettitt's Test acts on

$$Uk=2\sum_{i=1}^{k} ri-k(n+1),\ k=1,\cdots,n \quad \text{……(vi)}$$

Where, ri is the rank in ascending order of the nth element of the series. The most probable change point *T* will be the one that satisfies the following equation:

$$K_T = U_{r,}T = max\left[U_{t,\mathrm{T}}\right], 1 \leq t < T \text{ ……. (vii)} \textit{(Salarijazi 2012)}$$

Thus, given a significance level $\alpha\ if\ p < \alpha$, the null hypothesis, that the two distribution H_0 that the two distributors are equal is rejected. Here, it has been done using the software R Studio (version 4.3.2) and with the package *Trend* and with the command *pettitt.test. (ProgrammingR 2023).*Now, In the Pettitt test, the U value represents the test statistic that is used to assess the presence of a change or discontinuity in a time series data. The magnitude of the U value is compared to critical values derived from the distribution under the null hypothesis of no change to determine whether the U value is statistically significant *(Hakuba et al. 2013).*

- **Buishand Range Test: (Buishand,1982)**

The Buishand range test, also known as the Buishand U test, is a statistical method used to detect changes in the location and/or scale of a time series data. The test is based on the calculation of the range of consecutive data points within a moving window. By comparing the observed range with the expected range under the assumption of no change, the Buishand range test determines if there is evidence of a change point in the data. This test is valuable in detecting abrupt shifts in any environmental variables.*(Saifuddin 2007)*The formula for this test is -

U = max (|R1 - R|, |R2 - R|) ……(viii)*(Dhorde and Zarenistanak 2013)*

where: U is the test statistic, R1 is the range of the first part of the time series, R2 is the range of the second part of the time series, R is the range of the entire time series. Here, it has been done using the software R Studio (version 4.3.2) and with the package *Trend* and with the command *buishand.test (ProgrammingR 2023).* In the Buishand range test, the expression R/sqrt(n) represents the standardized range statistic, where R is the range of the observations and n is the sample size. A P value greater than the chosen significance level (often 0.05) indicates that there is not enough evidence to reject the null hypothesis, suggesting that there has been no significant change.

- **The Standard Normal Homogeneity (SNHT) Test: (Alexandersson 1986)**

The Standard Normal Homogeneity Test (SNHT) is a statistical test used to detect inhomogeneities or changes in the mean of a time series data. The SNHT assesses whether the mean of a series of observations significantly deviates from a standard normal distribution. By comparing the observed data to the expected distribution, the test determines if there are any significant changes in the mean value over time.*(Toreti et al. 2011)*

$$\text{SNHT statistic} = \max |Z(i)| \quad \text{(ix)}$$

where Z(i) is the standardized anomaly at each time point i. The standardized anomaly is calculated as:

$$Z(i) = (X(i) - \bar{X}) / S \quad \text{(x)}$$

where X(i) is the value of the time series at time point i, $\bar{X}$ is the mean of the time series, and S is the standard deviation of the time series.

Here, it has been done using the software R Studio (version 4.3.2) and with the package *Climtrend* and with the command *snht.test*. In the context of the Standard Normal Homogeneity Test (SNHT), the T value refers to the test statistic that is calculated to assess whether a shift in the mean of a time series is statistically significant. *(Tuomenvirta 2002)*

4.2.3.3. Identification of Monotonic Trend in Rainfall Data Via Mann Kendall's Test

The Mann-Kendall (MK) test (Mann 1945, Kendall 1975, Gilbert 1987) is a statistical tool used to determine whether an interest variable has been trending upward or downward over time. A continuous increase (down) in the variable over time is shown by a monotonic upward (downward) trend, which may or may not be linear. The MK test can be used to ascertain whether the slope of the anticipated linear regression line deviates from zero rather than performing a parametric linear regression analysis. Regression analysis requires that the residuals of the fitted regression line be regularly distributed; however, the MK test, a non-parametric (distribution-free) test, does not depend on this assumption.*(Wang et al. 2020).*

The first step in the Mann-Kendall test for a time series $x_1, x_2, x_3 \ldots\ldots\ldots\ldots x_n$ of length *n* is to compute the indicator function $\text{sgn}(x_i - x_j)$ such that (*Kamal and Pachauri 2018)*:

$$\text{sgn}(x_i - x_j) = \begin{cases} 1, & x_i - x_j > 0 \\ 0, & x_i - x_j = 0 \\ -1, & x_i - x_j < 0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xi)}$$

which tells us whether the difference between the measurements at time \(i\) and \(j\) are positive, negative or zero. Next, the mean and variance of the above quantity are computed. The mean \(E[S]\) is given by:

$$E[S] = \sum_{i=1}^{n-1} \quad \sum_{j=i+1}^{n} \text{sgn}\,(x_i - x_j) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xii)}$$

and the variance *VAR(S)* is given by:

$$\text{VAR}(S) = \frac{1}{18}(n(n-1)(2n+5) - \sum_{k=1}^{p} q_k\,(q_k - 1)(2q_k + 5)) \ldots\ldots\ldots\ldots \text{(xiii)}$$

where (p) is the total number of tie groups in the data, and q_k is the number of data points contained in the k-th tie group *(Reshu Yadav et al. 2014).*Here, it has been done using the software R Studio (version 4.3.2) and with the package *Trend* and with the command *mannkendall (ProgrammingR 2023).* Sen's slope, on the different hand, is a non-parametric technique for estimating the slope of a linear trend in a dataset. It is often referred to as the Sen's estimator or the Sen's slope estimator. The MK test establishes whether or not the observed trend is statistically significant, whereas the Sen slope measures the trend's amplitude. They are often used together to analyze and interpret trends in a time series data set. Also, the values of Kendall's Tau have been calculated for the fact that Kendall's tau measures the association or dependence between two variables *(Roy and Chakravarty 2021).* These are two important parameters while analyzing the outcome of Mann-Kendall test.

4.2.3.4. Intensity-Duration-Frequency (IDF)Curve:

Intensity-duration-frequency (IDF) curves, or its inverse, likelihood of exceedance, depict the connection between rainfall intensity, time frame, and return period. IDF curves are widely used in the conception of hydrologic, hydraulic, and water resource systems.. IDF

are obtained from the examination of the frequency of rainfall observations. Based on rainfall intensity data from 1979 to 2019, the important frequency analysis technique (Gumbel distribution) was used to develop this relationship of 5min,10min,15min,30min,60min,120min,720min,1440 min with 2, 5, 10, 25, 50,75 and 100 years return periods.

For simulating an annual rainfall series, the Gumbel distribution (GD) approach is the most often used distribution technique (*Bharali 2015; Sasireka, Suribabu, and Neelakantan 2019; Mayank B 2020; Gulap 2019; Osei et al. 2021; Mujumdar, 2012*).The type 1 extreme value distribution, also referred to as the Gumbel distribution, is a widely used statistical technique for analysing rainfall extreme values. (Gumbel, Koutsoyiannis,). It is used in hydrologic research to estimate flood peak, maximum rainfall, and other parameters using the probability distribution of extreme quantities. The following equation gives the precipitation frequency P_T (in mm) for every duration with a certain return period T_R (in a year)

$$X_T = \bar{X} + K_T S$$

Or

$$\text{Log } X_T = \text{Log } \bar{X} + K_T S_{logx} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xiv)$$

where X_T represents the rainfall frequency (in mm) for each duration, S represents the standard deviation of precipitation data, $\bar{X}$is the average of annual precipitation data, and K_T is the Gumbel frequency factor given by equation

$$K_T = -\sqrt{6}/\pi\{0.5772 + In[In(^{T}/_{T-1})]\} \ldots\ldots\ldots\ldots\ldots\ldots (xv)$$

where, TR is the return period (2, 5, 10, 25, 50, 75 and 100) years. Then, the rainfall intensity I_T (in mm/h) for return period T_R is obtained by equation.

$$I_T = P_T / T_d \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xvi)$$

where T_d represents the time duration in hour.

*But,*First to get the data of 5min,10min,15min,30min,60min,120min,720min,1440 min which means of a shorter duration, the 49 years old daily rainfall data has been split with

the help of the formula originally propounded by Ramaseshan of the Indian Meteorological Department (IMD)(*Sam et al. 2023)*. Where:

$$R_{t=R_{24}(t/_{24})}n \text{..... (xvi)}$$

$$\text{I}=R_{t/t} \text{.....(xvii)}$$

$$R_{t=R_{24}}\left(\frac{t}{24}\right)n \quad + C \text{..... (xviii)}$$

R is the daily rainfall depth (mm), t is duration (hours), n is an exponential constant =1/3 and I = rainfall intensity (mm/hr.).

4.2.3.5. Rainfall Indices:

Rainfall indices are statistical measures used to analyze and quantify various aspects of rainfall patterns and characteristics. These metrics help with agricultural planning, water resource management, and the assessment of the implications of climate change by offering insightful information on precipitation trends, variability, and extremes. The total yearly rainfall, mean monthly rainfall, seasonal distribution of rainfall, and frequency of extreme rainfall events are examples of common rainfall indicators.These indices help identify drought or flood-prone regions, assess the duration and intensity of dry or wet spells, and evaluate the overall climatic conditions of a particular area. By analyzing rainfall indices, researchers and policymakers can make informed decisions regarding water allocation, infrastructure development, and disaster preparedness, ultimately contributing to sustainable resource management and climate resilience*(Silva et al. 2022).*

- **Rainfall Anomaly Index (RAI) (Van Rooy,1960)**

The rainfall anomaly index is a measure used to assess deviations or anomalies in rainfall patterns from a long-term average. It helps in identifying periods of unusually high or low rainfall compared to the expected or normal conditions. The calculation of the rainfall anomaly index involves comparing the observed rainfall data for a specific time with the long-term average or historical data for the same period. The difference between the observed rainfall and the average rainfall is calculated, and this difference is then standardized using statistical methods such as z-scores or percentiles. The resulting rainfall

anomaly index provides a quantitative measure of how much the observed rainfall deviates from the expected or normal conditions. Positive values indicate above-average rainfall (wet anomalies), while negative values indicate below-average rainfall (dry anomalies) (*Silva et al. 2022).*

For a positive anomaly when $P > \bar{P}$, $\text{RAI} = 3\left[\frac{P-\bar{P}}{\bar{M}-\bar{P}}\right]$ ……(xix)

For a negative anomaly when $P < \bar{P}$, $\text{RAI} = -3\left[\frac{P-\bar{P}}{\bar{X}-\bar{P}}\right]$

The terms of the equations are denoted as P is the present monthly rainfall, $\bar{P}$ indicates the average of the past monthly rainfall data, $\overline{M}$ points out the mean of 10 of the maximum monthly rainfall values and $\bar{x}$ denotes the mean of 10 of the minimum monthly rainfall values.

- **Precipitation Concentration Index (Oliver 1980)**

The Precipitation Concentration Index (PCI) is a measure used to assess the distribution of precipitation over a given period. It quantifies the degree to which precipitation is concentrated or dispersed within that time frame. The PCI is estimated by dividing the sum of the squared daily precipitation values by the square of the sum of the daily precipitation values (*Silva et al. 2022).*The formula for estimating the PCI is as follows:

$$\text{PCI} = (\Sigma(\text{Pi}^2)) / (\Sigma\text{Pi})^2 \text{……. (xx)}$$

Where: Pi represents the daily precipitation value for each day in the given period, Σ denotes the sum of the values.

Table No. 4.7. Standardized Table for PCI as proposed by IMD

Values	Details
<10	Low Precipitation Occurrence
10-15	Moderate Precipitation Occurrence
16-20	Irregular Precipitation Occurrence
>20	Very Much Irregular Precipitation Occurrence

- **Rainfall Seasonality Index (RSI) (Walsh and Lawler 1981)**

The Rainfall Seasonality Index (RSI) is a metric used to quantify the seasonality of rainfall patterns in a particular region. It provides a measure of the concentration or distribution of rainfall throughout the year. RSI value represents the degree of seasonality in the rainfall pattern. Higher RSI values indicate greater seasonality, meaning that rainfall is more concentrated in certain months or seasons, while lower RSI values indicate more evenly distributed rainfall throughout the year *(Shamarti 2017).*

$$SIi = \frac{1}{Ri}\sum_{n=1}^{n=i}\left|Xin - \frac{Ri}{12}\right| \ldots\ldots\ldots\ldots\ldots\ldots \text{(xxi)}$$

Where Ri is the total yearly precipitation for the particular year under study and Xin is the actual monthly precipitation for month (n). This index can vary from 0 (if all the months share equal rainfall) to 1.83 (if all the rainfall takes place in a single month).

- **Rainfall Deviation Index (RDI):**

The rainfall deviation index is a measure used to measure the deviation or departure of observed rainfall from a reference or long-term average. It provides a quantitative understanding of whether the rainfall in a particular period is above or below the expected or normal rainfall. The Rainfall Deviation (Rfdev) which is denoted in percentage terms is calculated as below (*Saini, Singh, and Bhardwaj 2022):*

$$\text{Rf dev} = \{(\text{Rfi} - \text{Rfn})/\text{Rfn}\}*100 \ldots\ldots\ldots\ldots\ldots \text{(xxii)}$$

where, Rfl is present rainfall for a comparable period (in mm) and Rfn is the normal rainfall (at least 30 years average) for the same time frame (in mm). The IMD demarcation of rainfall deviation is given in table

Table No. 4.8. Standardized Table for RDI as proposed by IMD

Normal (%)	Category
60 to 100	Large Surplus
20 to 59	Surplus
+19 to -19	Normal
-20 to -59	Deficient
-60 to -99	Large Deficient
-100	No Rain

4.3. To Calculate the Run-Off through InVEST (Integrated Valuation of Ecosystem Services and Trade-offs)-UFRM (Urban Flood Risk Mitigation) Model

Flood modeling is an important technique for understanding and forecasting flood behavior and consequences. Mathematical models that replicate the hydrologic and hydraulic processes that create floods must be developed in order to forecast the temporal and geographical distribution of flood waters as well as the hazards and damage they bring with them. Risk evaluation for flood prediction Flood models can be used for crisis management, planning, and prevention, among other things. *(Kumar et al. 2023).* The risk of flooding in urban areas is influenced by factors such as the makeup of watersheds, climate variations, and the availability and state of flood mitigation and control technologies. *(Sandink and Binns 2021).* A variety of flood models, such as those based on hydraulics and hydrology, numerical modelling (HEC-RAS, MIKE, TUFLOW), rainfall-runoff modelling (WATFLOOD), remote sensing and GIS-based models (SRTM Flood, ArcGIS Flood), multiple-criteria decision analysis-based flood management, heuristic and metaheuristic methods used in flood management, and more, have also proven helpful in clarifying urban floods. *(Kumar et al. 2023).*

Natural Capital Project, a Stanford University endeavor, has created a relatively innovative and comprehensive model to mimic urban food risk. The model is known as the Urban Flood Risk Mitigation (UFRM) model, and it forms a component of the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) project *(Bose and Mazumdar 2023).*This is a newly dated robust approach, and it is frequently utilized in NASA DEVELOP programmes for disaster preparedness, urban planning, environmental justice concerns and for Nature Based Solutions (NBS). While the InVEST UFRM model produced sufficient surface water runoff and retention maps for previous project scopes, the model's accuracy and geographic variability require improvement*(Do 2023).*The model runs as an open-source software and can explain the run-off retention capacity in various places of an area with different value of rainfall occurrences within a specific period of time, the potential economic damages considering the watershed as per its built infrastructure. This model employs the basic SCS-CN (Soil Conservation Service-Curve Number) methodology to comprehend the quantity of surface runoff and employs a straightforward

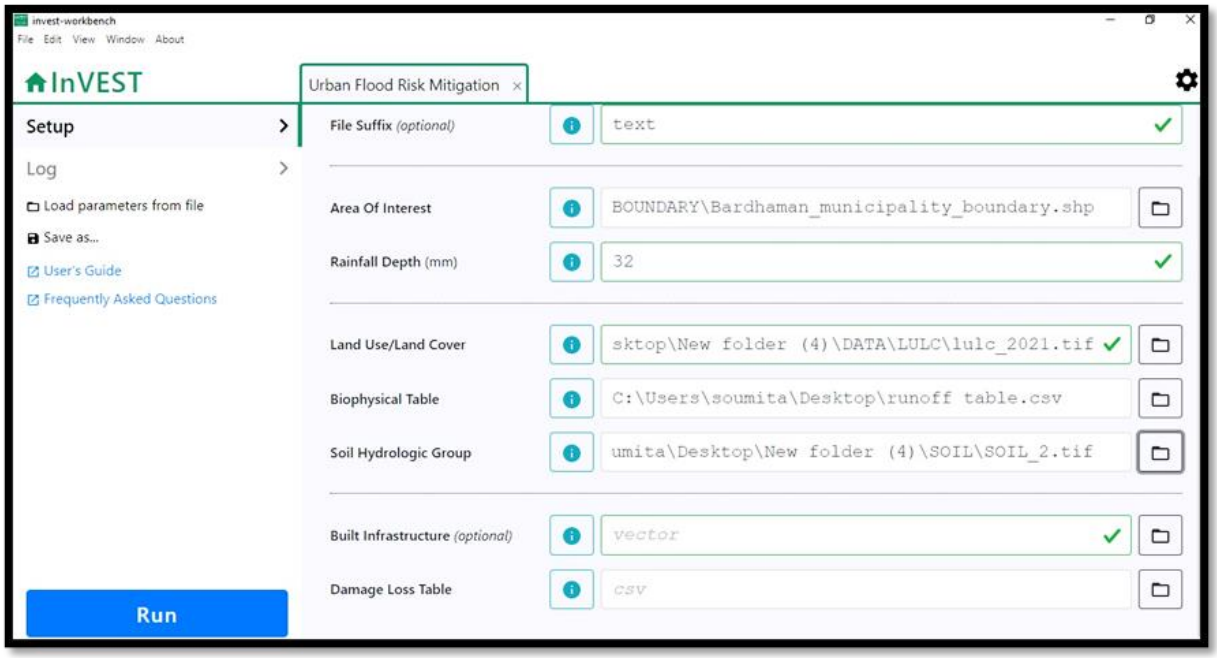
method for estimating the value associated with risk associated with food retention. This form is ideal for doing a city-specific food risk reduction study. *(Bose and Mazumdar 2023).*

4.3. 1.Introduction to the software:

In this work, the InVEST version 10.3.2 was employed. This software requires specific essential inputs to get a result. The steps and the data sources are given below:

(1)

(2)



(3) Figure No.4.4. Step-1 to 3 for Running InVEST UFRM Model

Table No.4.9. The Layers to Act as Inputs

SL No	Name of the Layers	Data Sources	Links	Purpose
1.	Land Use Land Cover Classification	LANDSAT Data	(https://www.usgs.gov/landsat-missions/landsat-data-access)	To delineate impermeable and permeable area
2.	Hydrological Soil Groups (HSG)	Earth Data (CMR Search)	EARTH DATA _https://cmr.earthdata.nasa.gov/search/concepts/C2216864285-ORNL_CLOUD.html	Basic attribute for estimating USDA CN (Curve Number) as a measure of calculating run-off
3.	The Watershed/ The administrative boundary whichever is applicable (Here the boundary)	The Official Website of Burdwan Municipality	https://burdwanmunicipality.gov.in/gis-map.php	To demarcate the AoI (Area of Interest)
4.	Analysis of Daily Rainfall Data	CFSR_SWAT Data	https://swat.tamu.edu/data/cfsr/	For calculating the depth of rainfall for different time periods
5.	Biophysical table covering the data of different land covers and associated curve number	HEC_HMS Technical Reference Manual	https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/cn-tables	Indicate the hydrological soil condition
The inputs like Built-Infrastructure and damage-loss are optional				

Source: Compiled from various sources.

The model runs on some specific algorithms based on python programming language. The predefined formula which the model relies on are listed below:

4.3.1.1. For Run-off Generation and Run-off Retention:

The curve number approach is used to predict the runoff Q for every pixel I, which is predetermined by a land use type and soil properties.

$$Q_{p,i=} \left\{(P-\lambda S_{max_i})\right\} \Big/ P + (1-\lambda)/S_{max,_i} \text{.....(xxiii)}$$

If P> $\lambda . S_{max,_i}$ is 0

Where Q= Run-off

where P is the design storm depth in mm,

$S_{max,_i}$ is the prospective retention in mm

$\lambda . S_{max,_i}$is the rainfall depth needed to onset runoff, (λ = 0.2 for simplification)

Smax (calculated in mm) is a function of the curve number, CN, an empirical indicator that depends on land use and soil traits

$$S_{max,\ i} = (25400/\ CN_i) - 254\text{..... (xxiv)}$$

The model then estimates runoff retention for every pixel R_i as:

$$R_i = 1 - Qp,i\ /P\text{.....(xxv)}$$

And runoff retention volume for each pixel R_m3_i as:

$$R\_m3_i = Ri \cdot P \cdot \text{pixel. area} \cdot 10^{-3}\text{.....(xxvi)}$$

with pixel. area in m2. Runoff volume (also referred to as “food volume”) for each pixel Q_m3i is also estimated as: Q_m3i = Qp, i · pixel.area · 10^{-3}*(Bose and Mazumdar 2023).*

4.4. Methodology Opted for Objective.3(*To recognize the impact of urban flooding on the various socio-economic groups in the municipality.)*

4.4.1. Selecting the Wards for Primary Survey:

To estimate the effect of urban flooding on the citizens, first it needs to be understood which are the wards those get most affected by the flooding, which one are the least affected and which wards are moderately impacted. For the selection of the wards the following aspects are considered:

I. Consulted with the report named 'Land Use and Development Control Plan 2017' published by Burdwan Development Authority where the areas of probable inundations are mentioned based on past events.
II. The pilot survey (January,2019), that was done with the toto/auto driver (because they must travel the whole municipality as a part of their job) and local passing by people to gauge the preliminary concept of the wards those suffer from water logging or flooding issue.
III. Generation of probable water inundation zone map based on the relief map to ascertain the locations of water depressions.

4.4.1.1 Inferences from the relief map of Burdwan Municipality:

Keeping relief map of Burdwan town as a base, five cross sections have been drawn from West to East direction (as the slope follows the same inclination) namely, AB, CD, EF, GH and IJ. (**Figure No.4.5)** From the cross sections, the height of lowlands or depressions could be easily identified and taking those heights, a map is generated where there are four stages of inundation has been portrayed which would help understanding that which are the zones those have a probability of being flooded first and fast.

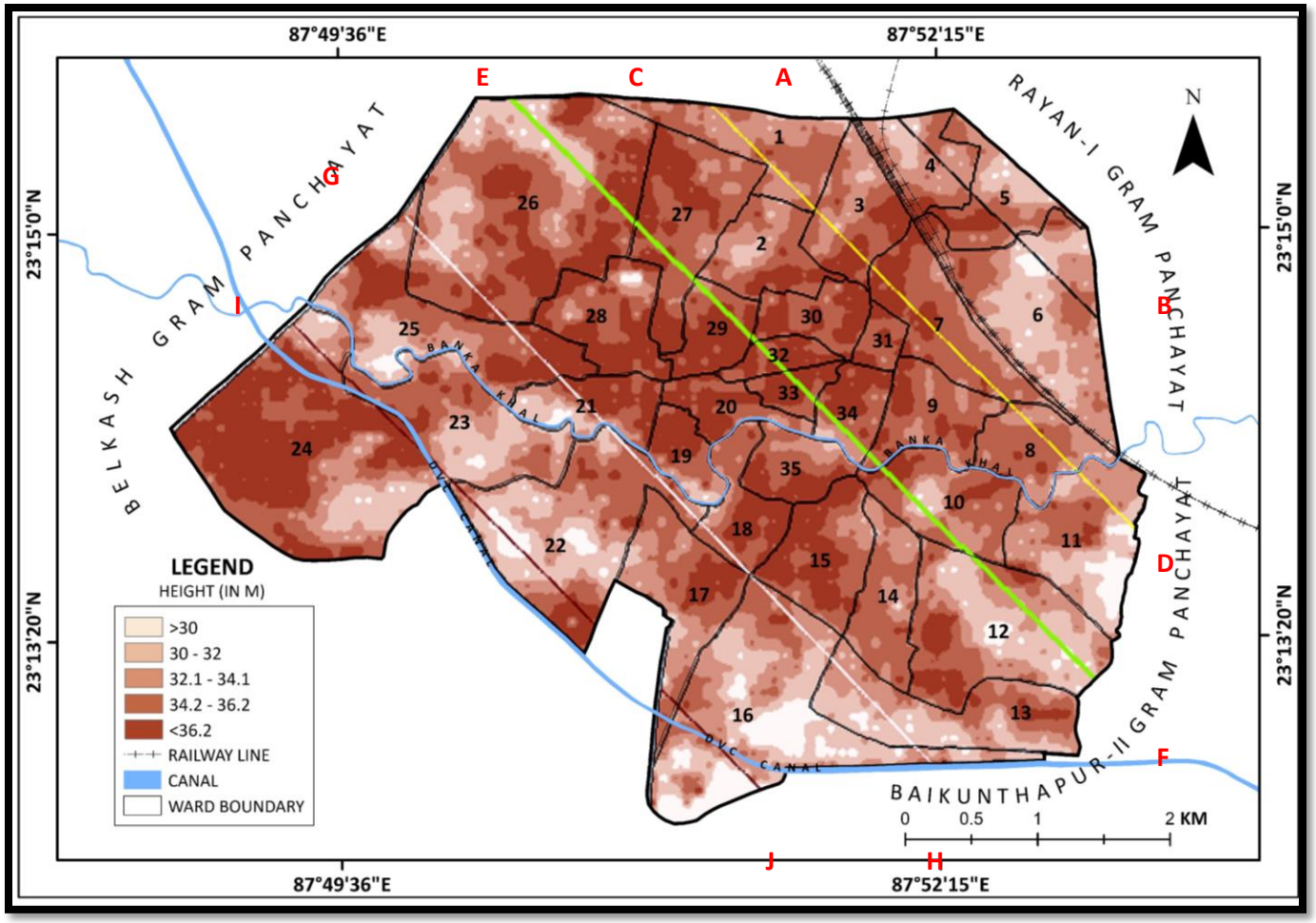
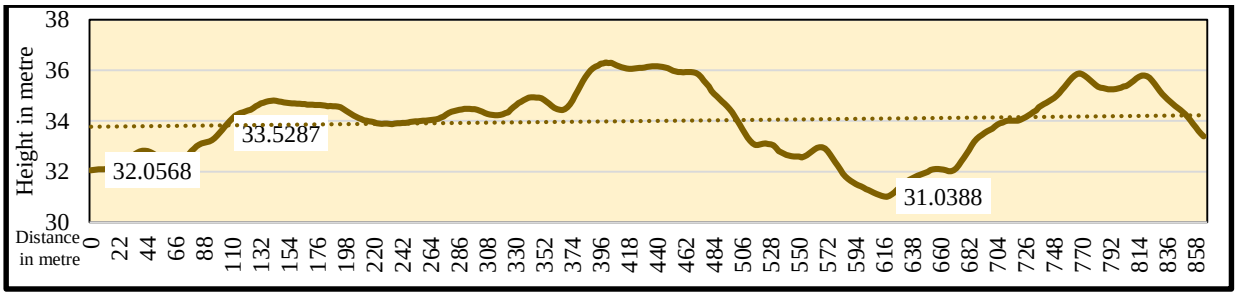


Figure No.4.5. Relief Map with Cross-Sections of Burdwan Municipality (*Source*: Source: GSI Provided Map of Burdwan Urban Agglomeration,1987 along with 33 collected GPS Point



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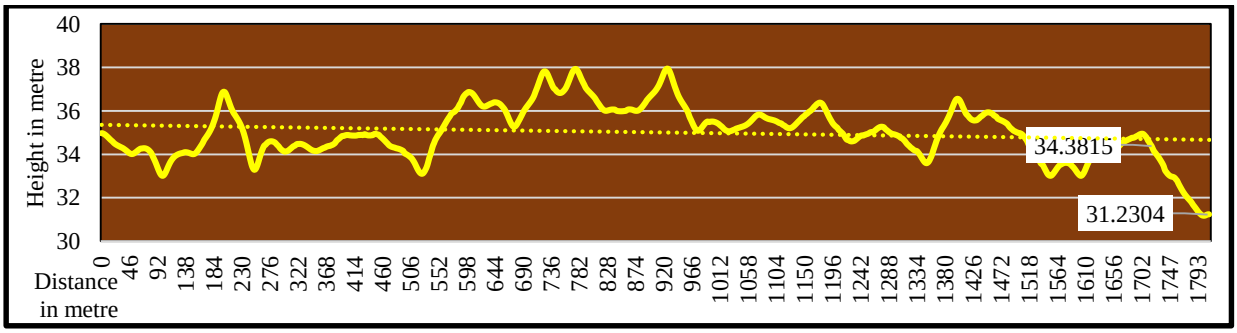

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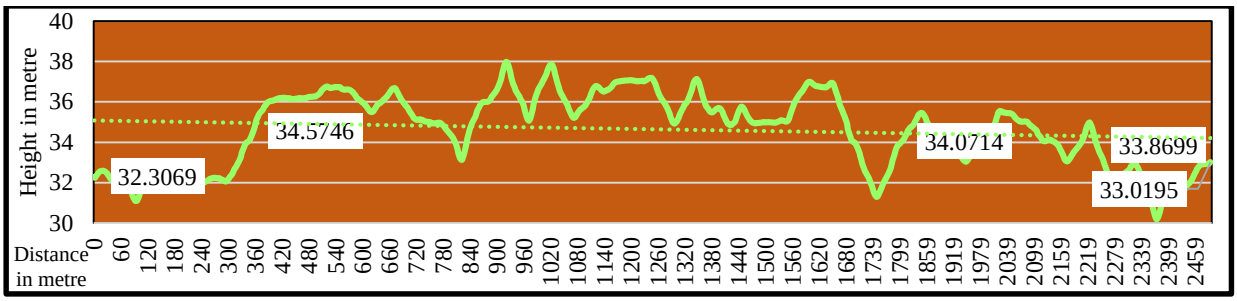
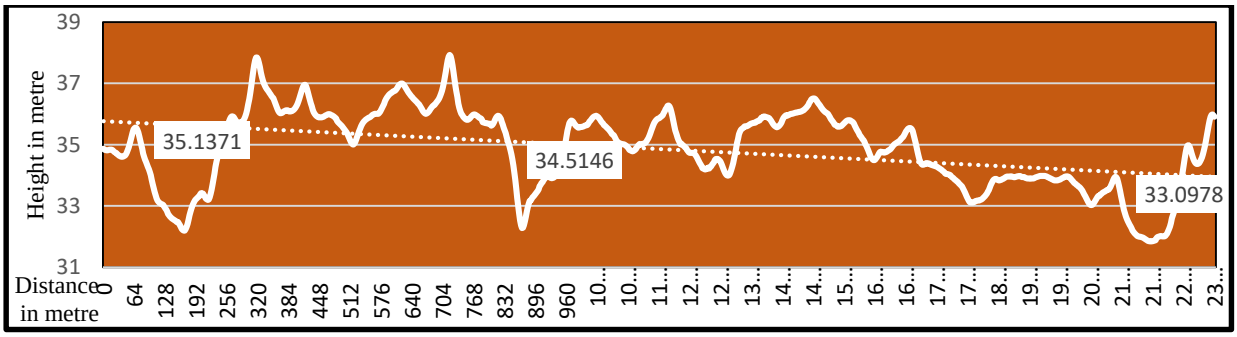
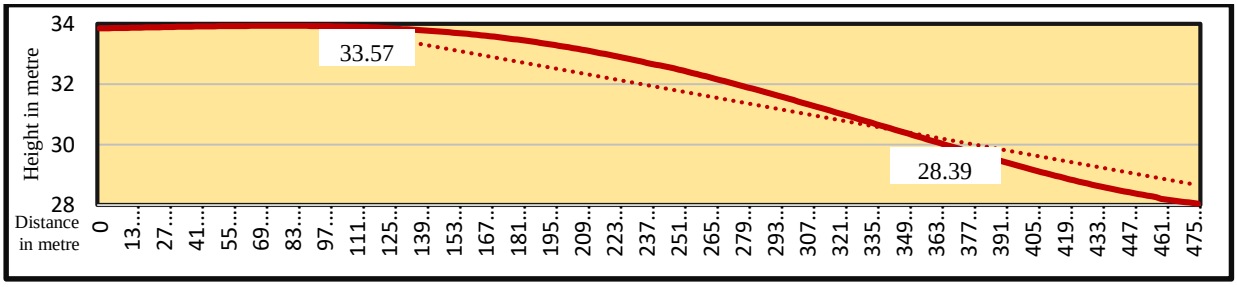


III



IV



V

Figure No. 4.6.(I-V) Cross-Sections AB, CD, EF, GH, IJ (From Top to Bottom)

With the help of the highest(35m) and lowest(28m) heights of break of slope, the zones of inundation have been generated. **(Figure No.4.7.)** It is clearly seen that the central part of the Municipality area is the last to get drowned where the peripheral region is more prone to inundation even with a little amount of rainfall.

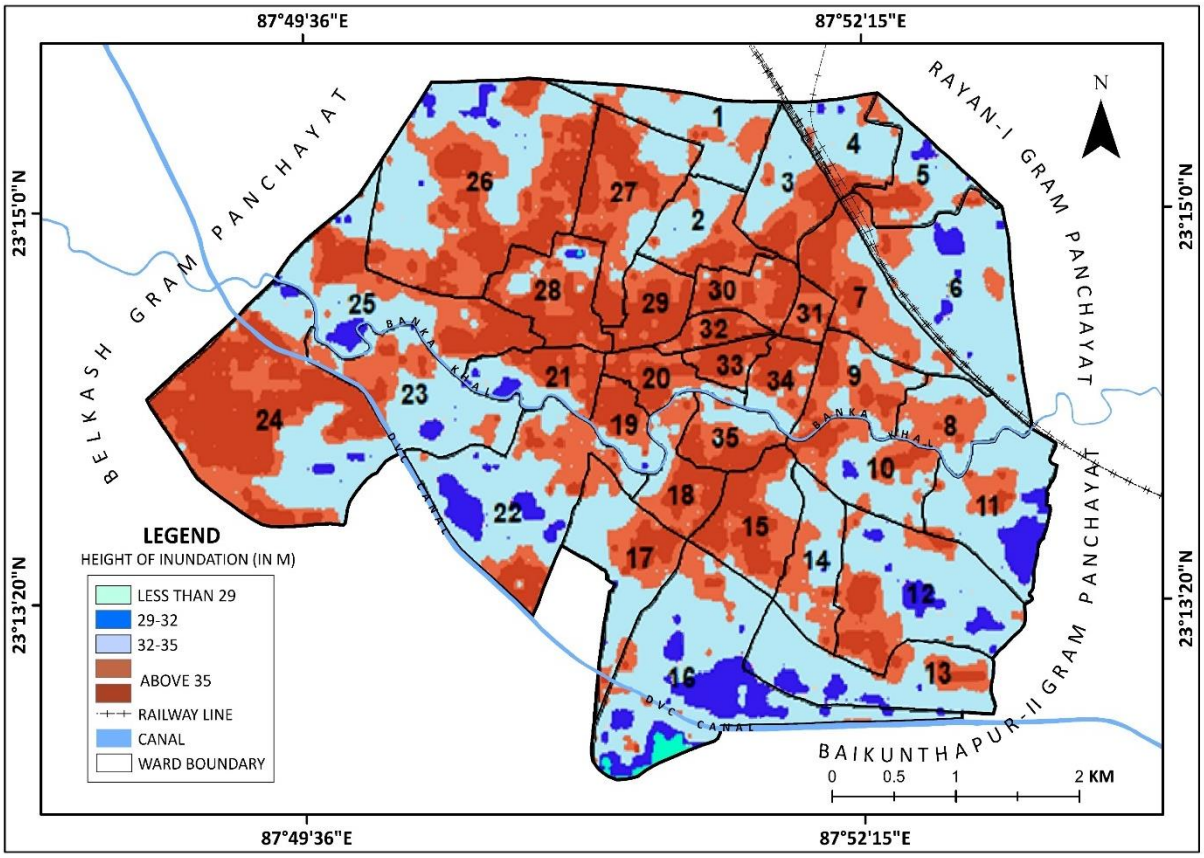


Figure No. 4.7. Probable Stages of Inundation (Less than 29 m being Zone-1 to above 35 being Zone-4) *(Source*: taken Relief map as the base map)

4.4.2. Sampling Technique and information related to Sampling:

The Sample method followed here is Purposive Sampling. This kind of non-probability sampling involves the deliberate selection of particular subjects or cases for a study by the researchers on the basis of their applicability or significance to the goals of the investigation. Making ensuring the selected participants have the traits or attributes that are relevant to the research subject is the main goal of purpose sampling. Researchers use their judgment and expertise to select individuals or cases that can provide relevant and valuable

information to address the research questions or objectives. This sampling method is commonly used in qualitative research or in situations where the focus is on specific subgroups or unique cases. Here the group for the survey is made based on the economic activities they are engaged in, and a special group of Municipal waste workers have been formed as they are one of the key players of urban flooding in the Municipal area.(*Thomas 2022)* (**Table No.4.10.)**

Table No.4.10. The Targeted Groups for Questionnaire Survey

Characteristics	Strata	Groups	Places to Survey
Economic groups	Daily Wage Earner	People who sell perishable commodities like vegetables, milk, etc.	Local Vegetable Market
		Toto/Auto Driver	Roadside survey
	Municipal Workers	Waste and Drainage Workers	At the local vat site
	Service or Businessmen	Resident of Burdwan Municipality	Household survey

4.4.2.1. Some Particulars Related to the Survey:

For the Daily wage earner and Municipal Waste workers groups,

- There are 4500 to 5000 Toto/Rickshaws that run every day in Burdwan including the totos that commute from outside the boundary. (As per the pilot survey, January 2019)
- About 5-6 waste workers are appointed in each ward of the Municipality, amounting to 175-210 people. (As per conversation with the Municipal Officer in Solid Waste Management, September 2022).

- Tetul Tala Bazar (vegetable market) and Nilpur Bazar at Chowmatha (vegetable market) which are usually affected by the water inundation have 60-70 vendors and 40-45 vendors, respectively. (As per field visits,2022-23)
- For estimating the impact of urban flooding on the permanent citizens, the household survey is done categorizing the wards into most to least affected. Table **4.11** shows the actual population of the wards and the surveyed individual.

Table No.4.11. The Size of Surveyed Population within Burdwan Municipality

Ward No.	Population	Ideal Sample Size	Actual Sample Taken
13(Highly affected)	13612	374	28
11	13842	374	25
6	18420	376	30
19	8460	368	32
10(Moderately affected)	9820	370	25
13	13612	370	27
21(Least affected)	8406	367	25
23	10054	370	20
Total			**212**

The total people surveyed combining these three categories-At 95% Confidence Level and 5 % Confidence Interval,

1. **Out of 5000 toto drivers- 33 people**
2. **Out of 200 waste workers- 132 people (taking almost 10% of them 15 people almost)**
3. **Total Persons Surveyed = 212+33+14 =259**

Objective 4 is formulated based on the outcome of the previous objectives**.**

List of References:

1. A.Merry, Marwa. 2017. "Experimental Study for Determine Manning'S Coefficient With Different Slopes and Channel Bed Materials." *Kufa Journal of Engineering* 8(3):76–88. doi: 10.30572/2018/kje/8031160.
2. Arif, Siti Nur Afiqah Mohd, Mohamad Farhan Mohamad Mohsin, Azuraliza Abu Bakar, Abdul Razak Hamdan, and Sharifah Mastura Syed Abdullah. 2017. "Change Point Analysis: A Statistical Approach to Detect Potential Abrupt Change." *Jurnal Teknologi* 79(5):147–59. doi: 10.11113/jt.v79.10388.
3. Arumugam, Thangavelu, Ram Lakhan Yadav, and Sapna Kinattinkar. 2021. "Assessment and Predicting of LULC by Kappa Analysis and CA Markov Model Using RS and GIS Techniques in Udham Singh Nagar District, India Thangavelu." *Research Square* 1–4.
4. Bengtson, Harlan. 2017. "Manning Equation for Open Channels." (833).
5. Bharali, B. 2015. "A Study on Frequency Analysis for Puthimari Catchment by Gumbel Distribution Method." *Journal of Civil Engineering and Environmental Technology* 2(10):19–22.
6. Bureau of Indian Standards. 1988. "Indian Standard Code of Practice For Drainage of Building Basements."
7. Chadchan, J., and R. Shankar. 2012. "An Analysis of Urban Growth Trends in the Post-Economic Reforms Period in India." *International Journal of Sustainable Built Environment* 1(1):36–49. doi: 10.1016/j.ijsbe.2012.05.001.
8. Champion, R., C. T. Lenard, and T. M. Mills. 1998. "Demonstrating the Durbin-Watson Statistic." *Journal of the Royal Statistical Society Series D: The Statistician* 47(4):643–44. doi: 10.1111/1467-9884.00161.
9. Dhorde, Amit G., and Mohammad Zarenistanak. 2013. "Three-Way Approach to Test Data Homogeneity : An Analysis of Temperature and Precipitation Series over SouthWestern Islamic Republic of Iran." *J. Ind. Geophys. Union* 17(3):233–42.
10. Djajadi, R. 2009. "Comparative Study of Equivalent Manning Roughness Coefficient for Channel with Composite Roughness." *Civil Engineering Dimension* 11(2):113–18.
11. Gulap, Sonowal. 2019. "Method: A Lower Downstream of Lohit River (Dangori

River).” *International Journal of Civil Engineering and Technology* 10(11):229–34.

12. Hakuba, Maria Z., Arturo Sanchez-Lorenzo, Doris Folini, and Martin Wild. 2013. “Testing the Homogeneity of Short-Term Surface Solar Radiation Series in Europe.” *AIP Conference Proceedings* 1531:700–703. doi: 10.1063/1.4804866.
13. Huitema, Bradley, and Sean Laraway. 2015. “Autocorrelation.” (August 2006).
14. Jayasree, V., and B. Venkatesh. 2015. “Analysis of Rainfall in Assessing the Drought in Semi-Arid Region of Karnataka State, India.” *Water Resources Management* 29(15):5613–30. doi: 10.1007/s11269-015-1137-1.
15. Kalmukov, Yordan. 2021. “Using Word Clouds for Fast Identification of Papers’ Subject Domain and Reviewers’ Competences 15.” *Proceedings of University of Ruse* 60:114–19.
16. Kamal, Neel, and Sanjay Pachauri. 2018. “Mann-Kendall Test - A Novel Approach for Statistical Trend Analysis.” *International Journal of Computer Trends and Technology* 63(1):18–21. doi: 10.14445/22312803/ijctt-v63p104.
17. King, Maxwell L. 1995. “The Application of the Durbin-Watson Test to the Dynamic Regression Model under Normal and Non-Normal Errors.” *Econometric Reviews* 14(4):487–510. doi: 10.1080/07474939508800333.
18. Mayank B, Patel. 2020. “Flood Frequency Analysis Using Gumbel Distribution Method at Garudeshwar Weir, Narmada Basin.” *International Journal of Trend in Research and Development* 7(1):2394–9333.
19. McHugh, Mary L. 2012. “Lessons in Biostatistics Interrater Reliability : The Kappa Statistic.” *Biochemica Medica* 22(3):276–82.
20. National Disaster Management Authority, GoI. 2017. “Urban Floods.” *Natural Hazards*.
21. NRSC National Remote Sensing Centre. 2014. “Natural Resource Census - Land Use Land Cover Database.” *Technical Report – Ver.1* 1–9.
22. Osei, Marian Amoakowaah, Leonard Kofitse Amekudzi, Akoto Yaw Omari-Sasu, Edmund Ilimoan Yamba, Emmanuel Quansah, Jeffrey N. A. Aryee, and Kwasi Preko. 2021. “Estimation of the Return Periods of Maxima Rainfall and Floods at the Pra River Catchment, Ghana, West Africa Using the Gumbel Extreme Value Theory.” *Heliyon* 7(5):e06980. doi: 10.1016/j.heliyon.2021.e06980.

23. ProgrammingR. 2023. “Beginner to Advanced Resources for the R Programming Language.” Retrieved (https://www.programmingr.com/statistics/how-to-perform-a-durbin-watson-test-in-r/).
24. Razafinimaro, Arisetra, Aimé Richard Hajalalaina, ZoJaona Tantely Reziky, Eric Delaitre, and Avisoa Andrianarivo. 2021. “Landsat8 Satellite Image Classification with ERDAS for Mapping the Kalambatritra Special Reserve.” *American Journal of Remote Sensing* 9(1):16. doi: 10.11648/j.ajrs.20210901.12.
25. Reshu Yadav, S. K. Tripathi, G. Pranuthi, and S. K. Dubey. 2014. “Trend Analysis by Mann-Kendall Test for Precipitation and Temperature for Thirteen Districts of Uttarakhand.” *Journal of Agrometeorology* 16(2):164–71. doi: 10.54386/jam.v16i2.1507.
26. Roy, Sukumar, and Nabajit Chakravarty. 2021. “Rainfall Analysis by Using Mann-Kendall Trend, Sen’s Slope and Variability at Six Stations of Andaman & Nicobar Islands.”
27. Saifuddin, a K. M. 2007. “Homogeneity and Trend Analysis of Temperature for Urban and Rural Areas.” (Civil):1–6.
28. Saini, Divya, Omvir Singh, and Pankaj Bhardwaj. 2022. “Standardized Precipitation Index Based Dry and Wet Conditions over a Dryland Ecosystem of NorthWestern India.” *Geology, Ecology, and Landscapes* 6(4):252–64. doi: 10.1080/24749508.2020.1833614.
29. Salarijazi, Meysam. 2012. “Trend and Change-Point Detection for the Annual Stream-Flow Series of the Karun River at the Ahvaz Hydrometric Station.” *African Journal of Agricultural Reseearch* 7(32):4540–52. doi: 10.5897/ajar12.650.
30. Sam, Masi G., Ify L. Nwaogazie, Chiedozie Ikebude, Ubong J. Inyang, and Jonathan O. Irokwe. 2023. “Assessment of Climate Change Induced Trend, Magnitude, and Change Point Date in 24-Hourly Annual Maximum Series Rainfall Data for Port Harcourt Metropolis in Nigeria.” *International Journal of Environment and Climate Change* 13(7):118–28. doi: 10.9734/ijecc/2023/v13i71859.
31. Sasireka, K., C. R. Suribabu, and T. R. Neelakantan. 2019. “Extreme Rainfall Return Periods Using Gumbel and Gamma Distribution.” *International Journal of Recent Technology and Engineering* 8(4S2):26–29. doi: 10.35940/ijrte.d1007.1284s219.
32. Shamarti, Hasanain. 2017. “Analysis of Rainfall Seasonality Index in Iraq.” *Diyala*

Journal For Pure Science 13(1):188–202. doi: 10.24237/djps.1301.158a.

33. Silva, Tarciana Rafaela Barbosa Figueiroa, Carlos Antonio Costa dos Santos, Delson José Figueiroa Silva, Celso Augusto Guimarães Santos, Richarde Marques da Silva, and José Ivaldo Barbosa de Brito. 2022. "Climate Indices-Based Analysis of Rainfall Spatiotemporal Variability in Pernambuco State, Brazil." *Water (Switzerland)* 14(14):1–26. doi: 10.3390/w14142190.
34. Sudhakar, S., and Kameshwar SVC Rao. 2010. "Land Use and Land Cover Analysis." *Remote Sensing Applications* 21–48.
35. Thomas, Fr Baiju. 2022. "The Role of Purposive Sampling Technique as a Tool for Informal Choices in a Social Sciences in Research Methods." *Just Agriculture Multidisciplinary* 2(5):1–8.
36. Toreti, A., F. G. Kuglitsch, E. Xoplaki, P. M. Della-Marta, E. Aguilar, M. Prohom, and J. Luterbacher. 2011. "A Note on the Use of the Standard Normal Homogeneity Test to Detect Inhomogeneities in Climatic Time Series." *International Journal of Climatology* 31(4):630–32. doi: 10.1002/joc.2088.
37. Tuomenvirta, Heikki. 2002. "Homogeneity Testing and Adjustment of Climatic Time Series in Finland." *Geophysica* 38(1–2):15–41.
38. Wang, Fan, Wei Shao, Haijun Yu, Guangyuan Kan, Xiaoyan He, Dawei Zhang, Minglei Ren, and Gang Wang. 2020. "Re-Evaluation of the Power of the Mann-Kendall Test for Detecting Monotonic Trends in Hydrometeorological Time Series." *Frontiers in Earth Science* 8(February):1–12. doi: 10.3389/feart.2020.00014.
39. Yasin, Muhammad Yazrin, Jamalunlaili Abdullah, Norzailawati Mohd Noor, and Mariney Mohd Yusoff. 2020. "Land Cover and NDBI Analysis to Map Built up Area in Iskandar Malaysia." *IOP Conference Series: Earth and Environmental Science* 540(1). doi: 10.1088/1755-1315/540/1/012073.

CHAPTER: FIVE

RESULTS AND DISCUSSIONS

***5.1.0. Foreground*:**

Urbanization, by definition, is the process through which rural areas are transformed into urban areas because of industrialization and economic growth*(Peng, Chen, and Cheng 2012)*. Given that urbanization is a complicated phenomenon involving social, ecological, and administrative aspects, it stands to reason that the developmental challenges it presents will be much more intricate *(Khayrullin, Yakovlev, and Nenilina 1993)*. Because over half of the world's population lives in cities, there is an extreme increase in the density of people, crowding, resource imbalances, urban poverty, unplanned slums and shanty settlements, pollution, etc. One of the main countries contributing to the enormous urban population is India. 31% of Indians live in large cities, according to the 2011 census; by 2025, 46% of the population would reside in cities with a population of one million or more. By 2050, there will be 814 million people living in urban areas in India, up from 410 million in 2014 *(Sridhar 2019).* Based on growth in population trends and size of the population, West Bengal is ranked fourth and is expected to stay there until at least 2101, according to projections made by the Population Reference Bureau in 2007 *(PRB 2007).*Although it has always been greater than the national average, the level of urbanization is relatively low when compared to the other developed states in the nation. unexpectedly up to the 2011 census, a few centers in the state had drawn a population that represented unscientific urbanization.*(Das and Kar 2022).* The present study area, Burdwan Municipality, is among one of those. Urbanization can contribute to urban flooding through various mechanisms. Natural ground surfaces are frequently replaced by impermeable surfaces like concrete and asphalt as cities grow and develop. Rainwater cannot seep through these surfaces into the ground, increasing surface runoff. *(Konrad 2003).* Additionally, the construction of buildings, roads, and other infrastructure can alter natural drainage patterns, causing water to accumulate in certain areas. Urbanization often involves the removal of vegetation and the destruction of natural water storage areas such as wetlands. These natural features help absorb and store excess water during heavy rainfall events. Without them, there is a higher likelihood of water accumulating and overwhelming drainage system inadequate or poorly designed urban drainage systems can also

contribute to urban flooding. If the infrastructure is not able to handle the increased volume of water, it can impact in water backing up and flooding streets, buildings, and other urban areas*(Tucci 2018*).

5.1.1. Land Use and Land Cover Classification and Change Detection:

Even though the terms "land use" and "land cover" are occasionally used in the same sentence, they have rather different meanings. The word "land cover" refers to the surface of the earth, and "land usage" talks about how that area is used. *(Sudhakar and Rao 2010).* Land use and land cover classification refers to the categorization of different types of land use and land cover in each area using remote sensing and geographic information system (GIS) technologies. It involves identifying and mapping different land use categories such as agriculture, urban areas, forests, wetlands, water bodies, and more. Now, Change detection in land use and land cover has become a very important procedure for regulating and keeping an eye on urban development and natural resources *(Hassan et al. 2016).* So, to study the temporal changes in the urban setup, the classification of LANDSAT Images has been executed following section following the **4.1.1. Image Classification of Chapter-Four (Methodology).**

5.1.1.1. Analysis of LULC Classified Image:

To study the temporal and spatial dynamics in urban landscapes the satellite images of the year 1991,2001,2011 and 2021 were selected, processed, and classified **(Figure No. 5.1.1 to 5.1.4)** which would help to the ways of identifying and categorizing changes that have occurred in the land use patterns over the given period of decades.

Photo.5.1.1. The Entry Gate to Burdwan Municipality from the Alisha Bus stand
Source: Primary Survey,2022

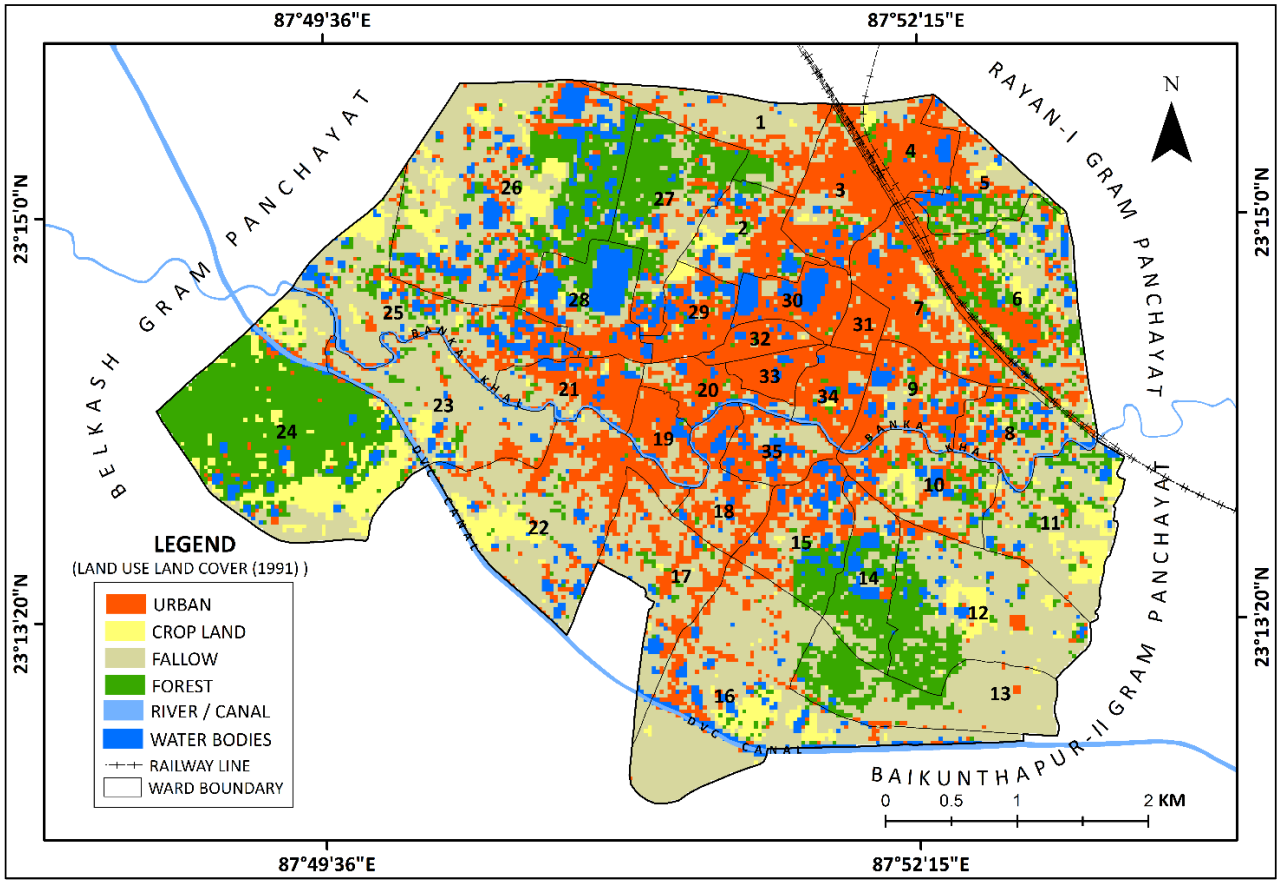


Figure No. 5.1.1. The LULC Classified Image of 1991

(Source: LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

In the year 1991, it is seen that the fallow was the pre-dominant land use type (12.10 sq km) followed by the urban area (7.08 sq km), which was quite centralized in nature covering the areas like Subhaspally, Khosbagan, Babur Bagan, Railway colony, Alamganj etc. mostly due to the accumulation of the medical facilities firstly and for the administrative advantages in this area.

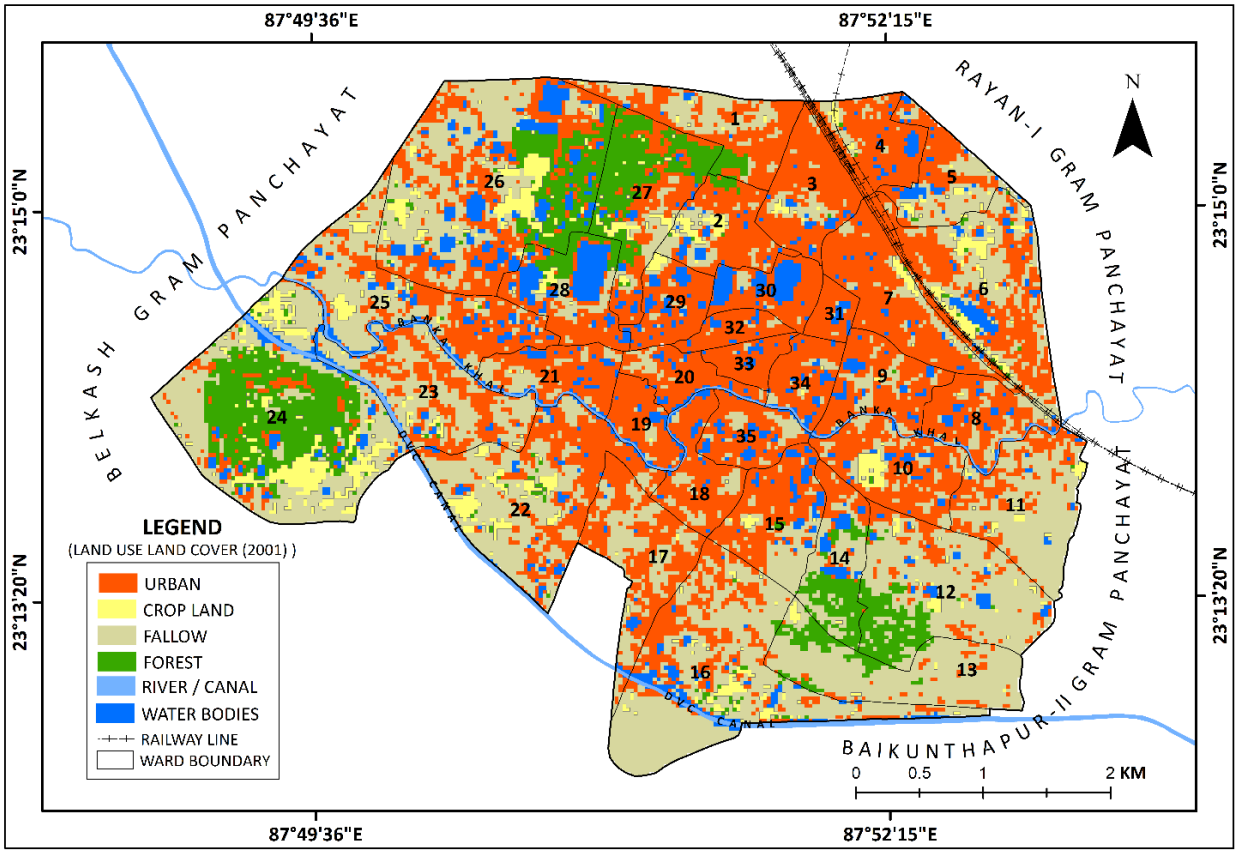


Figure No.5.1.2. The LULC Classified Image of 2001

(Source: LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

The urban area at the central of the Municipality got more intensified and stretched over the North-Eastern, Western and Southern portions of the Municipality owing its spread toward Kalna Road, Railway Lines, Mirchoba, Nilpur, ichlabad probably due to the spread of educational facilities. (9.23 sq km) On the other hand, the area under fallow and waterbodies are decreasing (9.97 and 1.94 sq km).

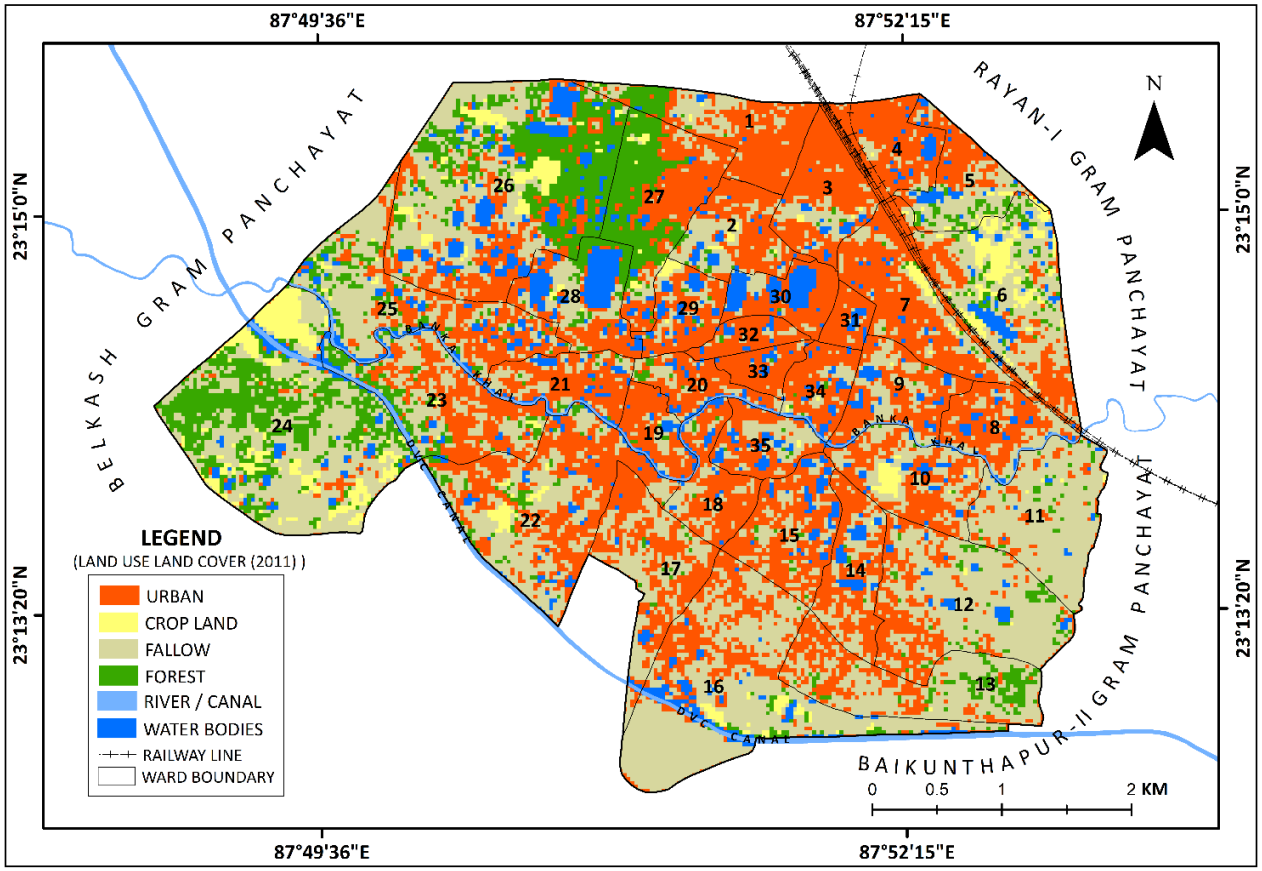


Figure No.5.1.3. The LULC Classified Image of 2011

(*Source*: LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

The Urban expansion adjacent to Delhi-Kolkata Road, is profound (10.79 sq km) and to the areas like Becharhat of South or Southeastern part took place in fragmentation. On the other hand, the green cover is diminishing significantly with time.

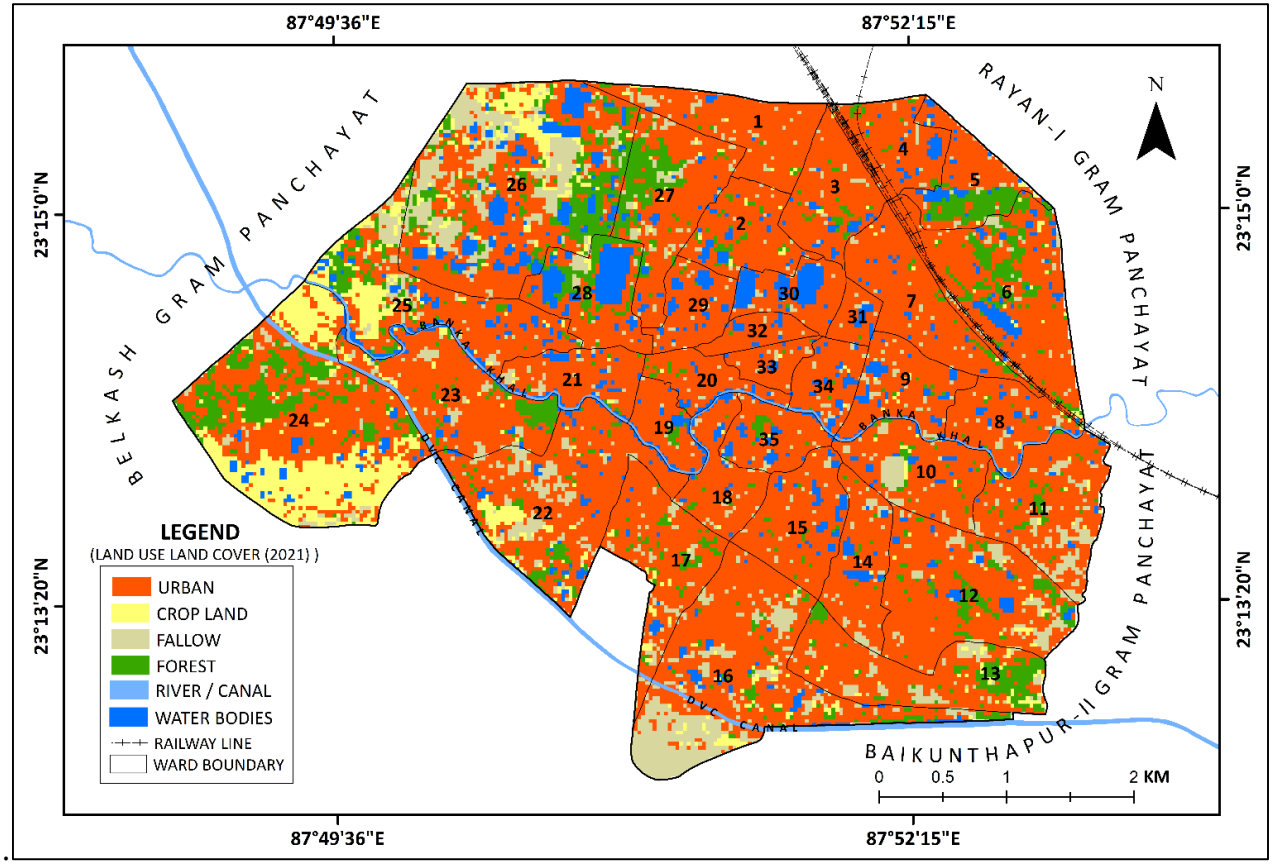


Figure No.5.1.4. The LULC Classified Image of 2021

(Source: LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

Leaving some of the Western part adjacent to Katrapota, Cyphon Dam, all other parts of the Municipality got highly urbanized. (16.09 sq km.

5.1.1.2. Accuracy Checking of the Classified Images:

Here all four classified images have been checked for accuracy with kappa's co-efficient matrix and they exhibited the values of 0.83,0.84,0.80,0.85, for the years 1991,2002,2011 and 2021 which signify that the classified outputs are much closer to the point of perfection. (Detailed table showing the calculation in given in Appendix-2)

5.1.1.3. Change in the proportion of Land uses:

After the image classification has been performed, the share of each LULC class over the decades can easily be calculated and put in **Table No:5.1.3.** and **Figure No 5.1.5.**

Table: 5.1.1. The Proportions of Land Use Over the Years (1991-2021)

Name of The Classes of LULC	Area (in sq km)			
	1991	**2001**	**2011**	**2021**
Cropland	1.93	1.37	0.94	0.64
Fallow	12.10	9.97	7.48	2.76
Forest	2.65	2.67	2.84	2.52
Urban	7.082	9.23	10.79	16.09
Water Bodies	2. 16	1.94	1.65	1.46

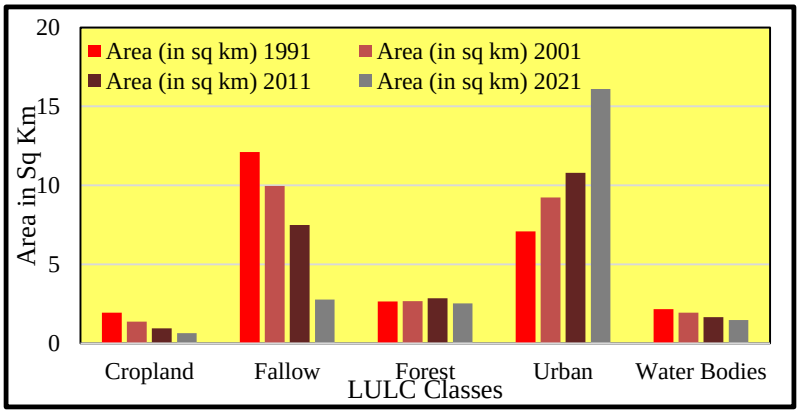
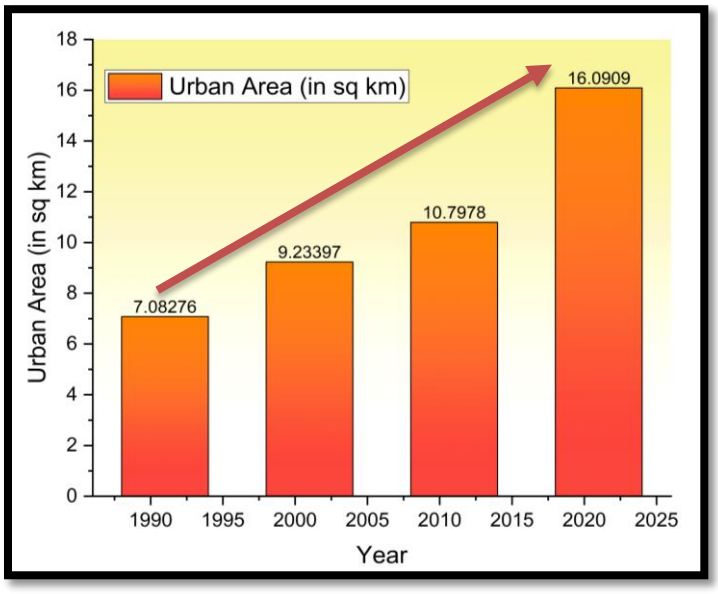


Figure No.5.1.5. Year Wise Land Use Proportion (1991-2021)

(Source for both Table and Figure in this page: Computed from LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

According to NRSC, an **urban area** is designated as "*non-linear built-up areas covered by impervious structures adjacent to or connected by streets. This cover is related to centers of population. This class usually occurs in combination with vegetated areas that are connected to buildings that show a regular pattern, such as vegetated areas, gardens etc. and industrial and/or other areas. (FAO, 2005).It includes residential areas, mixed built-up, recreational places, public / semi-public utilities, communications, public utilizes/facility, commercial areas, reclaimed areas, vegetated areas, transportation, industrial areas and their dumps, and ash/cooling ponds."(NRSC National Remote Sensing Centre 2014)* from the table above **Table No. 5.1.1.** The proportion of urban surface has gone almost double (16.09 sq km) in 2021 than it was in 1991 (7.08 sq km) (**Figure No. 5.1.5.)** and if the rate becomes persistent by the year 2050, the whole geographical area of the town will be urbanized. This figure represented the significant shift in land cover inside the built-up area category, which was placing tremendous pressure on non-built-up areas, especially on the fallow land. The rapid construction of residential, commercial buildings, as well as road networks, pavements, and recreation areas, and other impermeable surfaces, all contributed to the expansion of the city's built-up areas, which are now found in all its corners. Initially, this town originated as an agricultural market, as well as agro-based industry such as rice mills, for the neighboring lush rural region. The service sector has grown in importance in this town's economy throughout time as educational, healthcare, transport, and marketing facilities have developed. The number of wards has increased from 5 (at the time of inception) to 25 in 1960. There are now 29 wards, up from 25 previously. There is also an increase in the number of wards from 29 to 35 because of redistribution and new area extension *(Laha 2019).* Since 2000, the town has been growing vertically to cater to these migrators *(Laha 2019).*There are now 203 multistory residential units, with an average density of 8 multistory residences per km2 area, up from fewer than 10 in 2000 which aggravates furthermore population density and less urban expansion to a physical extent *(Ganai and Sarkar 2018)*The research area's urbanization pattern is unplanned and thus unscientific, resulting in various socio-environmental problems like traffic congestion, water logging, and pollution *(Laha 2019).*



Year	Urban Area (in Sq. km)
1991	7.08276
2001	9.23397
2011	10.7978
2021	16.0909
2031	**18.3422344**
2041	**21.27075487**
2050	**23.9064233**

Table No .5.1.2. The Projected Growth of Urban Area

Figure No.5.1.6. The Expansion of Urban Area (in Sq Km)

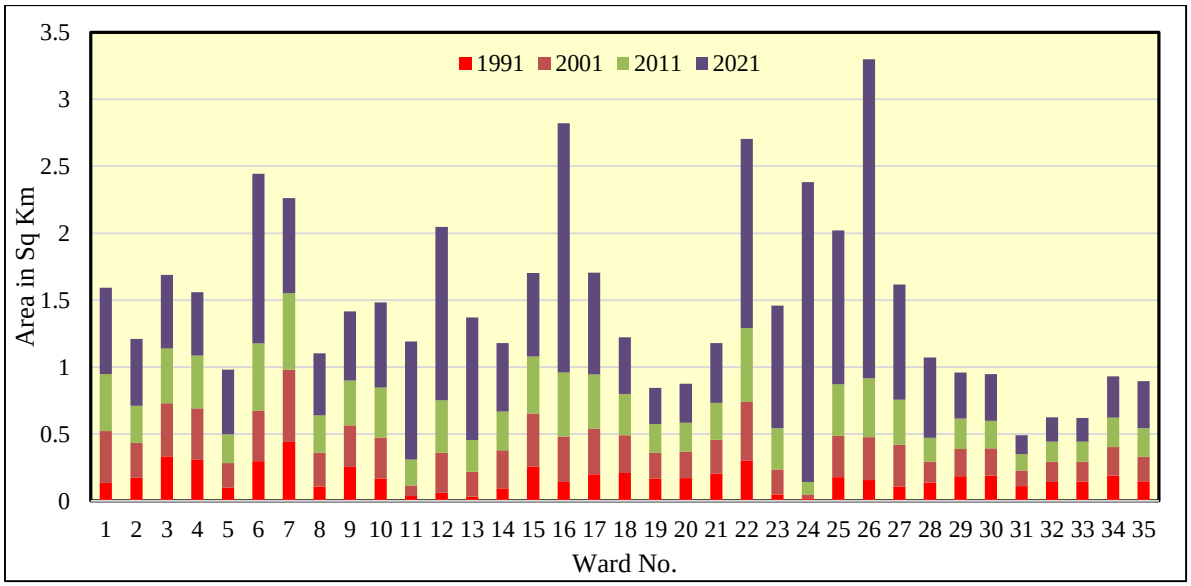


Figure No.5.1.7. Ward-Wise Expansion of Urban Area (in Sq Km)

Source: Computed from LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

All the wards received their highest growth in terms of urban expansion in the last decade of 2011 to 2021 **(Figure No.5.1.6)** probably due to migration from the surrounding areas like Galsi, Budbud from the West of the Municipality. The wards towards Western and

South-western part of the Municipality have experienced the maximum growth (Ward No.22,23,24) as the wards which are centrally located (Wards like 33,34) or situated in the North-Eastern parts, were already built up heavily. **(Figure No.5.1.7)** Not only that, but the urban expansion is also reinforced in the Eastern and South-Eastern part of Municipality as the new high-rises appeared in the scenario. Some informal settlements emerged at both sides of River Banka hiking the newly generated slums there. **(Figure No.5.1.8)** The Result of the classified maps indicate the growth of urban area at the cost of fallow land mostly followed by agricultural land and forest lands and it happened along the major axial lines like railway, Delhi- Kolkata Bypass Road, DVC Canal and by both banks of River Banka. The Wards which were prominently characterized by fallow like Ward no. s 12,13,14 in the South-Eastern Part of the Municipality in the decades of 1991 and before.

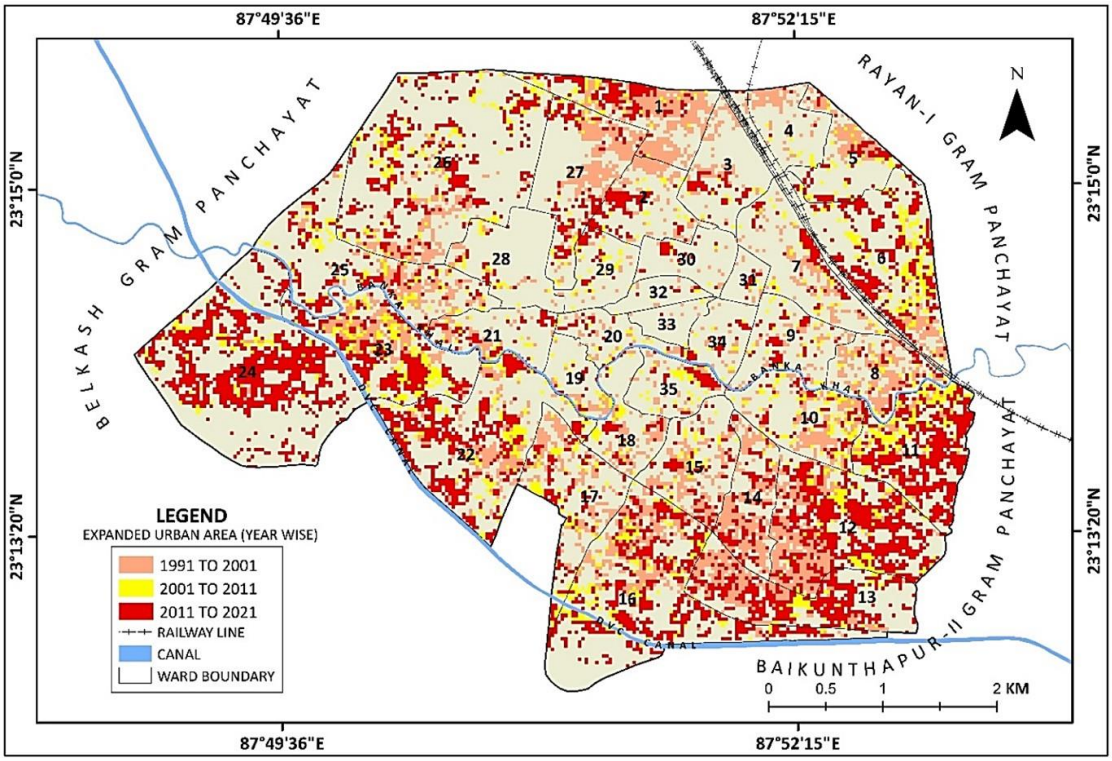


Figure No. 5.1.8. Decade Wise Expanded Urban Area in Burdwan Municipality
Source: Computed from LANDSAT Data
(https://www.usgs.gov/landsat-missions/landsat-data-access)

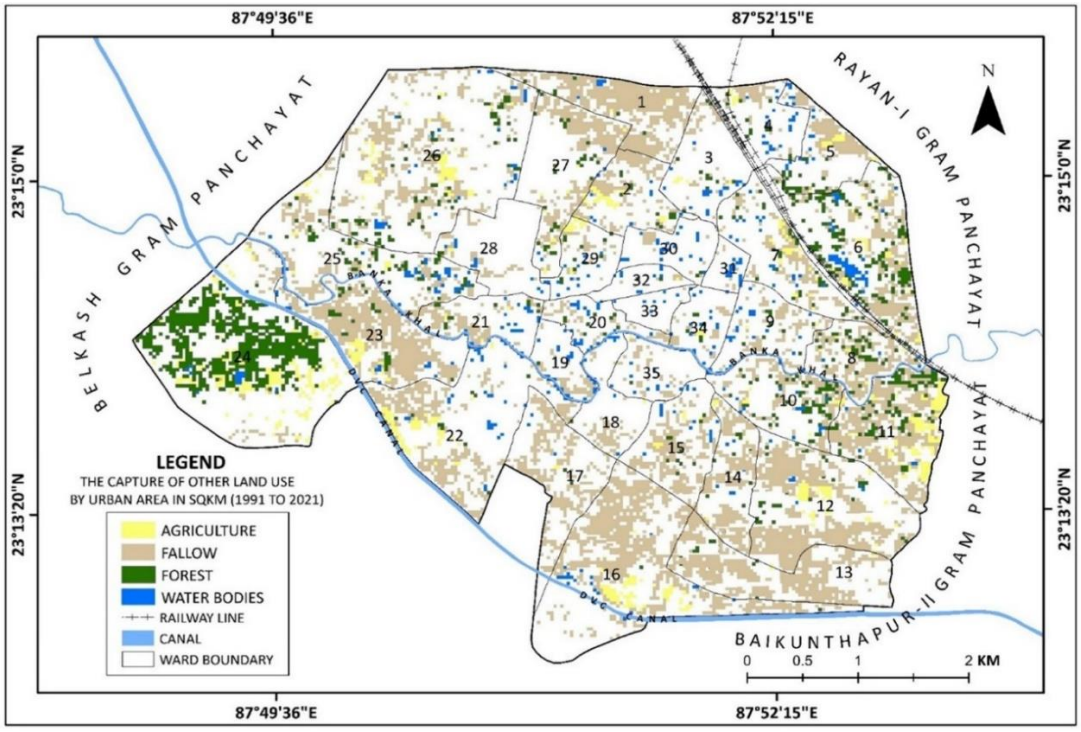


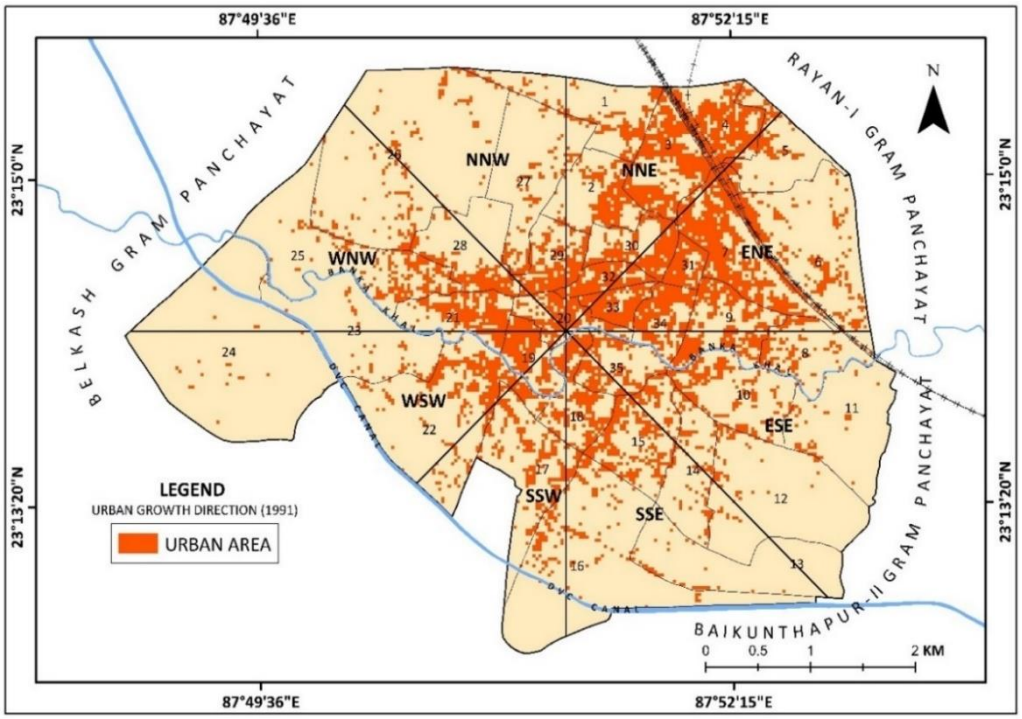
Figure No. 5.1.9. Encroachment of Urban Area into Other Land uses (1991-2021)

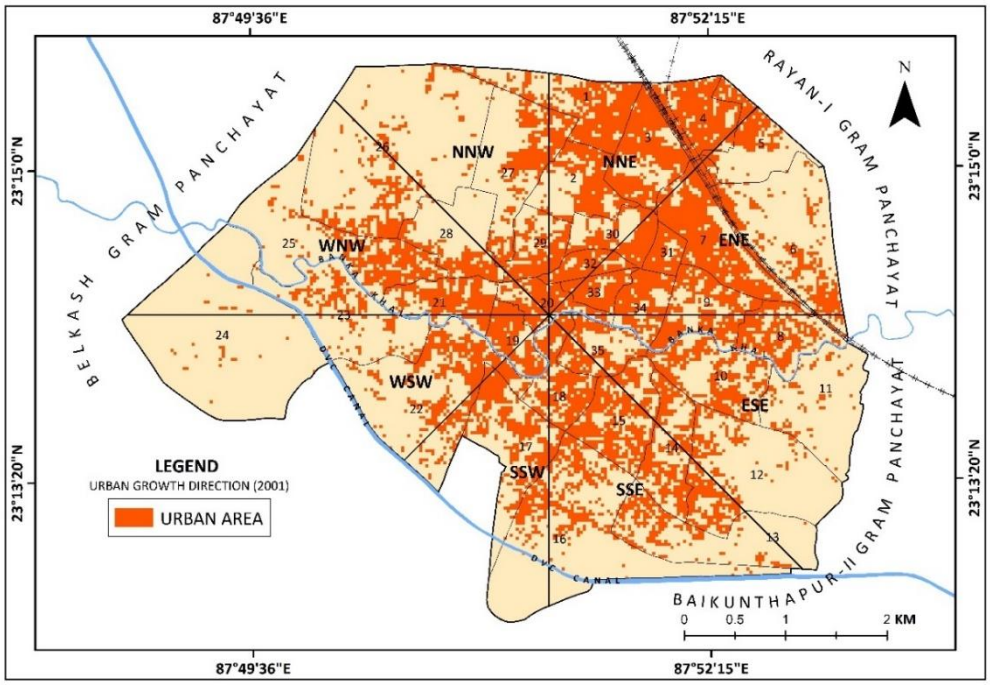
Source: Computed LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

5.1.1.4 Directional Growth of the Urban Area (1991-2021)

Direction analysis is a method used to analyze the spatial patterns and directionality of phenomena in urban expansion. In the context of urban sprawl, gradient direction analysis can provide insights into the expansion and direction of urban development over time *(Woldesemayat and Genovese 2021)*. Here, the town of Burdwan is subdivided into (in clockwise order): North-North East (NNE) or 0º to 45º, East-North East (ENE) or 45º to 90º, East-South East,(ESE) or 90º to 135º, south-south East (SSE) or 135º to 180º, South-South-West(SSW)180ºto225º,West-South West (WSW) or 225º to 270º , West-North-West (WNW)or 270º to 315º, and North-North-West or 315º to 360º *(Zhao et al. 2019).* Keeping the Urban area of 1991 as its base, in the year 2001 it is seen that the segments of NNE, SSE, SSW and WNW have recorded the highest growth in a centrifugal manner. In the year of 2011, all the directional fragments have experienced approximately a fair expansion, but the decade of 2021 has observed almost doubling growth in the

directions of NNW and WSW a moderate expansion in ESE, SSE side and lowest expansion in NNE, SSW and WSW because there was very minimum place left to expand further.





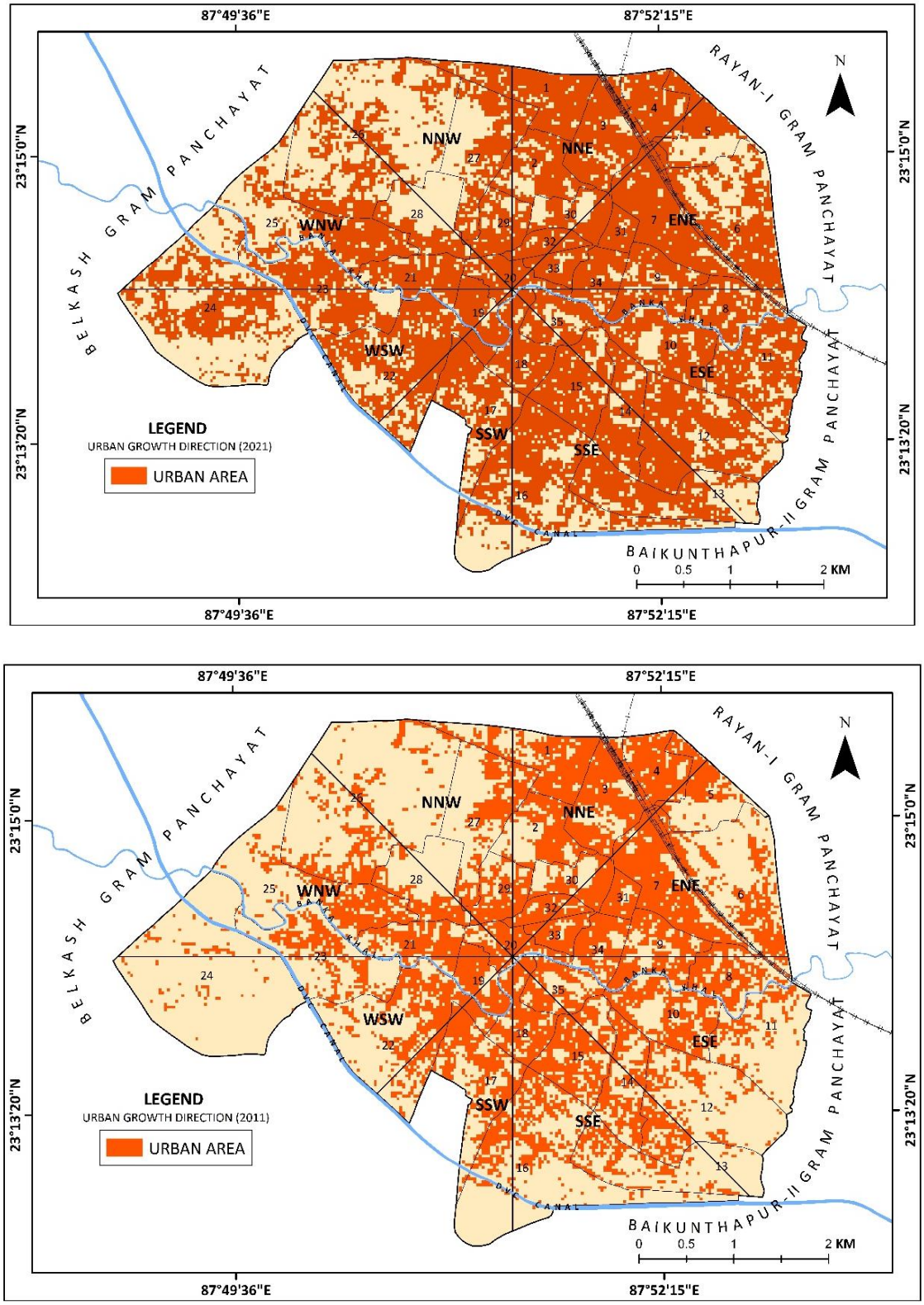


Figure No. From5.1.10 to 14. Directional Growth of Urban Area in 1991-2021

Table No.5.1.3. Extra Added Area in Each Decade Direction Wise

Direction	Base Area of 1991	Added area in 2001	Added area in 2011	Added Area in 2021
NNE	1.274798	0.554321	0.058763	0.215577
ENE	1.474531	0.327446	0.224965	0.476751
ESE	0.708544	0.56936	0.356712	1.182334
SSE	0.579082	0.784296	0.177135	0.919133
SSW	0.397859	0.26098	0.170643	0.273354
WSW	0.414312	0.147949	0.177487	1.037168
WNW	0.664405	0.466287	0.270511	0.755451
NNW	0.375764	0.234034	0.127618	0.433319

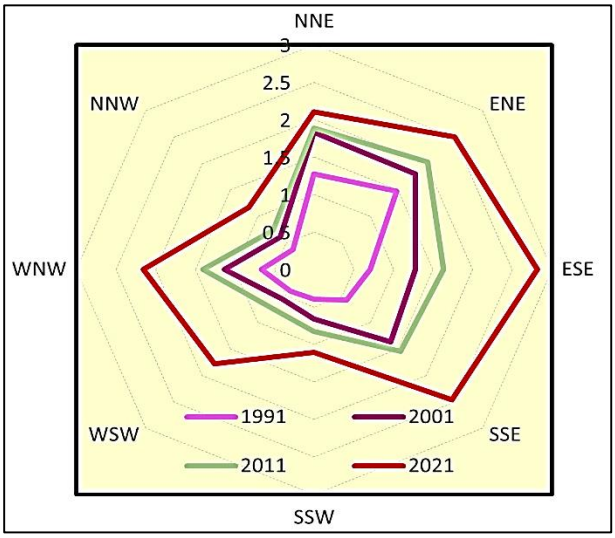


Figure No. 5.1.15. The Directional Growth in Burdwan Municipality (1991-2021)

Source: Figure No. 5.1.10.-14 and Table No..5.1.5: Computed from LANDSAT Data (https://www.usgs.gov/landsat-missions/landsat-data-access)

5.1.1.5. Mean Centre of Urbanization and its Shift over Time (1991-2021)

The mean center of urbanization refers to the average geographic location of urban development within a specific area. It is a statistical measure used to determine the central tendency of urbanization patterns. The mean center provides valuable information about the spatial distribution and concentration of urbanization within a region. It can aid to identify areas of high urban development and understand the overall pattern of urban growth*(Mohan et al. 2011).* The gradual revolving of mean center in the central part of the Municipality from 1991 to 2021 proves that the concentration of urbanization lies in the core of the municipality since last 30 years but the influence of the sphere of urbanization is shifting towards the Western part of the municipality which resonates with the outcome

of the previous LULC classifications- the urban area is expanding towards the periphery of the town.

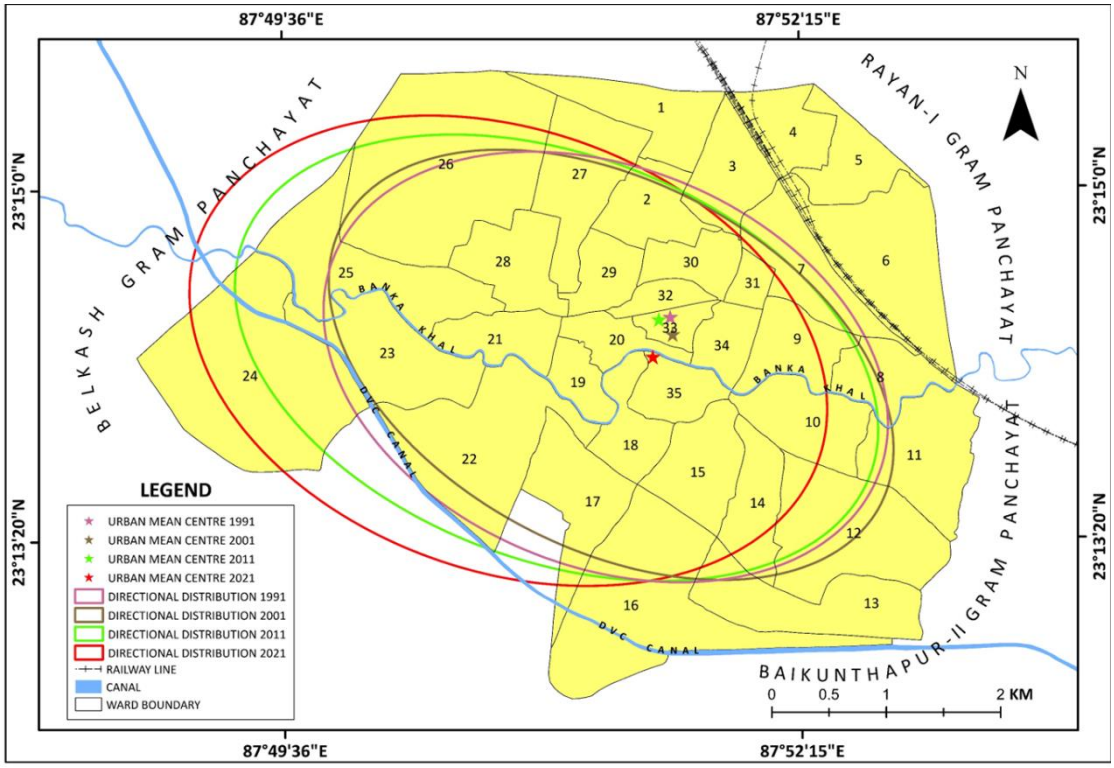
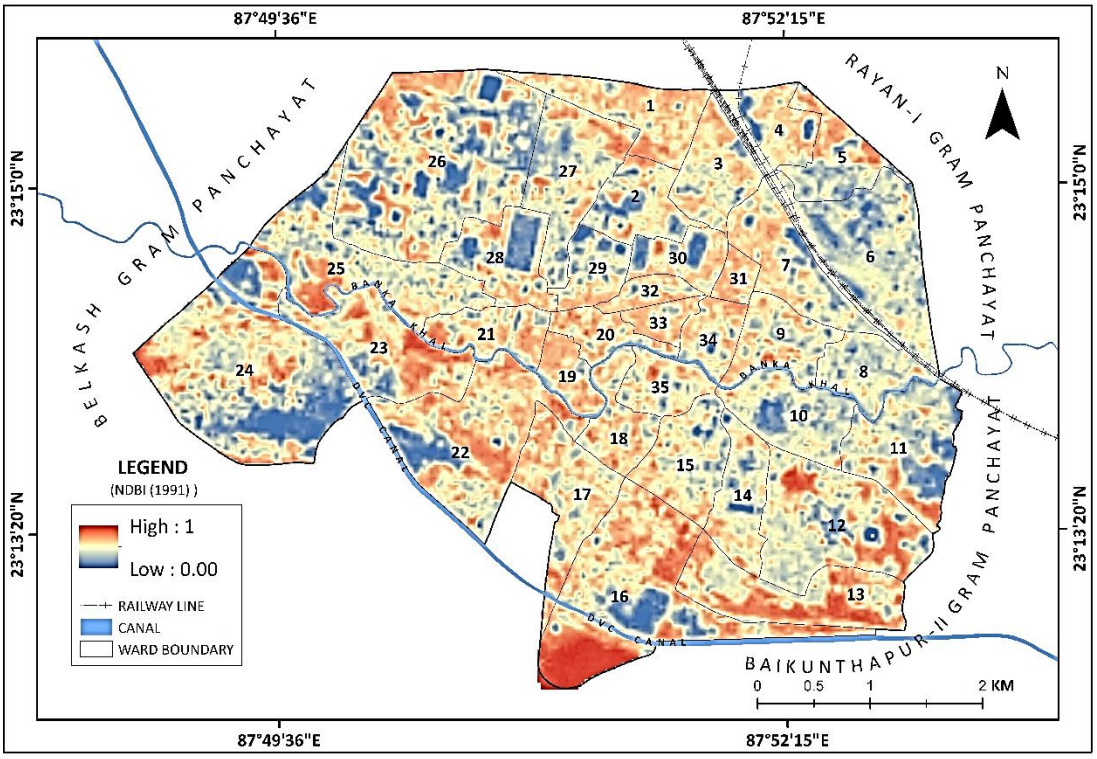


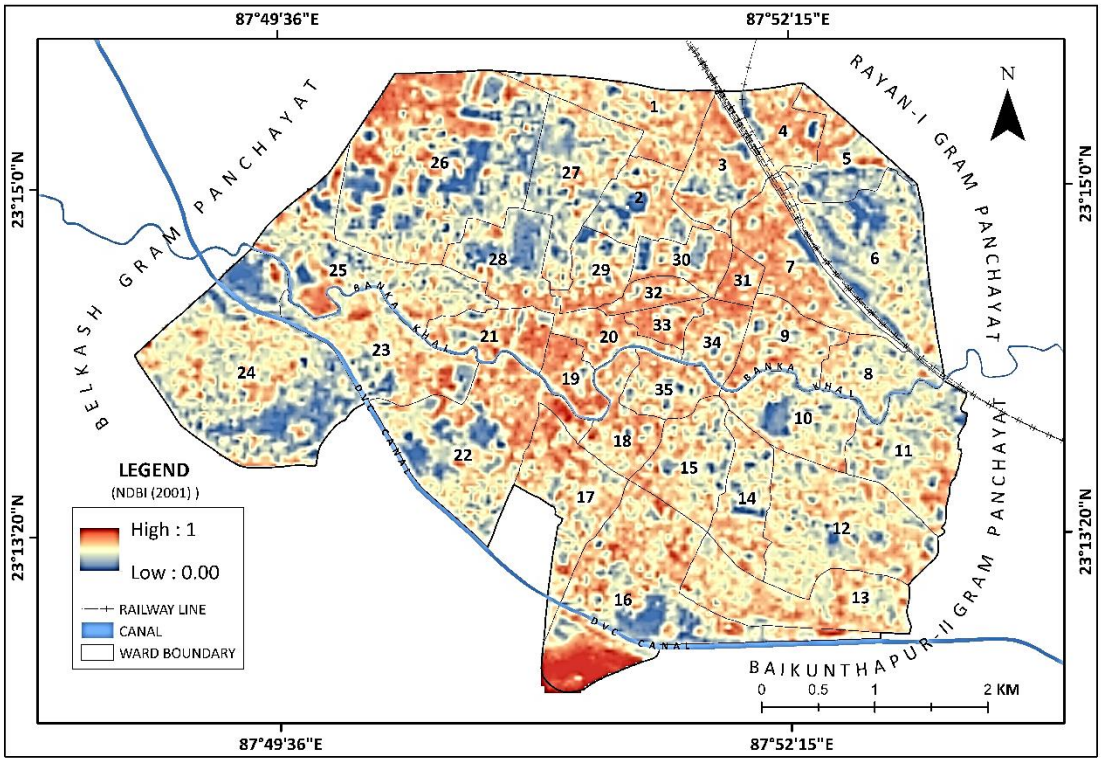
Figure No.5.1.16. The Mean Centre and its Shift along with its Sphere of Influences in Burdwan Municipality (1991-2021)

5.1.1.6. The Normalized Differential Built Up Index (NDBI)

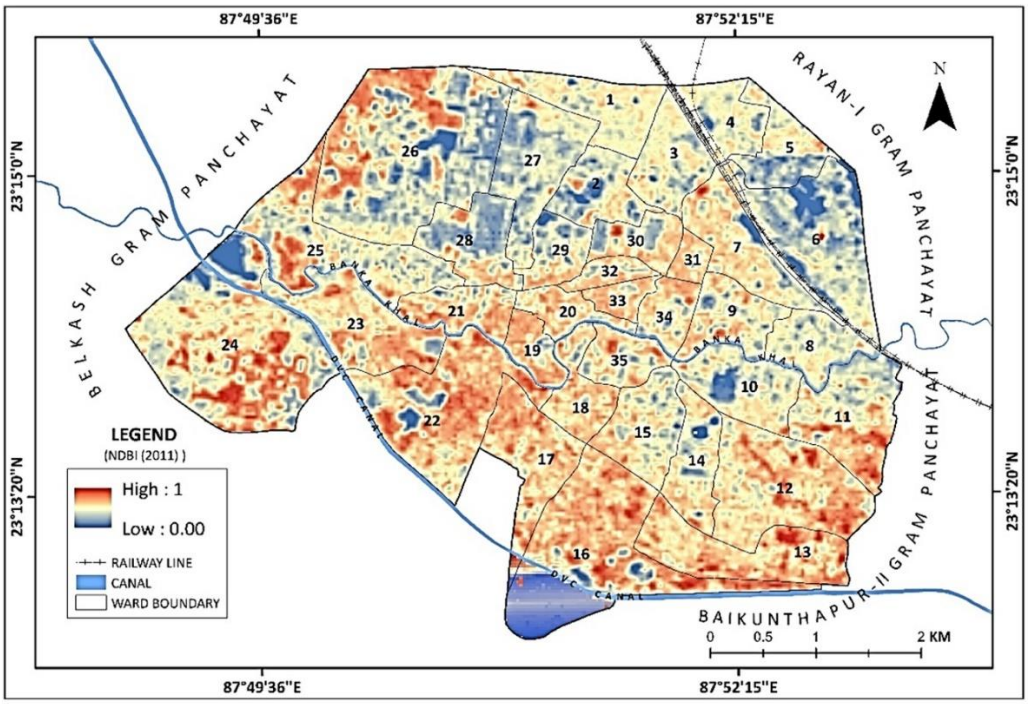
A built-up area is a region where people live that was created for non-agricultural purposes and includes structures, utilities related to water, vegetation, and open space, as well as transportation and communication infrastructure. (NRSC National Remote Sensing Centre 2014) Following the 4.1.3.The Normalized Differential Built Up Index NDBI)of Chapter-Four(Methodology) the NDBI is calculated which again confirmed the pattern and the spread of urban areas in the Municipality- that is from the central part of the town it diffused toward the North-Eastern, Eastern and Western Part at the last and still there is some small portions left in the Western side of the Municipality. The values closer to 1 or near about 1 denotes the area highly built up and if it is closer to 0, it is less likely to be concreted.


87°49'36"E
87°52'15"E
23°15'0"N
23°13'20"N
BELKASH GRAM PANCHAYAT
RAYAN-I GRAM PANCHAYAT
BAIKUNTHAPUR-II GRAM PANCHAYAT
BANKA KHAL
DVC CANAL
N
LEGEND
(NDBI (1991))
High : 1
Low : 0.00
RAILWAY LINE
CANAL
WARD BOUNDARY
0 0.5 1 2 KM

.(i)


87°49'36"E
87°52'15"E
23°15'0"N
23°13'20"N
BELKASH GRAM PANCHAYAT
RAYAN-I GRAM PANCHAYAT
BAIKUNTHAPUR-II GRAM PANCHAYAT
BANKA KHAL
DVC CANAL
N
LEGEND
(NDBI (2001))
High : 1
Low : 0.00
RAILWAY LINE
CANAL
WARD BOUNDARY
0 0.5 1 2 KM

(ii)



(iii)

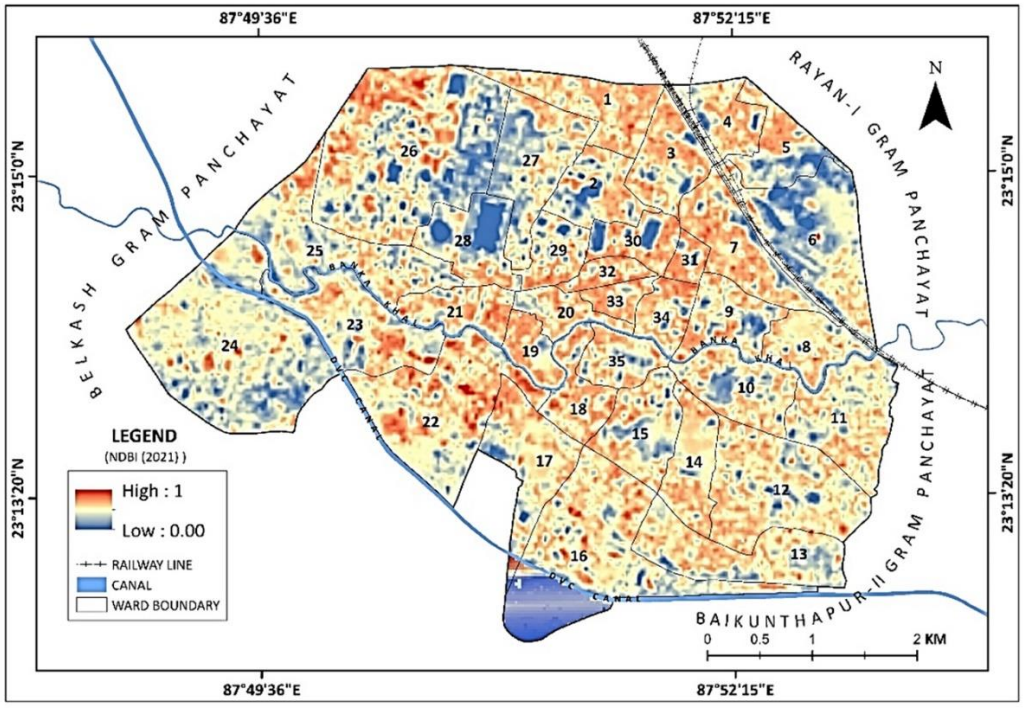


Figure No. 5.1.17.(i-iv) The Normalized Differential Built Up Index NDBI (1991-2021)

5.1.2. Population Density:

The estimation of the number of people residing in a particular location is known as population density, and it is commonly stated as the number of people per unit of land area. It is determined by dividing the area's entire population by its land area. *(Malik, Suparta, And Dewancker 2016*). Population density is an important demographic indicator that provides insights into the concentration of people within a given region and usually it is aligned with the growth of urban areas in a particular place *(Guo and Wang 2022).* Burdwan Municipality is also no exception. In the case of mapping of population density, the year 2001(**Figure No.5.1.18A)** is considered as the base year to keep the similarity in the number of wards. The year 2001 is showing highest population density (more than 28,000 persons/Sq Km) in the wards like 33,31 and 3 and a moderate concentration in the wards like 1,2,21,29 which is at per with the LULC map of 2001 where urbanization was still concentrated in the central part. **(Figure No. 5.1.2)** On the contrary when the map of

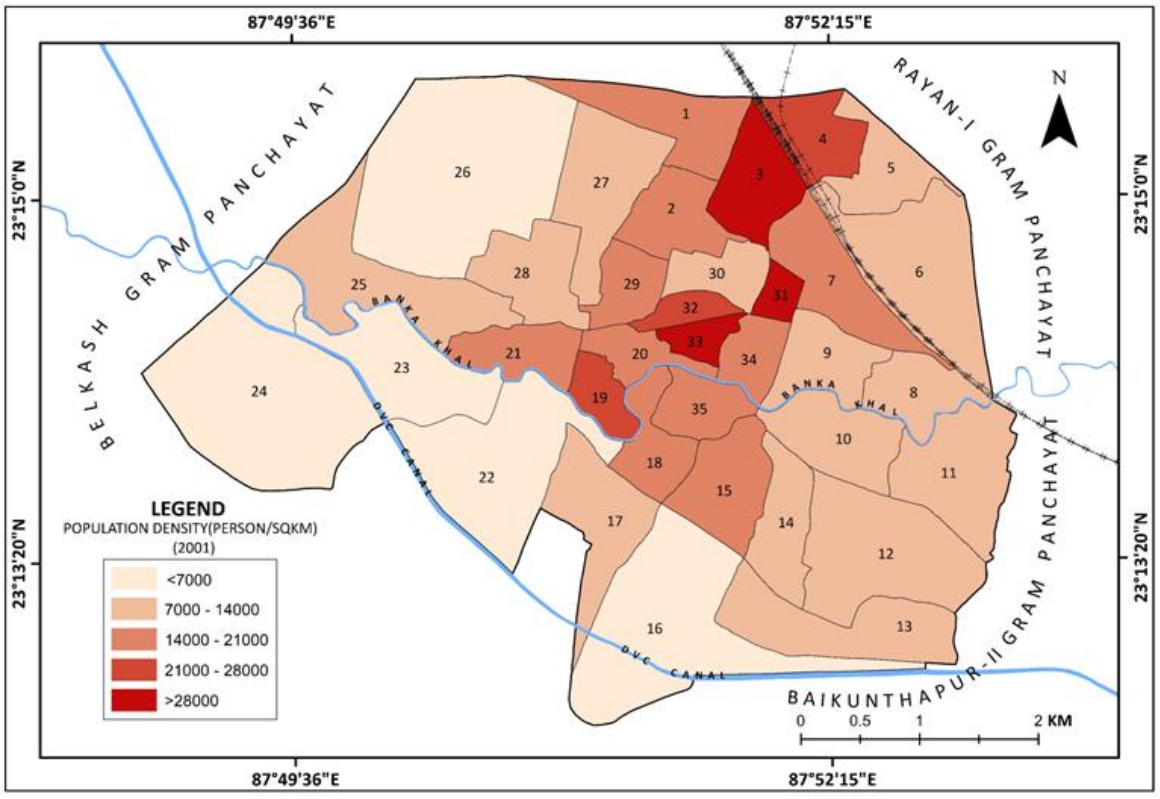


Figure No.5.1.18A: Population Density of Burdwan Municipality,2001

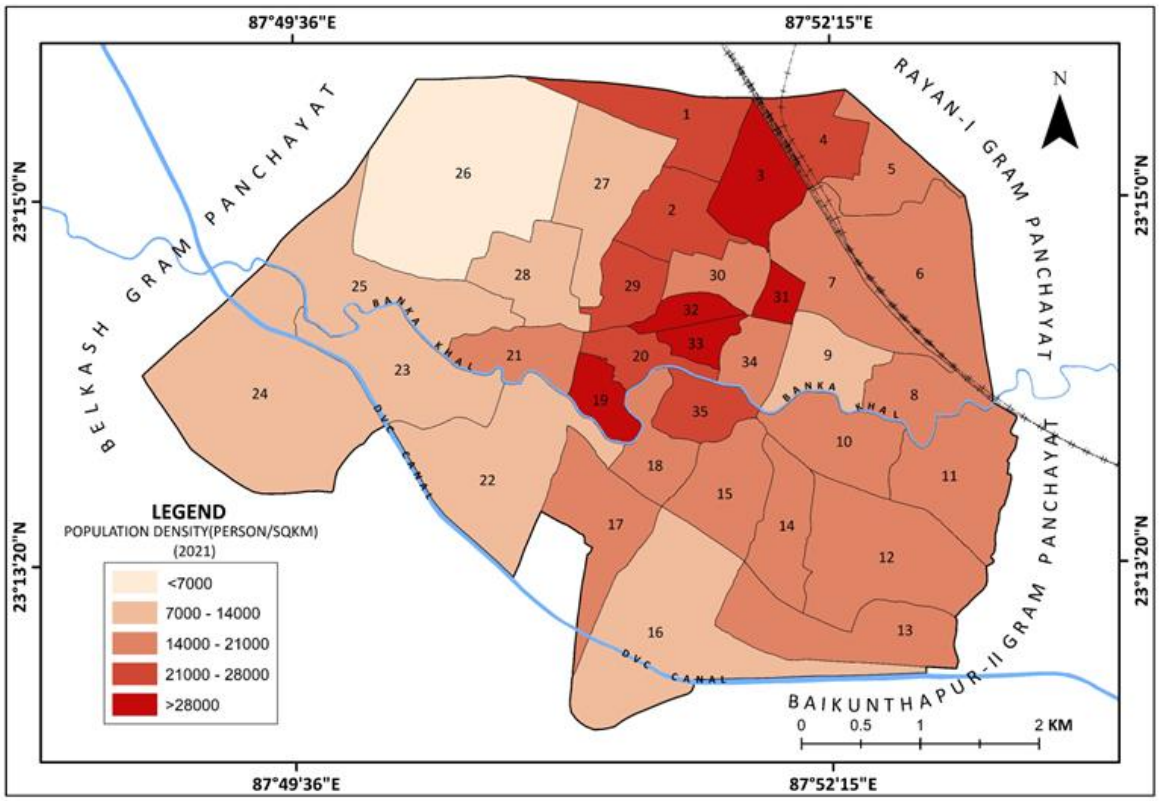


Figure No.5.1.18B: Population Density of Burdwan Municipality,2021

Source: Office of Burdwan Municipality,2020

2021 is prepared, it is seen that there is no such change in the values of the population density, but the wards have undergone a major shift in terms of classes. The wards like 22,23,24 which were at the class of below 7000 persons/sq km in the year of 2001 has emerged in the group of 14000-21000 persons/sq km and the wards like 19 has come upward in the section having population density of 28000 persons/sq km, thereby reassuring the path of urban expansion in the last decade of 2011-2021. **(Figure No. 5.1.4)**

List of References:

1. Das, Sriparna, and Bimal K. Kar. 2022. "Patterns of Urbanization and Urban Development in West Bengal." *Transactions of the Institute of Indian Geographers* 44(1):79–92.
2. Ganai, Biswajit, and Koyel Sarkar. 2018. "Distribution of High-Rise Building and Its

Relationship with Increase in Population of Burdwan Municipality , West Bengal." *International Journal of Computational Engineering Research* (12):17–28.

3. Guo, Min, and Shijun Wang. 2022. "Research on Urban Expansion and Population Density Change of an Urban Agglomeration in the Central-Southern Region of Liaoning Province, China." *Complexity* 2022. doi: 10.1155/2022/5327023.
4. Hassan, Zahra, Rabia Shabbir, Sheikh Saeed Ahmad, Amir Haider Malik, Neelam Aziz, Amna Butt, and Summra Erum. 2016. "Dynamics of Land Use and Land Cover Change (LULCC) Using Geospatial Techniques: A Case Study of Islamabad Pakistan." *SpringerPlus* 5(1). doi: 10.1186/s40064-016-2414-z.
5. Khayrullin, K. S., B. A. Yakovlev, and Y. M. Nenilina. 1993. "Impact of Urbanization on Fogs." *Izvestiya - Russkogo Geograficheskogo Obshchestva* 125(1):43–49.
6. Konrad, Christopher P. 2003. "Effects of Urban Development on Floods." *U.S. Geological Survey* d(November):1–4.
7. Laha, Mahamaya. 2019. "Centripetal Forces of Urbanization in Barddhaman Municipality, West Bengal." *Transactions of the Institute of Indian Geographers* 41(1):33–50.
8. Malik, Ida Bagus Ilham, Wayan Suparta, And Bart J. Dewancker. 2016. "A Study of Population Density in Developing Countries." 11(2):39–50. doi: 10.21163/GT.
9. Mohan, Manju, Subhan K. Pathan, Kolli Narendrareddy, Anurag Kandya, and Sucheta Pandey. 2011. "Dynamics of Urbanization and Its Impact on Land-Use/Land-Cover: A Case Study of Megacity Delhi." *Journal of Environmental Protection* 02(09):1274–83. doi: 10.4236/jep.2011.29147.
10. NRSC National Remote Sensing Centre. 2014. "Natural Resource Census - Land Use Land Cover Database." *Technical Report – Ver.1* 1–9.
11. Peng, Xizhe, Xiangming Chen, and Yuan Cheng. 2012. "Urbanization and Its Consequences." *Demography* II:37–39.
12. PRB. 2007. *Population Reference Bureau 2007 Annual Report*.
13. Sridhar, Kala S. 2019. "Urbanisation in India." *Socio-Economic Change and the Broad-Basing Process in India* 163–79. doi: 10.4324/9780429316418-11.
14. Sudhakar, S., and Kameshwar SVC Rao. 2010. "Land Use and Land Cover Analysis."

Remote Sensing Applications 21–48.

15. Tucci, Carlos E. M. 2018. “Urban Flood Managemnent.” *Cap-Net (APFM)* (1372):1–10. doi: 10.1201/9780203734582.
16. Woldesemayat, Eyasu Markos, and Paolo Vincenzo Genovese. 2021. “Monitoring Urban Expansion and Urban Green Spaces Change in Addis Ababa: Directional and Zonal Analysis Integrated with Landscape Expansion Index.” *Forests* 12(4):1–19. doi: 10.3390/f12040389.
17. Zhao, Yi, Kaiwen Zhong, Jianhui Xu, Caige Sun, and Yunpeng Wang. 2019. “Directional Analysis of Urban Expansion Based on Sub-Pixel and Regional Scale: A Case Study of Main Districts in Guangzhou, China.” *Chinese Geographical Science* 29(4):652–66. doi: 10.1007/s11769-019-1048-9.

5.2.0. Foreground:

Trash from human or animal activity that is thrown away because it is unwanted and useless is known as solid waste. It can be controlled in a number of ways and is generally produced by industrial, commercial, and residential activity within a certain area. Comprehensive solid waste disposal management is necessary to provide optimal environmental standards *(Pulp and Paper Technology 2023)*. There are several types of solid wastes, like municipal, medical, industrial electronic, etc. *(Pulp and Paper Technology 2023)*Removal and management of Municipal Solid Waste (MSW) comes under the conservancy services of a Municipal body or a Town by which a city gets itself garbage free *(Kumar and Goel 2009).* The towns and cities in developing nations are breeding grounds for solid waste creation due to immense population growth and haphazard urbanization. Uncollected rubbish piles in the streets, obstructed drainage channels, or deposited in watercourses constitute a significant public health risk, and unmanaged disposal of waste can harm water supplies and pose serious environmental health risks to people who live nearby. Solid waste and rubbish collection workers confront severe occupational health and safety risks *(Ferronato and Torretta 2019).*Every year, the world produces 2.01 billion tons of municipal solid garbage, at least 33 percent of which, to put it very conservatively, is not managed in a way that is safe for the environment. *(World Bank 2017)*. As a result of its rapid urbanization, robust economic growth, and higher rates of urban consumption, India ranks among the top 10 countries in the world in terms of MSW production. According to the Energy and Resources Institute (TERI), India produces about 62 million tons (MT) of garbage each year. *(International Trade Administration 2023).*The National Action Plan for Municipal Solid Waste Management Act 2000 and Solid Waste Management Rules,2016 (India) both emphasized the duty of an Urban local body to deal with the municipal solid waste management starting from its generation to its recycling processes *(Ministry of EnvironmentForest and Climate Change 2016).*

5.2.1. History of Solid Waste Management Services in Burdwan Town:

Burdwan town was a lovely residence under the reign of the *Jamindars* because it was clean, quiet, and pollution-free. The *Jamindars* took considerable care in making Burdwan a modern metropolis, notably Sir B.C. Mahatab and his son Sir U.C. Mahatab. The group of individuals created a sewage system using science. They built the first water purifying system in Lakurdi. Burdwan residents never experienced water logging during their existence in the town, at any location. But in today's life, people frequently had to walk through or wade through muddy water since the majority of the drains had clogged and the whole sewer system was in disrepair, even if it drizzles at some part of the Municipality.

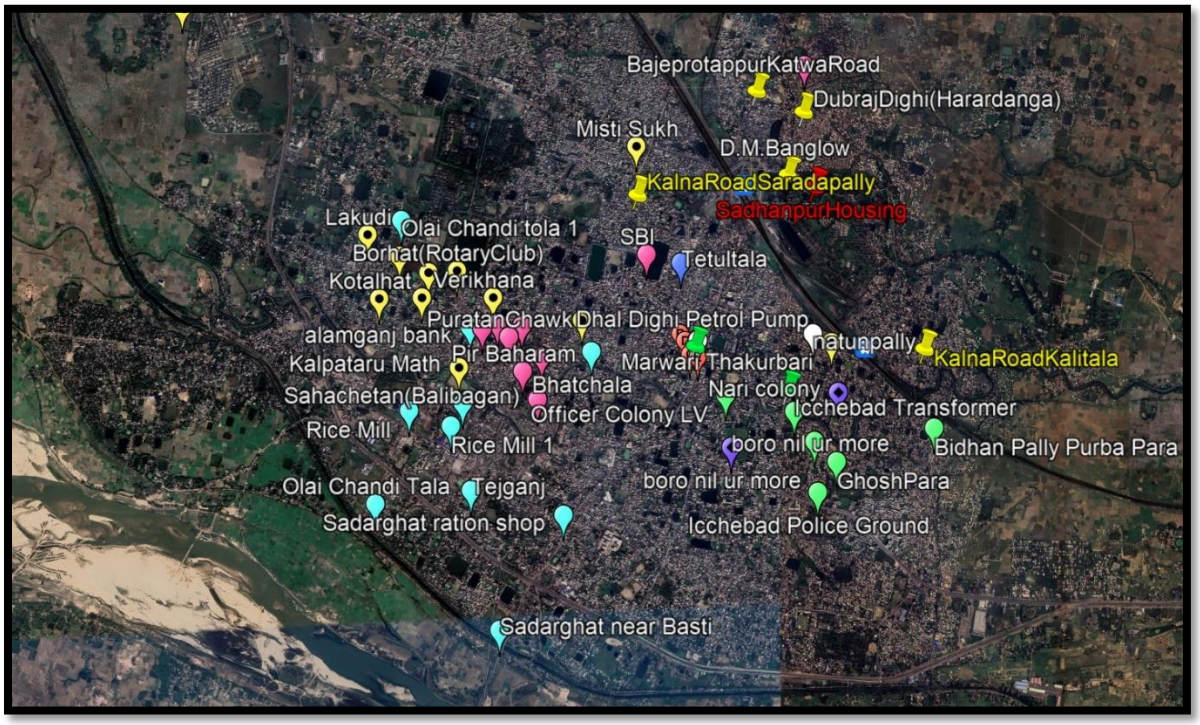
Burdwan Municipality didn't have a distinct conservatory department at the beginning or area since there weren't many people there and most of them lived near Raj palace in Burdwan. The locals were used to using traditional earthen pots, sal leaves, and other materials for sewage disposal, as we described at the beginning. Paper bags (or "Thonga"). Because the clay pots, sal leaves, and paper packages were biodegradable, there was no such thing as solid garbage. The early beginnings of the Burdwan Municipality, the majority of the rubbish is on the road or on the side. It also spreads bed odors and infections. The sanitation facilities were deplorable. In Burdwan, there were several unclean latrines. People used to carry feces and urine on their heads. Most of the roads are unpaved and narrow. The locals have a drinking water shortage. The current municipal board has taken the required steps to address the previous issue. Since 1981, the municipality has been carrying out several development projects to enhance Burdwan town. There were just a few metallic roadways nearby at the time. There were just a few metallic roads near Burdwan town at the time, and the remaining roads are non-metallic. There was a paucity of water and no electricity. People were not aware of the waste management system at the time. People's awareness grows throughout time, as does the growth of municipal conservation services. The number of technical service professionals, trucks, equipment, and infrastructure is growing. The labor union's responsibility, the State Government's grant for trash management, and the municipality's portion of waste management income all rose *(Mondal 2015).*

5.2.2 Present-Day Scenario of Solid Waste Management in Burdwan Town:

The majority of urban local authorities' municipal solid waste management services fall significantly short of expectations due to poor organizational frameworks and insufficient resources. There is demand in India for constructive changes to the municipal solid waste management system as a result of the Municipal Solid Waste (Management and Handling) Rules, 2000. *(Singh and Kalamdhad 2016).*In present days, the municipal officials of the Town seem quite hopeful regarding the progress they are making in the solid waste sector as per the Administrative Report of Burdwan Municipality,2021:

i. As per Municipal Solid waste Rule 2016, the Municipal administration has taken different measures for up gradation of Solid Waste Management work time to time.
ii. Collection of garbage from house to house has already been implemented and in the meantime 70 % of the wards have been covered under this system. This Municipality has got its own land where the collected garbage is transported and stored by dumping.
iii. The method of Segregation of biodegradable and non-bio-degradable waste at source level on and from 22/03/2020 as per order of State Govt. and the process is going on. Municipality is looking for a partner after the contract of TAAS agency got over, who has got experience and resourceful persons in disposal of Solid, and bio-medical Waste and can work using the Municipal manpower, vehicle etc. with reasonable charge to be paid by this Municipality. Medicare, a non-Govt. organization (approved by W.B.P.C.B.- West Bengal Pollution Control Board) tendering the service of collection and disposal of Biomedical waste in all Nursing Homes, hospital, and pathological centers within Burdwan Municipal area.
iv. A Mechanical Sweeper has since been introduced on a trial run for impactful and efficient management of solid waste in the Municipal Area.
v. Besides, measures are being adopted for handling and disposal of solid and bio-medical waste scientifically and hygienically as per guidelines of the Act and Rules. 3 no.s Movable compactor , 5 no.s stationary compactor with 1 no Hook Loader, 1 No Hydraulic Dumper, 2 no.s 2.2 cum fuel operated Tipper, 7 no.s Battery operated Tipper and 1nos Tractor with trolley are engaged for collection & disposal of solid waste through department directly.

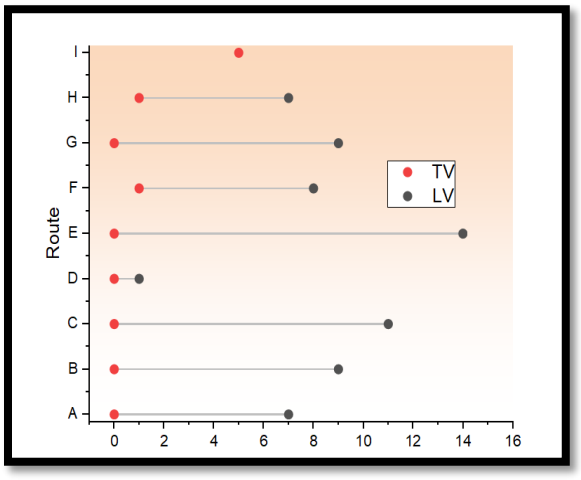
vi. Private agencies are also engaged for accumulation and disposal of solid waste from the rest part of the Municipal area daily*(Burdwan Municipallity 2021).*



Google Earth Image.5.2.1 Showing the Routes of Land Vat and Trolley Vat (Route- A B C, D E(dotted with black), F G H) (Retrieved in the month of April,2023)

The above image shows how extensively the Municipality tries to cater for the maximum area by dividing the whole area into some routes of collections, namely from route-A to route-H. The no of Land Vats (LV) and Trolley Vats (TV) those were engaged in these routes are shown in Figure **No. 5.2.1**. The Number of Land Vats are more in number and open to air. As far as the composition of municipal solid waste is concerned, it forms mainly due to the household wastes which included large number of plastics and other non-biodegradable stuffs. (**Figure No. 5.2.2**) The waste from the market areas are the second highest proportion followed by the waste from trade and commerce or industries. During the field study, the wastes from the vegetable markets were found to be left here and there open on the streets and a few drainages from the industries situated on the bank of River Banka happened to be linked in Banka, but most of them have become clogged due to unfiltered wastes. While the profile of the waste generation/day and consequent collection is analyzed, it might be inferred that at least 1/3rd of the waste, (1/2 in some wards) go

under the section of 'not collected' and dumped here and there.(**Figure No. 5.2.3)** It is also seen that the wards which generate the more waste than the average value, some of them are situated in the adjacent to the river Banka. This on the other hand, might signify that they have a greater chance of littering the river than the rest of the wards. Even the proportion of non-degradable wastes such as plastic, artificial polymer, electronic waste and the hazardous wastes like batteries, pesticides, motor oils released by these wards are much higher than its average value of all the wards. (**Table.5.2.1)** As the Municipal Officials informed that the ward no 28 has been put as a role model for waste collection and management since the very beginning due to the efficiency of its workers. Each word has 3-4 people engaged in the cleaning of drains and roads and 2 people for sweeping of the roads. The Municipality has taken its baby steps towards recycling the products through an agency recruited by KMDA (Kolkata Metropolitan Development Authority), namely TAAS for the project 'Legacy' which is currently on going in the wards for solid waste management as conversed with the chief-handling officer of Municipal Solid Waste of Burdwan Municipality.



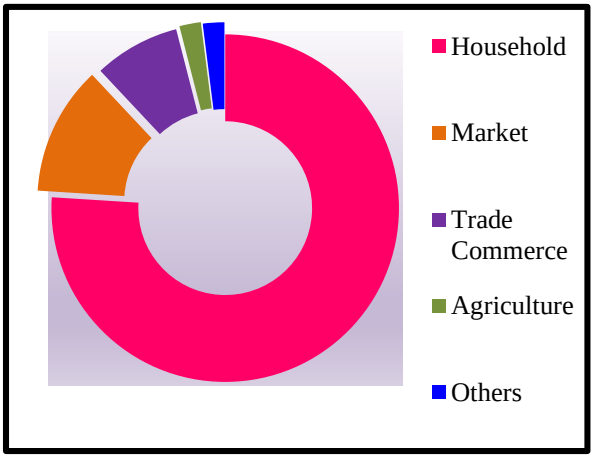


Figure No. 5.2.1 Number of Land Vats and Trolley Vats along with the Route Divisions (Left)

Figure No. 5.2.2 Composition of Solid Waste Management in the Burdwan Municipal Area (Right) *Source:* Burdwan Municipality,2021

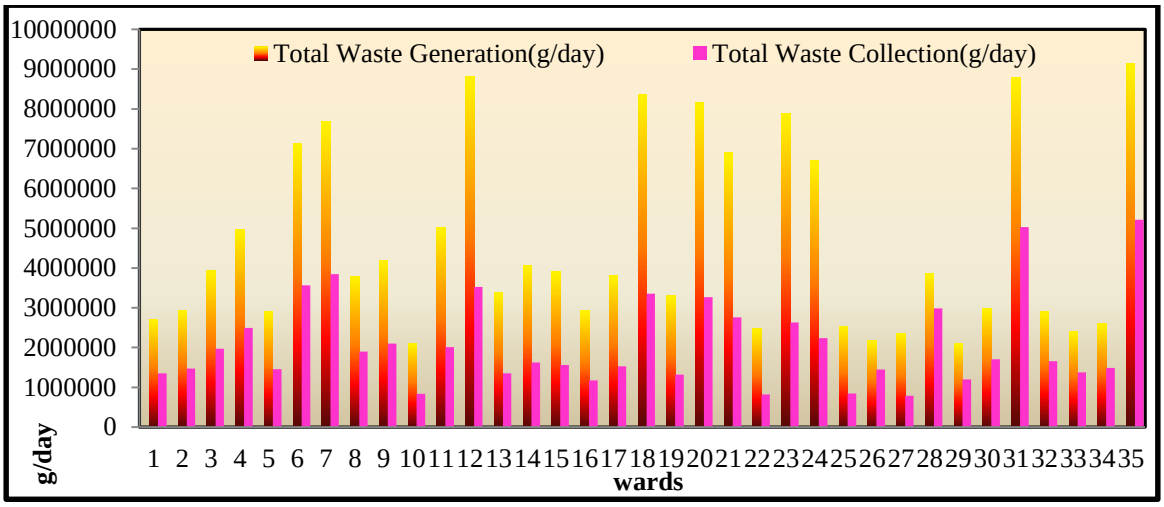


Figure No. 5.2.3 The Amount of Waste Generated and Collected, 2021

Source: Burdwan Municipality,2021

Table No.5.2.1: Proportions and Types of Municipal Solid Waste Generation, 2022

Ward No	Biodegradable waste (g/day)	Non-Biodegradable Waste(g/day)	Hazardous Waste(g/day)
1	2295000	378000	27000
2	2352000	529200	58800
3	3320000	602250	15450
4	4083600	846600	49800
5	2473500	407400	29100
6	5680000	1374506	68681
7	6145645	1483245	65565
8	3076840	667898	53260
9	3553256	608464	38000
10	1680000	404250	15000
11	4125767	882696	15750
12	7154399	1617000	37303
13	2722900	556200	98597
14	3373392	664480	30900
15	3184924	628151	92328
16	2378000	493000	66924

Ward No	Biodegradable waste (g/day)	Non-Biodegradable Waste(g/day)	Hazardous Waste(g/day)
17	3215577	569628	29000
18	6840540	1398288	140172
19	2805000	478000	16000
20	6657000	1466000	34100
21	5546000	1236100	117900
22	2025000	419100	24700
23	6232000	1593950	67550
24	5422605	1215329	63365
25	2082000	431800	25400
26	1768550	390600	10850
27	1888000	448400	23600
28	3212100	638550	19350
29	1680000	315000	105000
30	2290247	443712	251734
31	7078000	1320000	400985
32	2436000	319000	145000
33	1968000	408000	24000
34	2158000	364000	78000
35	7520300	1459100	151000
Total =	**130424142**	**27057897**	**2490164**
	118 T 280 kg 518 g	27 T 77 kg 997g	2 T490 kg 164 g
Average=	3726404.057	773082.7714	71147.54286

Source: Burdwan Municipality, 2023 (the highlighted values are above average values)

5.2.2.1. The Status of the Waste Compactors:

Following the decision of the National Green Tribunal in the year 2016, the usages of compactors as a mean to reduce the municipal solid waste in the cities have been restricted (*Bandyopadhyay 2022).* Burdwan Municipality has already got five compactor stations, which are used to reduce the size of waste material before dumping them into the landfill sites, thus helping in better processing of trash. The Stations are at Good Shade Road,

Powerhouse Para, Boro Nilpur Balidanga, Sarkhana Goli Municipal Store, Shyamlal near Student Health Home. To analyze the current working influence of the compactors, a network analysis is performed through ArcGIS with the option Location-allocation – which assists in determining the optimal impact area for the installed facilities generating the buffers of 1500m,2000m,2500m and 5000m based on the distance to boundary of one station. If the results are discussed, it seems that the peripheral wards of the Northwest and Western parts are getting deprived of this facility, rather some added pressures of performance are being given to the station of Boronilpur Balidanga. So, it can be said that from the very beginning of its installation, all the wards were not prioritized equally.

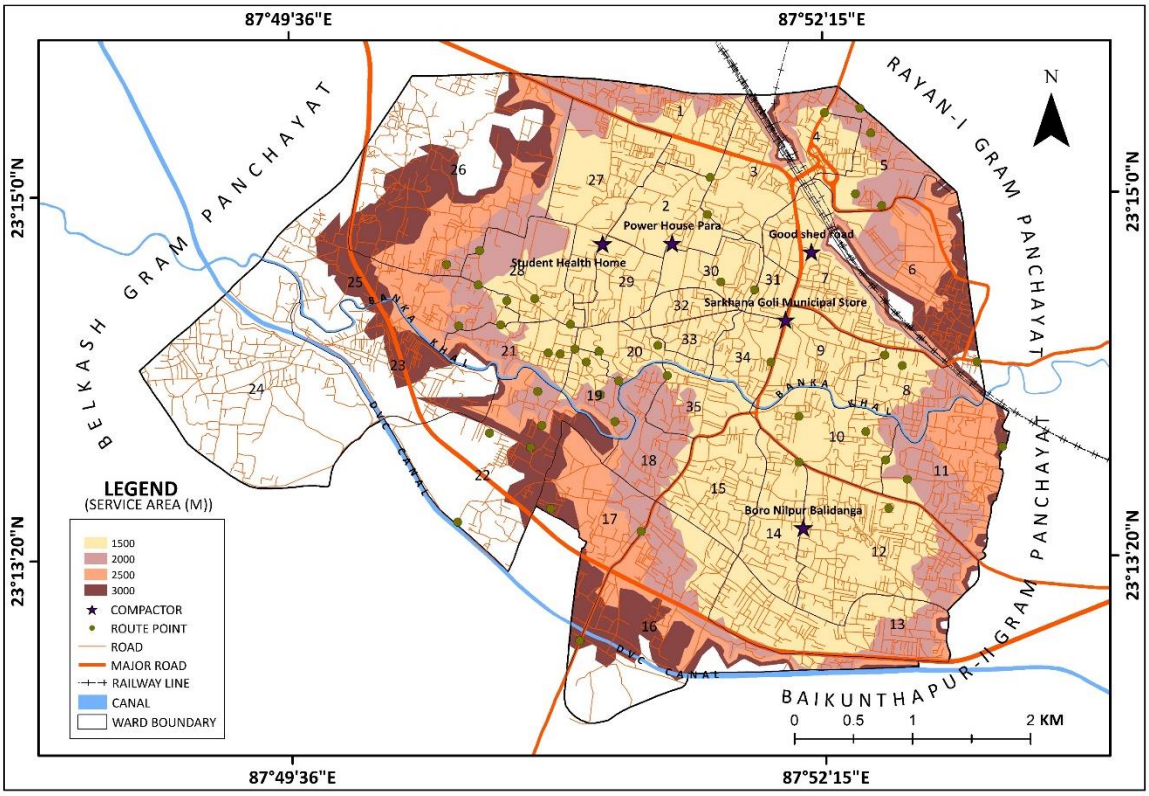


Figure No. 5.2.4 The Existing Compactors and their Service Areas of Specified Buffers (*Source*: Computed after the data provided by the Office of Burdwan Municipality,2022)

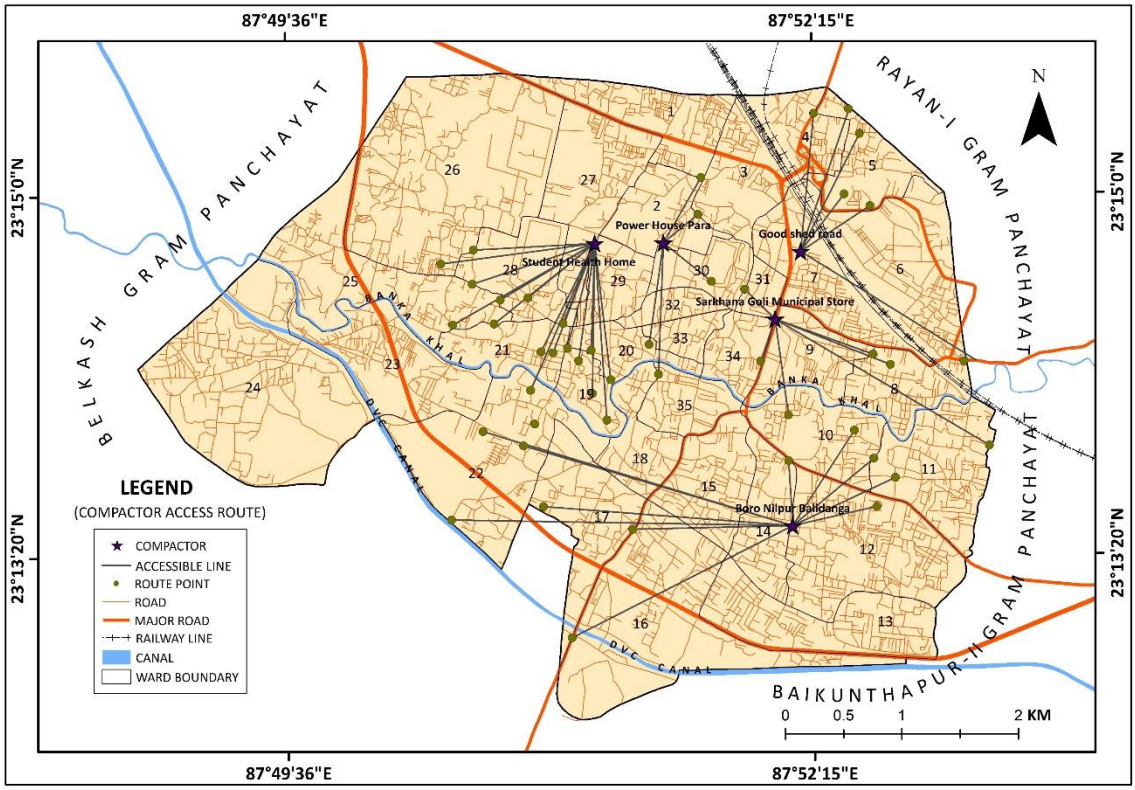


Figure No. 5.2.5 The Routes of Access towards the Compactors (*Source*: Computed after the data provided by the Office of Burdwan Municipality,2022)

Photo.5.2.1. The Solid Waste Compactor Station (Unit-2)

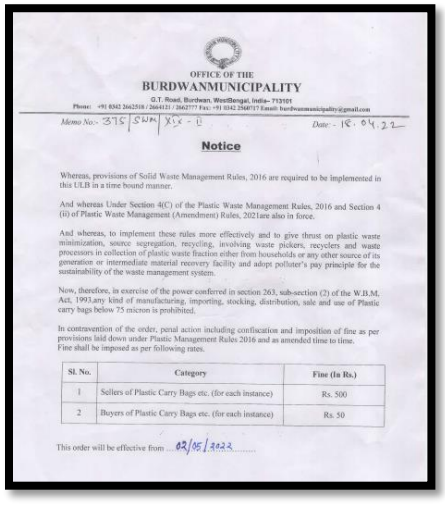
The Municipal Solid Waste Management System in Burdwan Municipality

Photo.5.2.2 The Drain Cleaning Workers

Photo.5.2.3 Segregation of Waste at Source

Photo.5.2.4 The Land-fill Site outside the Municipal Boundary (Left)

Photo 5.2.5. The Trolley Vat in Ward No.28 (The Model Ward for Waste Management)



OFFICE OF THE
BURDWANMUNICIPALITY

Notice

Whereas, provisions of Solid Waste Management Rules, 2016 are required to be implemented in this ULB in a time bound manner.

And whereas Under Section 4(C) of the Plastic Waste Management Rules, 2016 and Section 4 (ii) of Plastic Waste Management (Amendment) Rules, 2021are also in force.

And whereas, to implement these rules more effectively and to give thrust on plastic waste minimization, source segregation, recycling, involving waste pickers, recyclers and waste processors in collection of plastic waste fraction either from households or any other source of its generation or intermediate material recovery facility and adopt polluter's pay principle for the sustainability of the waste management system.

Now, therefore, in exercise of the power conferred in section 263, sub-section (2) of the W.B.M. Act, 1993,any kind of manufacturing, importing, stocking, distribution, sale and use of Plastic carry bags below 75 micron is prohibited.

In contravention of the order, penal action including confiscation and imposition of fine as per provisions laid down under Plastic Management Rules 2016 and as amended time to time. Fine shall be imposed as per following rates.

Sl. No.	Category	Fine (In Rs.)
1	Sellers of Plastic Carry Bags etc. (for each instance)	Rs. 500
2	Buyers of Plastic Carry Bags etc. (for each instance)	Rs. 50

This order will be effective from 02/05/2022

Photo.5.2.6. The Awareness Campaign for segregating Waste at Sources (Left); Photo 5.2.7. The Notice on Plastic-Ban issued in March,2022 (*Source*: Field Survey,2022-23)

Unscientific solid waste management not only poses problems to cities' infrastructure and amenities, but causes air pollution, water, and soil contamination. Open and unsanitary landfills contribute to contamination of drinking water and can cause infection and transmit diseases. Solid garbage (such as plastic, packages, and aluminum cans) clogs most open surface drains. Therefore, regular flow is severely hindered. In the monsoon season, this stagnant liquid waste causes foul odors, pathogens, and urban floods.*(Dutta and Mistri* 2016). There is a huge discrepancy found between the paper-policies and the ground scenario and a complete absence of monitoring system from the authorities.

List of References:

1. Bandyopadhyay, Krishnendu. 2022. "Kolkata: Segregate Waste at Source, Orders National Green Tribunal." *The Times of India*.
2. Burdwan Municipallity. 2021. *Adminstrative Report of Burdwan Municipality*.
3. Dutta, Shyamal, and Biswaranjan Mistri. 2016. "Solid Waste Management and Sewerage Condition in Barddhaman Municipal Area , West Bengal- An Environmental Overview." (January 2016):1–16.
4. Ferronato, Navarro, and Vincenzo Torretta. 2019. "Waste Mismanagement in Developing Countries: A Review of Global Issues." *International Journal of Environmental Research and Public Health* 16(6). doi: 10.3390/ijerph16061060.
5. International Trade Administration. 2023. "India Solid Waste Management." *Market Intelligence*. Retrieved (https://www.trade.gov/market-intelligence/india-solid-waste-management).
6. Kumar, K. Naresh, and Sudha Goel. 2009. "Characterization of Municipal Solid Waste (MSW) and a Proposed Management Plan for Kharagpur, West Bengal, India." *Resources, Conservation and Recycling* 53(3):166–74. doi: https://doi.org/10.1016/j.resconrec.2008.11.004.
7. Ministry of Environment Forest and Climate Change. 2016. "Solid Waste Management Rules 2016." *MOEF, Government of India* 787–90.
8. Mondal, Biswajit. 2015. "Problems Of Accumulation And Disposal Of Solid Wastes And Their Management In Burdwan Municipal Area, West Bengal" Thesis Submitted For Ph. D Degree In Geography Visva-Bharati 2015." Visva Bharti University.

9. Pulp and Paper Technology. 2023. “Types of Solid Waste Disposal and Management.” Retrieved (https://www.pulpandpaper-technology.com/articles/types-of-solid-waste-disposal-and-management).
10. Singh, Waikhom Roshan, and Ajay S. Kalamdhad. 2016. “Role of Urban Local Bodies and Opportunities in Municipal Solid Waste Management BT - Urban Hydrology, Watershed Management and Socio-Economic Aspects.” Pp. 341–51 in, edited by A. K. Sarma, V. P. Singh, S. A. Kartha, and R. K. Bhattacharjya. Cham: Springer International Publishing.
11. World Bank. 2017. “What A Waste 2.0 A Global Snapshot Of Solid Waste Management To 2050.” *Understanding Poverty*. Retrieved (https://datatopics.worldbank.org/what-a-waste/404.html).

***5.3.0. Foreground*:**

The proliferation of paved and impervious surfaces in the cities breaks the natural ecosystem by restricting the rain from being absorbed by the soil and thereby increasing flood dangers, particularly in low-lying regions. Urban water management systems, especially in Indian cities, encounter four problems- A) Generally built on traditional engineering procedures that try to evacuate the runoff as rapidly as possible rather than storing and reusing it. B) Many of the old cities do not even have the provision of building urban stormwater drainage lines separately. C) The drainage system is very poorly managed. D) Drainage system design frequently relies on past precipitation figures for a specific period, without considering potential variations in precipitation extremes for the specified return periods *(Singh 2022).* Floods in an urban area caused by the dearth of natural or man-made drainage capacity have become a key issue in urban water management. To achieve better adaptations, it is vital to review the operation of drainage systems on a regular basis in a changing environment and analyse the risk for urban floods under various scenarios.. Rivers, streams, surface and subsurface drains, and manholes are all part of urban drainage. Speaking categorically, there are two types of drainage in an urban area, namely artificial and natural drainage. There are some natural drainages like wetlands, lakes, and rivers found in and around a city where the extra rainwater or runoff usually goes. However, man-made or artificial drainage is needed because natural drainage is frequently insufficient. In Man-made drainage, there are two types of divisions- surface drains and sub-surface drainages. The process of eliminating extra water from the land's surface is known as surface drainage and draining water from the root zone is known as subsurface drainage *(Brouwer, Goffeau, and Heibloem 1985).*

5.3.1. Urban Drainage (Natural):

In Burdwan Municipality, there are a few small rivulets that seem to exist, such as the Banka River, Sapjala, Bhalluka, and Gangur. **(Figure No.5.3.1)** [But only Banka River is prominent now, Sapjala could be traced back from the Toposheet No.73 M/15 and 73 M/16 among all others] These rivulets remain as paleo-channels within the municipality

boundary and reappear as prominent channels after the railway station *(Ghosh and Maji 2011).* Since ancient times, Burdwan town's urban effluents have been carried by the Banka and Sapjala rivers. Damodar River had changed its course a few times in the direction of the left or North bank during monsoonal flooding. Those streams and marshes remain as relics of spill routes and floodways *(Ghosh and Maji 2011).*The town of Burdwan has distinct topography about the Damodar River; this is due to the ground's slope (West- East) which restricts the surface runoff from meeting the Damodar River *(Ghosh 2020).* Hence the majority of surface run-off meets Banka Rivers and open surface drains, with ponds capturing the residual amount and marshes.

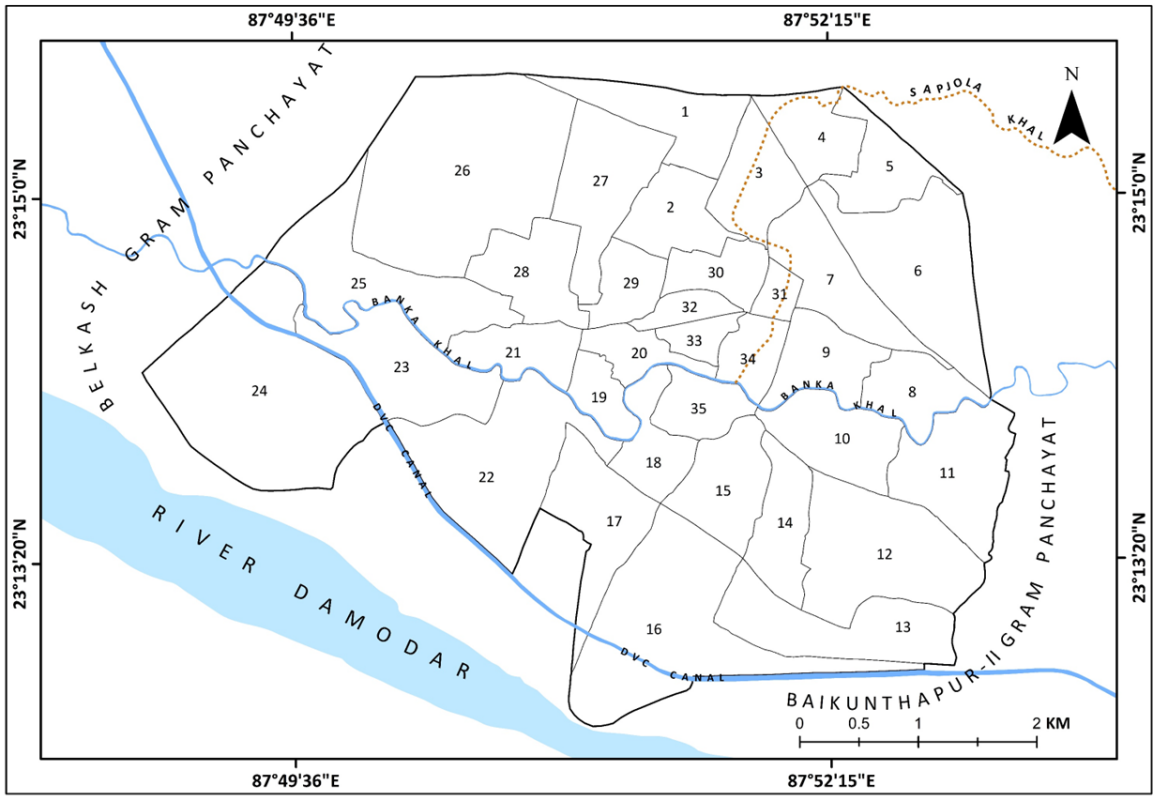


Figure No.5.3.1. The Canal, Rivers in and around Burdwan Municipality

Source: The map was combined from the base map is provided by the Burdwan Municipality,2022, and Toposheet No.73 M/15 and 73 M/16

5.3.2. Urban Drainage (Man-made):

According to tare available data from the Municipality it is found that there are four types of urban surface drainages available in the study area which are mostly open in nature - namely, High Drain, Boro Pucca Drain, Choto Pucca Drain and Kutcha Drain which in generic terms is known as High Drain, Large Concertized Drain, Small Concretized Drain, Earthen Drains respectively. The ward-wise distribution of these varieties of open surface drains are shown in **Figure No. 5.3.2**. The sub-surface drainage is found to be completely absent in the Municipality.

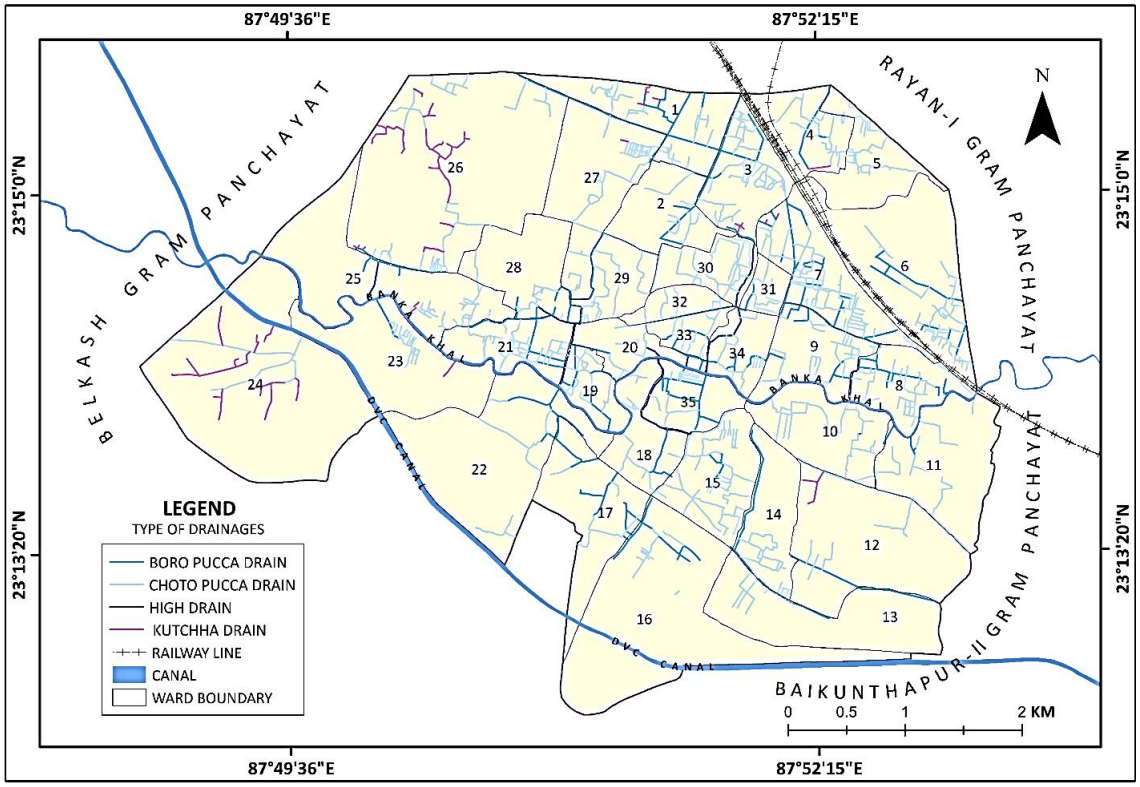


Figure No.5.3.2. The Variation of the Urban Open Surface Drainage in Burdwan Municipality (*Source*: The base map is provided by the Burdwan Municipality,2022.)

As far as the maps and the field observations are concerned, it is seen that only the wards which are on the either banks of the River Banka or in the central part of the Municipality like the Wards No. 20,32,33,34 have some high drain lines linked to the river Banka, but few of them are also found to have lost their connection to river or have become so much silted that they cannot pass the water trouble-free. **(Figure No: 5.3.2)**

Most of the wards are dominated by choto pucca drains (small, concertized drains) while the peripheral wards towards the Western boundary of the Municipality have some kutcha drains (earthen drains) which are curved out straight from the soil and with no concretization at all. But kutcha drains are also rare to find. The boro pucca drains (large, concertized drains) are quite less in number in terms of drainage hierarchy but present in all the wards mostly. **(Figure No: 5.3.3)** As far as the density of the different type of drainages count, the highest concentration of boro pucca drain and choto pucca drain are concentrated in the wards of most Eastern boundaries like Ward no 3(along the Burdwan railways station), 11,13, the kutcha drains in the Western wards like 25 and the wards 20,32,33 have the highest density of high drains. **(Figure No: 5.3.4.)**

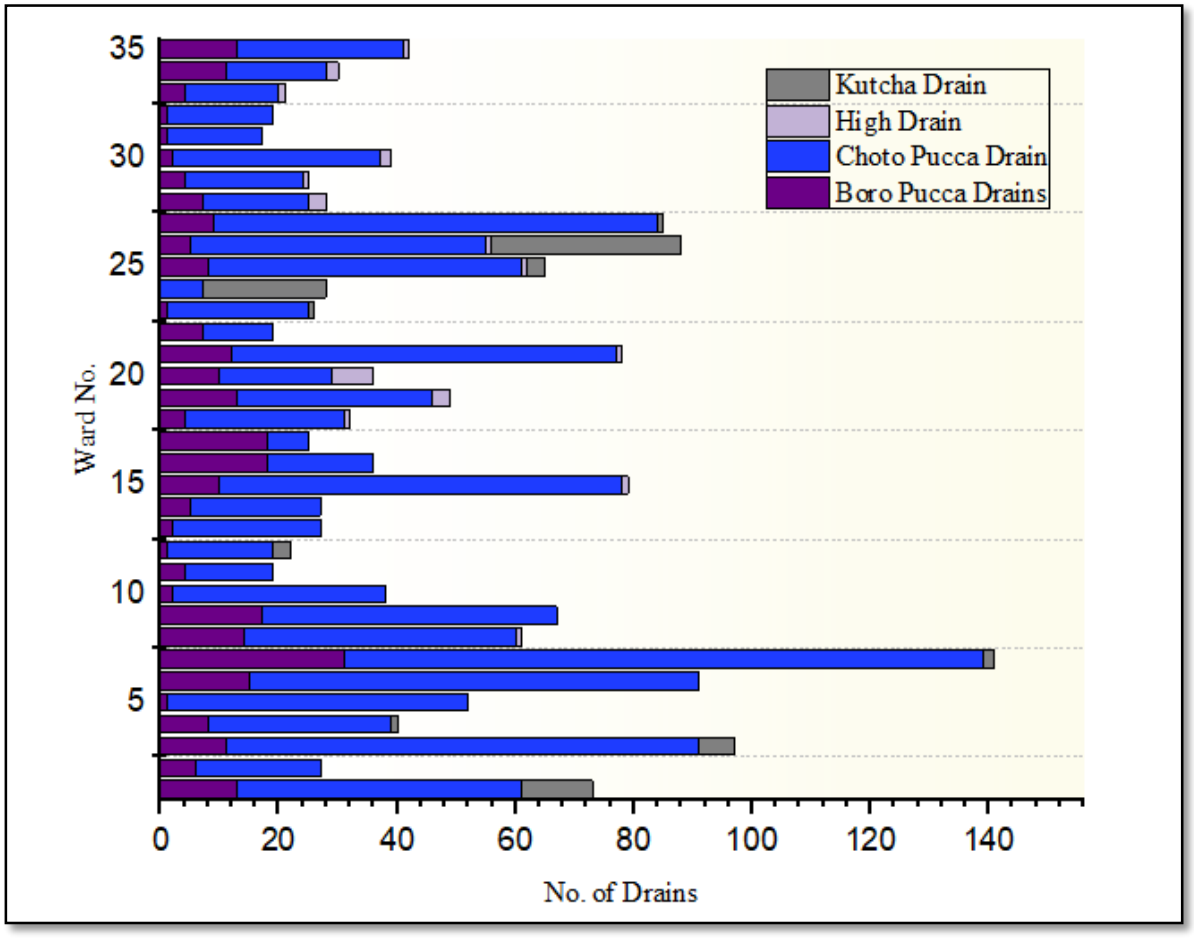


Figure No: 5.3.3. Ward-wise Distribution of The Urban Open Surface Drains (in number)

Source: Burdwan Municipality,2022

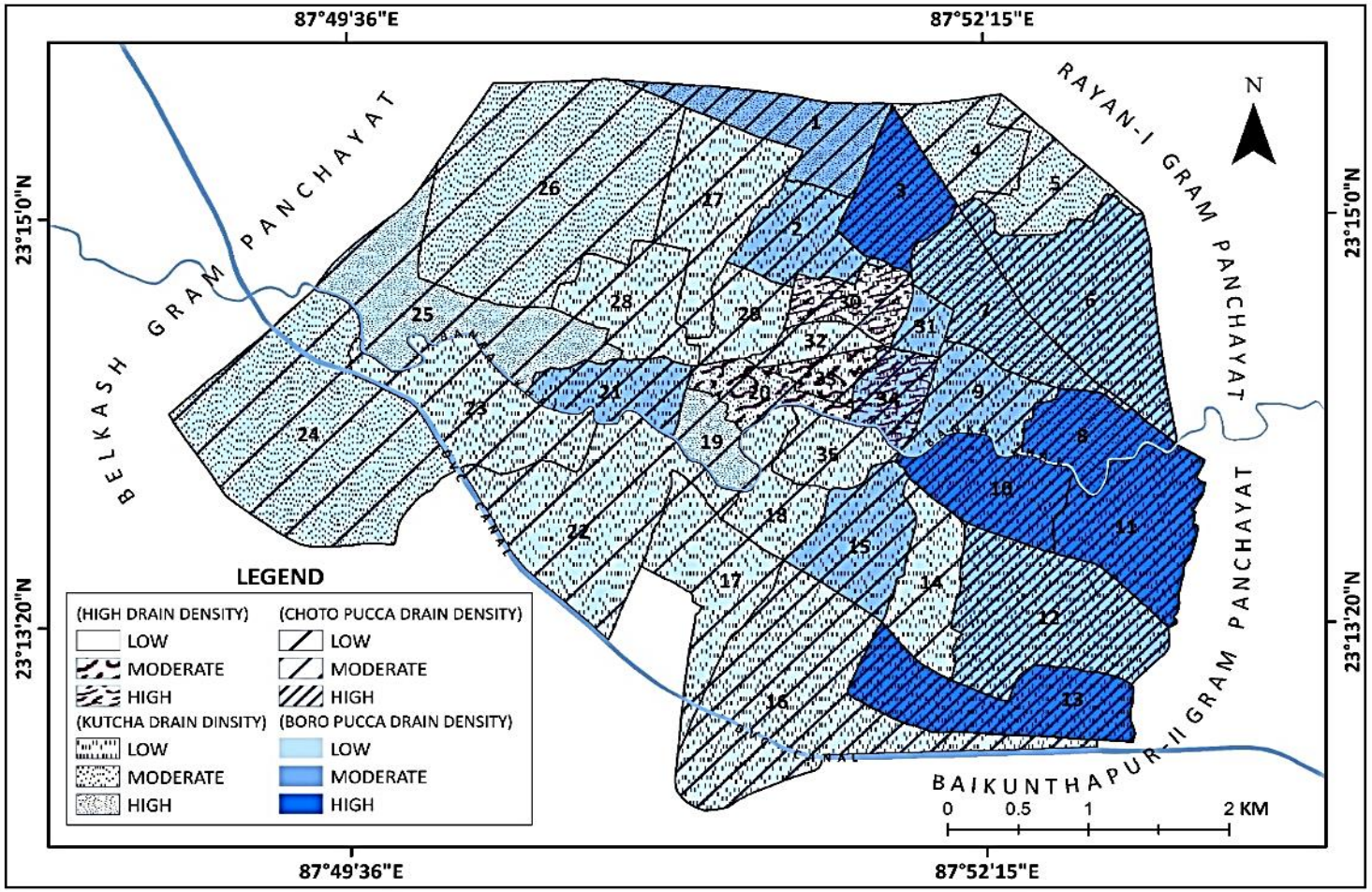


Figure No: 5.3.4. Ward-Wise Density of the Variety of Urban Open Surface Drains *Source*: Calculated from the data provided by Burdwan Municipality,2022

5.3.2.1. Drawing Cross-Sectional Profile of Various Types of Drainage:

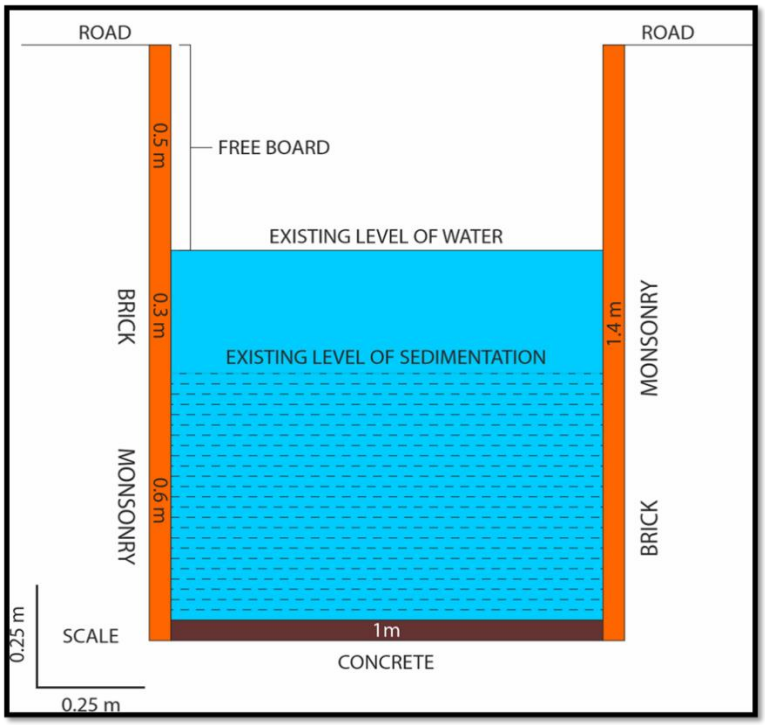


Figure No. 5.3.5. Cross-Section of a High-Drain

Photo: 5.3.2. The Long Drainage Line

Photo: 5.3.3. Dump of Waste in the Same Drain Adjacent to the Ground of *Ichlabad* Club, Ward No.11

Source: For Figure No. F5.3.5 and Photo P5.3.2 and P5.3.3: Primary Survey, July,2023

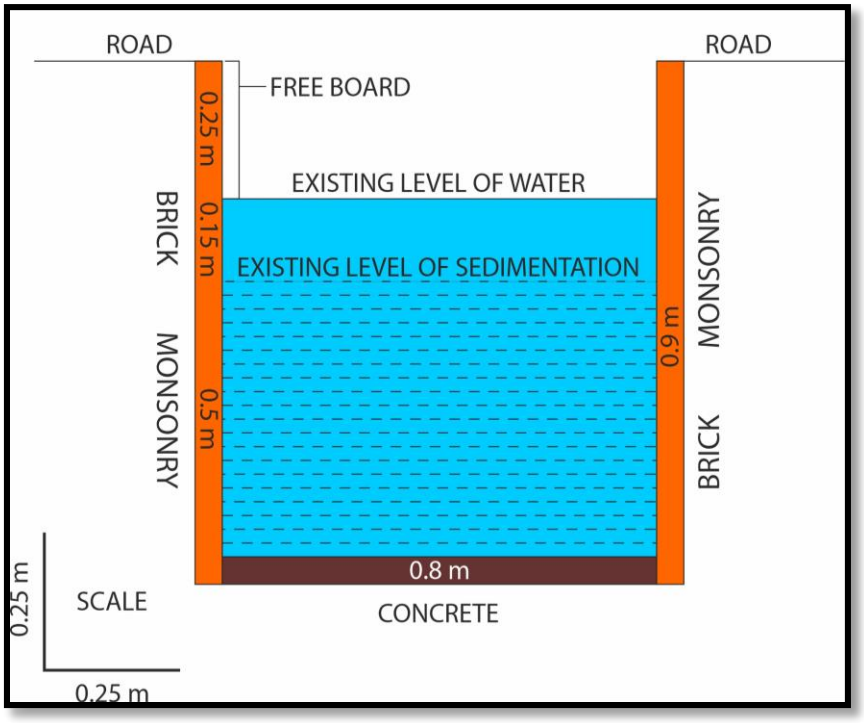


Figure No. 5.3.6. Cross Section of a Boro Pucca Drain (Large Concretized Drain)

Photo: 5.3.4. (Left) Drain adjacent to the ground at *Kali Bazar Para* Ward No.9

Photo: 5.3.5. (Right)Condition (Trash)of Boro Pucca Drain at *Bidhanpalli* Ward No.11

Source: For Figure No.5.3.7 and Photo 5.3.4 and 5.3.5: Primary Survey, July,2023

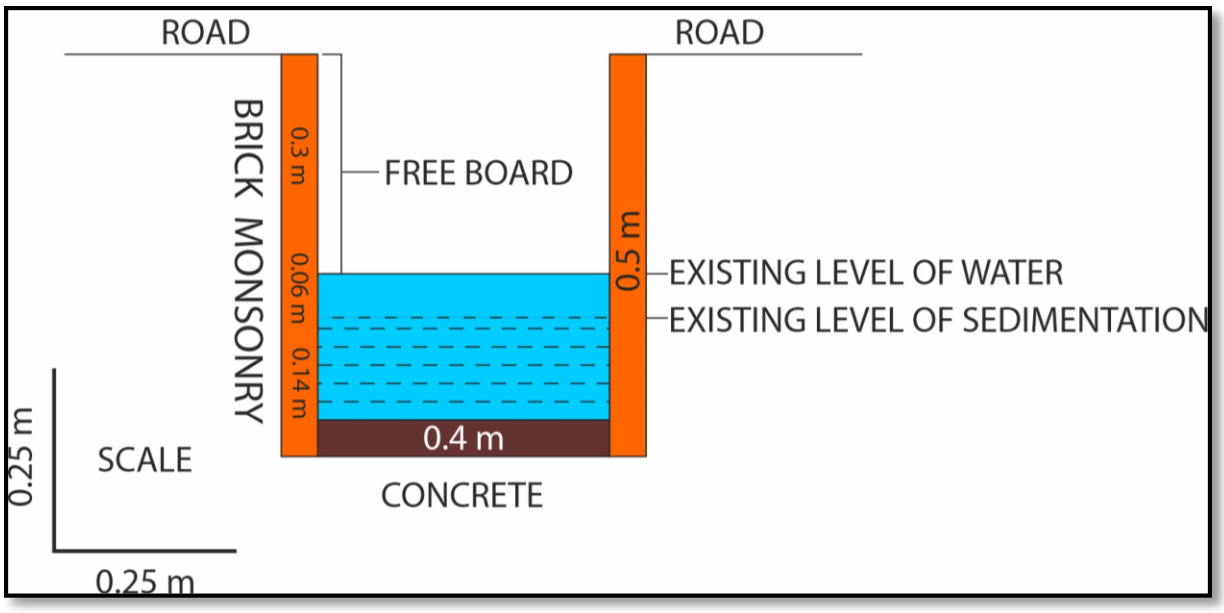


Figure No: 5.3.7. Cross Section of a Choto Pucca Drain (Small Concretized Drain)

Photo: 5.3.6. Drain adjacent to the *Adi Kali Bari* adjacent to *Kather Pool*, Ward No.8
Source: For Figure No.5.3.8 and Photo 5.3.6: Primary Survey, July,2023

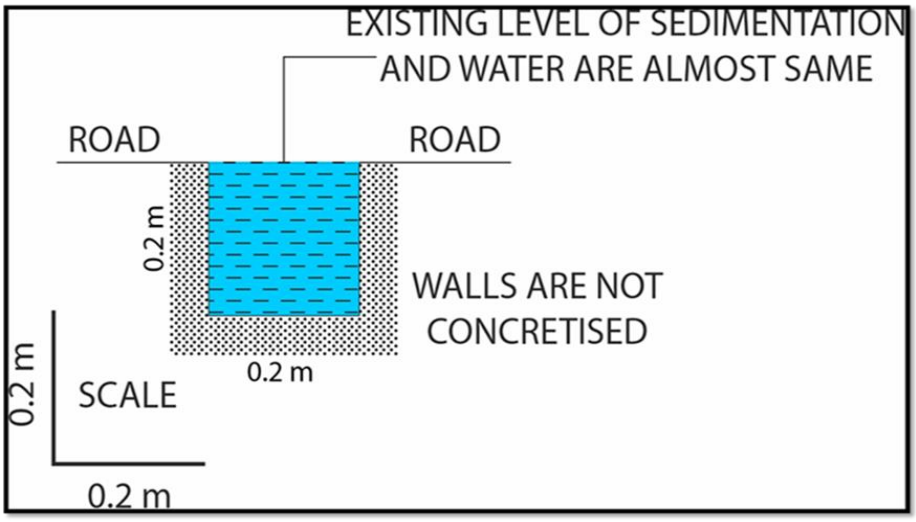


Figure No: 5.3.8. Cross Section of a Kutcha Drain (Earthen Drain)

Photo: 5.3.7. Drain adjacent to *Ananda Pally Road* (Pond) Ward No.10

The broken Infrastructure of a Choto Pucca Drain Turned into a Kutcha Drain

Source: For Figure No. 5.3.8 and Photo 5.3.7: Primary Survey, July,2023

5.3.2.2. Analysis of the Cross-Sectional Profile of the Various Types of Drainage-

Conditions pertaining to the drainage network have a significant impact on performance, particularly those elements that influence the drainage channel's capacity. Aspects like the sedimentation rate, building material and construction process that complement drainage channels also influence the drainage channel's dimensions. The pace at which sedimentation occurs in the channel decreases its potential, which lowers its serviceability. Additionally, if the channel is not equipped with sufficient measures to remove trash, this could further reduce the channel's drainage capacity and clogs the drainage lines. Following the study of Agrianto, Hadiani, and Purwana 2016, two kinds of method have been implemented to understand the condition (Physical), sedimentation and functionability of the urban drainage system.- a) Observational b)Empirical *(Agrianto, Hadiani, and Purwana 2016).* The observational assessment of the drainage is done based on the physical appearance and built structure. (**Table No: 5.3.2)**

Table No: 5.3.1. Overall Conditions of Drainage by Observational Analysis

	Built of Infrastructure	**Water Velocity**	**Amount of Trash**	**Functionality**
High Drain	Good	Moderate	Huge on the sidewalls and floating	Functioning
Boro Pucca Drain	Good	Moderate	Fair amount	Not properly in every place
Choto Pucca Drain	Good	Very low almost static	considerate	Not properly functioning in every place
Kutcha Drain	Very poor	No flow	Full of silt	No

Source: Primary Survey, July,2023

With the aid of mapping software ArcGIS 10.4, the total length of each type of drainage was easily calculated and after generating buffer the width has been computed. The information regarding depth of the drainage lines was averaged out from the data acquired

from the field study. To generate the water volume, the formula of [Length (converted into meter)* Depth * Width] is applied *(Minke, Westbrook, and Van Der Kamp 2010).* From **Table 5.3.1** it is clearly evident that the highest length of the drainage line is consumed by choto pucca drains but the highest amount of water volume is seen to be passed through the channels of boro pucca drain due to its width and lesser amount of trash into it in comparison with the other type of drains. The higher width-depth ratio indicates shallowness of the drainage channels.

Table 5.3.2. Fundamental Characteristics of Drainage

SL No	Type of Drains	Length (Total Length in Km)	Width (in m)	Depth (in m)	Water Volume (cubic m)	Width-Depth Ratio
1	High Drain	4.31	1	1.4	6039.6	.714
2	Boro Pucca Drain	35.64	.8	.91	25663.7	.879
3	Choto Pucca Drain	95.42	.4	.51	19084.4	.784
4	Kutcha Drain	7.29	.2	.2-.25	291.88	.8

Source: Calculated from the data provided by the Burdwan Municipality,2022

5.3.2.3. Analysis of Sedimentation Aspect Ratio:

Taking instance of **High Drain**, following the method mentioned in Chapter-4 (Methodology), The calculation shows

Cross Sectional Area =1 m X 1.4 m= 1.4 m^2

B=1 m, H= 0.9 m, A_{sed}=0.6m, bH_{sed}=1X0.6m= 0.6m

Sedimentation rate (Sed)= (100- A_{sed}/A*100)

= (100- .6m^2 / 1.4 m^2*100) %

= (100-43) % or 57%

Table No.5.3.3. Condition of the Drainages Based on Standard Sedimentation Rate

Index	Sedimentation rate (%)	Functionality	Condition
1	76-100	76-100	Good
2	51-75	51-75	Enough
3	26-50	26-50	Mildly Damaged
4	1-25	1-25	Heavy Damage
5	0(while sedimentation covers the whole cross section)	0	Dysfunction

Source:*(Agrianto et al. 2016)*

Table No.5.3.4. Assessment of the Functionability of the Drainages

	High Drain	**Boro Pucca Drain**	**Choto Pucca Drain**	**Kuccha Drain**
Sedimentation rate	57	45	76	0
Condition	**Enough**	**Mildly damaged**	**Good**	**Dysfunction**

Source: Calculated from the Primary Survey, July,2023

From **Table: 5.3.4** it was quite visible that except the kutcha drain (earthen one) which are least in numbers, rest of the types are performing quite good. **Still the question remains why did the flood occur?** The probable reason for this situation is that the drains which are supposed to drain larger amounts of water, they are less in number or completely absent in the hierarchical drainage layout and also they are not ubiquitously distributed, like the presence of high drains. Though the overall assessment of performance appeared to be moderately satisfactory but the areas which are succeptible to flooding, the urban drainage condition is overly silted, which is being shown in the photo no. from **5.3.7 to 5.3.24.**

5.3.2.3. Calculation of Flow and Discharge of each type of Drainage:

Taking instance of **High Drain**,

Q= V*A, which means Q= V*B (width of the base). Y (depth of the water)

$V= (R^{2/3} \sqrt{S})/n$ and $R=A/P$

So, calculating A and P first,

$A= B. Y=1m*0.9m= 0.9m^2$;

$P= B+2Y= 1m+(0.9m*2) =2.8m$,

$R=0.9m^2/2.8m=0.321m$

$V= (0.321^{2/3} \sqrt{1/200})/0.015 = (0.0247*.0707)/0.015 = 2.209m/s$; $Q= 2.209m/s*0.9m^2 =2.455\ m^3/s$

Table No.5.3.5 Potential Flow and Discharge of each type of drains by Manning's Equation

Type of Drains	V (Velocity in m/s)	Q (Discharge in m^3/s)
High Drain	2.209	2.455
Large concretized drains	2.059	3.961
Small concretized drains	1.015	12.693
Earthen Drain	0.464	11.624

Source: Calculated from the data retrieved through field survey, 2023

Table No.5.3.5 shows the potential velocity and the discharge of each type of drain. The Velocity decreases as we go towards the lower section of the drainage hierarchy. The high drain has got the highest velocity whereas the earthen drain shows the lEast. The small concretized drains, which are also the highest in number in the municipality, have the highest amount of discharge. The earthen drain which are lEast in numbers has also a potentiality of higher figure of discharge but as these drain are tagged as the dysfunctional one with zero velocity (in reality), it does not yield any help to the flooding situation. That is why the actual or the observed velocity and discharge is also calculated**.(Table No.5.3.5)**

Table: 5.3.6. Actual Flow and Discharge of each type of drains by Manning's Equation

Type of Drains	V (Velocity in m/s)	Q (Discharge in m^3/s)
High Drain	1.698	1.945
Large concretized drains	1.712	2.567
Small concretized drains	0.954	9.325
Earthen Drain	0.265	8.625

Source: Calculated from the data retrieved through field survey, 2023

Situation of Drainage at Ashram Para, Ward No 11

Photo.5.3.8. No Drainage on either side of the road

Photo.5.3.9. Chemical paint mixing in the drain

Photo.5.3.10 and 11. Dump of Waste on the bank of River Banka

No Open Surface Drains at Various Places in Burdwan Municipal Area

Photo.5.3.12. B L Hati Road Ward No 34

Photo.5.3.13. Pal Para Ward No 12

Photo.5.3.14. Chotonilpur Ward No.14

Situation of Drainage at Becharhat, Ward No. 13

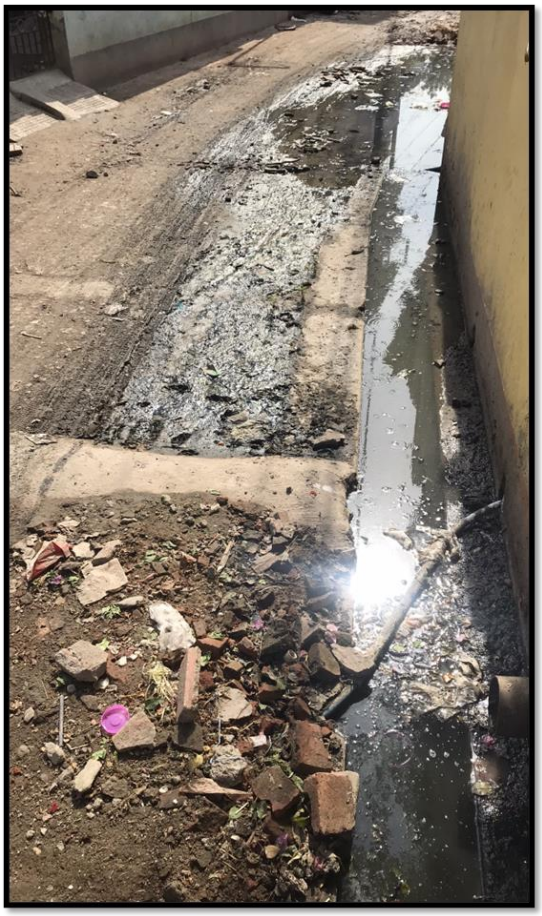


Photo.5.3.15 and 16 where the roads level off the drainages

Photo.5.2.17. Waste Dumps alongside the drainage

Source: Photo.5.3.8-5.3.11: Primary Survey, 2022-23

Photo 5.3.12-5.2.14: Primary Survey, 2022-23

Photo 5.3.15-17: Primary Survey, 2022-23

Condition of Drainages at different parts of the Town

Photo.5.3.18. Condition of High Drain near Kalna Gate Ward No.12

Photo.5.3.19. Condition of *Nala (local canal) near Bajepratappur adjacent to Municipality* Photo.5.3.20. Waste dump scenario almost everywhere in the Municipality

Photo.5.3.21.Condition of a High Drain near Sudarshan Setu, Ward No.25

Photo.5.3.22 A and B Construction of High Drain at Bypass Road and Condition of Adjacent Drains adjacent to Ward No. 13

Photo. 5.3.23 and 24 The Daily Condition at Kalna Gate and the nearby dewatering pump, Ward No 12

Source: Primary Survey, 2022-23

5.3.3. Urban Water Bodies:

In India, urban water bodies have been a victim of unplanned urbanisation, which has resulted in a number of problems including as encroachment, sewage disposal, groundwater decrease leading to a drop in water level, unplanned tourism, and a lack of administrative framework. Lakes and wetlands play an important part in the urban ecosystem. They serve vital environmental, social, and economic reasons, such as providing drinking water, recharging groundwater, sustaining biodiversity, and creating livelihoods. *(DTE Staff* 2018). The open spaces that have vanished to make place for concrete constructions are predominantly water bodies that behave as sponges, soaking up rainwater. As the population grew, so did waste, and the cities' aquatic bodies became dumping grounds for municipal solid waste*(Samuel 2016)* .

A body of water is an important component of the urban landscape. Rainwater harvesting structures such as tanks and ponds are built to collect rainwater for local consumption. These bodies of water perform a variety of environmental purposes, including flood management and soil erosion control, as well as irrigation, drinking water supply, and groundwater replenishment. Anthropogenic activities have recently resulted in the loss of a huge number of water bodies, and the remaining water bodies are under threat of deterioration.*(Neelakantan and Ramakrishnan 2017)* .

On the other hand, in the Municipality area, urban drainage systems tend to perform poorly, mostly as a result increased population and haphazard urbanization. Solid garbage (such as plastic, packages, and aluminum cans) clogs most open surface drains. Therefore, regular flow is severely hindered. In the monsoon season, this stagnant liquid waste causes foul odors, pathogens, and urban floods *(Dutta and Mistri 2016).*

5.3.3.1 The Current Scenario of the Water Bodies:

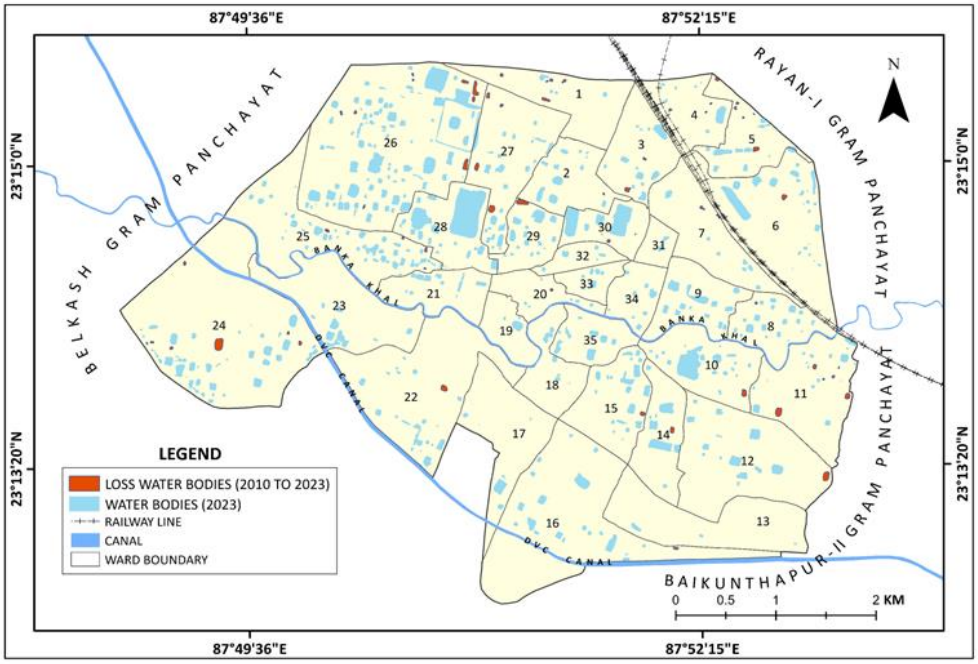


Figure No. 5.3.9. The Existing Water Bodies in Burdwan Municipality (2023) and the Lost Water Bodies since 2010 ***(****Source*: Google Earth Pro, September, 2023)

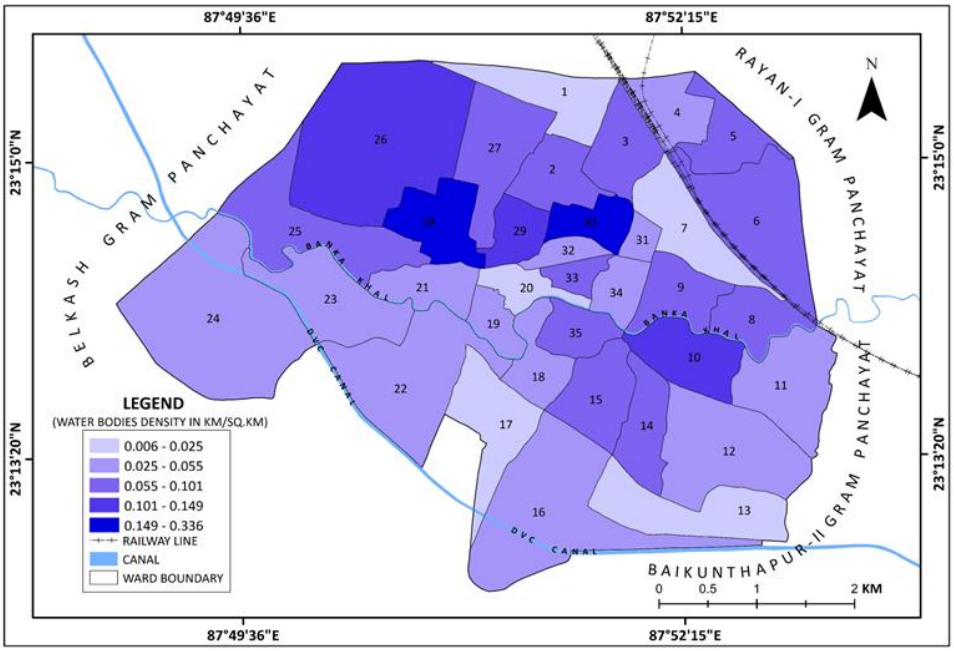


Figure No. 5.3.10. The Density of Water bodies (2023)
(*Source*: Google Earth Pro, September, 2023)

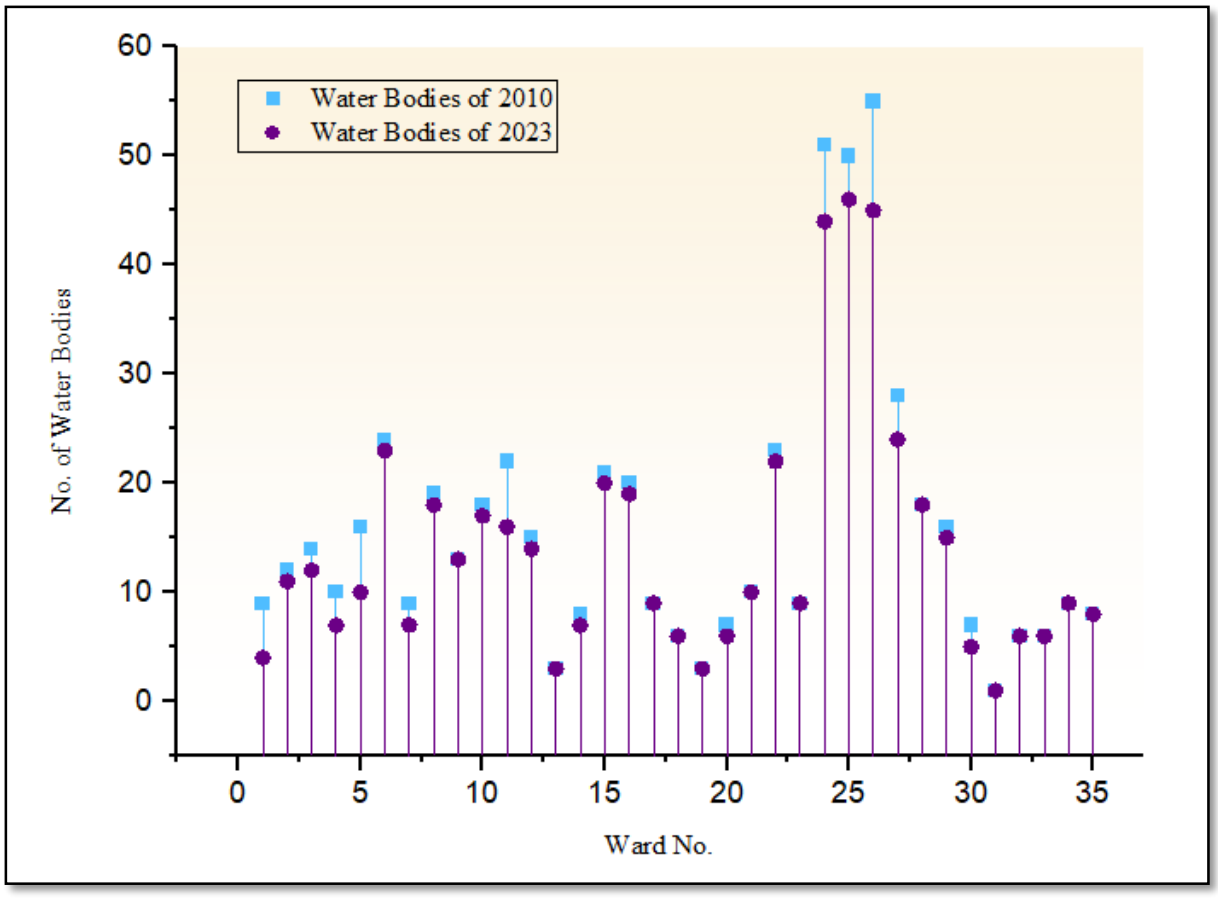
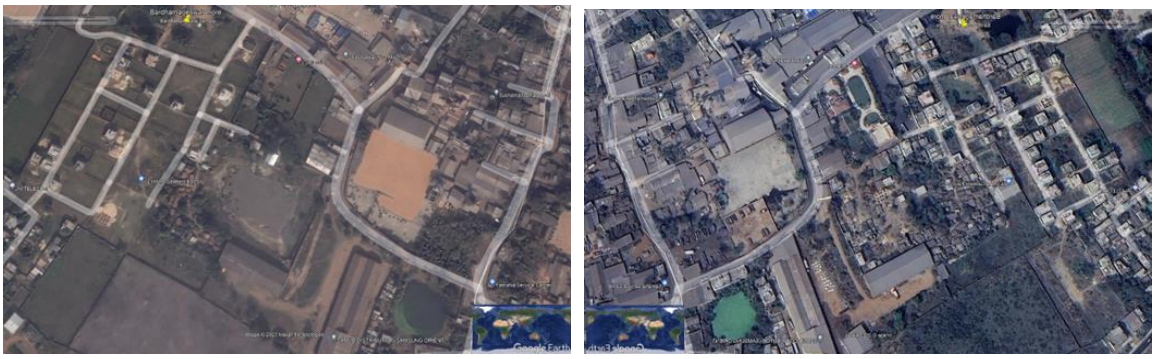


Figure No. 5.3.11. The number of Water bodies present in the year 2010 and 2023

*Source***:** Calculated after Google Earth Pro, September, 2023)

A comparison between the existing number of water bodies of the year 2010 and 2023 is shown in the **Figure No. 5.3.9 and Figure No. 5.3.11,** which evidently points towards a declining status. Over 60 number of water bodies got lost in the last 13 years and apart from a very few Wards like 17,18,19,31,32,33,34,35 all the other wards have undergone the disappearance of water bodies. The highest number of concentrations of water bodies is seen in Ward No. 26, followed by 24 and 25. The Water body density is also reported higher in these wards due to presence of many important water bodies like Krishna Sayer, Rani Sayer, Nazi Pukur, Ponds of the Burdwan University campus etc. (**Figure No. 5.3.10)**

A comparison of Water bodies of the same location between the year 2010 and 2023



Google Earth Image.5.3.2A and B Near Bardhamaneswar Crossing, Ward No.22

Google Earth Image.5.3.3A and B Near Police Line Primary School, Ward No.12

Google Earth Image.5.3.4A and B Near Aludanga Free Primary Crossing, Ward No.5

*Source***:** Google Earth Pro, September,2023

Condition of the Water Bodies at Different Corners of the Town


Photo No. 5.3.25 Pond in *Bidhanpally* Road, Ward no.11
Photo.5.3.26 Rani Sayer, Ward No.30


Photo.5.3.27 Railway Loco Pond, Ward No.6


Photo.5.3.28 and 29Pond at *Kanainatshal*, Ward No.12 and behind *Abasarika* Ground, Ward No.10(where it is clearly written not to litter the pond but hardly any existence of pond is being noticed) *Source*: Primary Survey,2022-23

5.3.3.2 Measuring the Water Holding Capacity of the Water Bodies:

Mostly, the Municipality is dominated by square and rectangular shaped water bodies- a few is there in complete oval shape and in irregular shapes. But majorly all the important water bodies are of rectangular shape. Following the methodology described in chapter-4, the average volume of water bodies are calculated below. Taking the instance of **Jora Pukur**,

The area is 6402 sq m and the depth recorded in four corners are 113 cm,138 cm,128 cm and 118 cm. so the average depth of the midpoint can be denoted as (113+138+128+118)cm/4=124.25 cm or 1.24 m. As the water is static in a water body, the volume of water will be (1.24m*6402 sq m) Cubic m or 7954.485 Cubic m. Following the same method all the volumes of the water of the surveyed water bodies are given here.

Table No.5.3.7. The Approximate Water volume of the Surveyed Water Bodies

Nature of Water Bodies	Average Water Volume (Cubic m)	No of Water Bodies present Approximately in the Municipality	Cumulated Volume (Cubic M)
Rectangular Water Bodies	27402	210	5754420
Square Water Bodies	22196	200	4433800
Oval Water Bodies	18632	103	1919096

Source: Field Survey,2023

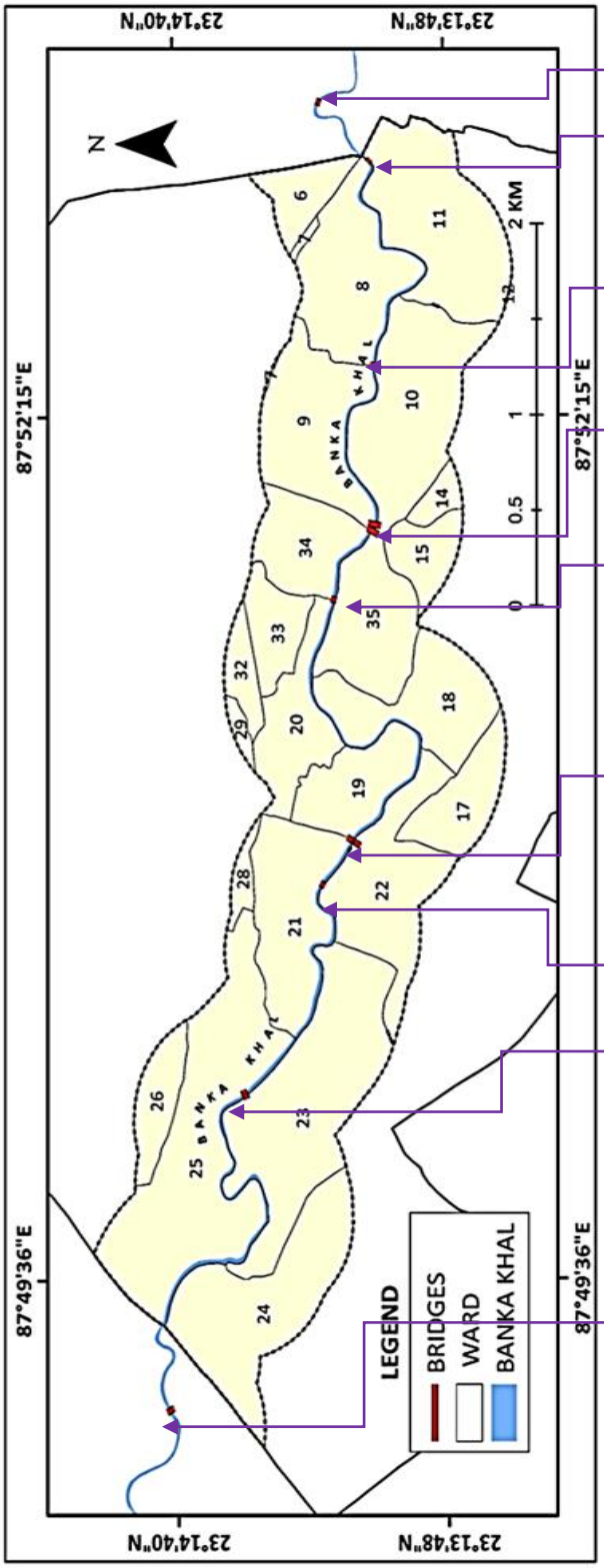
Summing up the water volume in the three different shaped water bodies, one can generate a rough idea about the water holding capacity of water bodies in the Municipality, which could facilitate further the understanding of water carrying capacity of the study area.

5.3.4. Only River of the Municipality (Banka River) and Its Degeneration Over Time:

The Banka River almost cutting the Burdwan Municipal Jurisdiction into two halves of North and South, is the smallest non-perennial river originating from the Western part of the Purba Burdwan District with a length of 96 miles and a catchment of 253 sq. km, which used to be a very prominent drainage until 1960 *(Sen 1976)*. This river originates from the agricultural land of Ramgopalpur village in the Galsi Police Station, Burdwan. This river

is classified as a third-order stream in the town of Burdwan *(Roy and Sahu 2013).* This river is not deep enough in many spots within the town. It flows through the unconsolidated sandy loam soil with medium to fine textural characteristics in general. The river's bank materials here are made up of loose, incoherent, and fine to medium sand *(Roy and Sahu 2013).* This river flows East parallel to the Damodar River after its origin and thus enters Burdwan town. Based on the Map of Rennell, it can be concluded that it originated as a branch of the Damodar River from the south-West section of Burdwan town *(Roy and Sahu 2013).* While this river could have been the best way out to channelize excess rain water, the excessive rate of urbanization along the riversides is hastening the degeneration of channel banks thus lessening river discharge, especially from the influx of urban waste water During the field visits, it was clearly evident that there are a thousands of migrators who have illegally (not having their papers of land) came from surrounding areas like Galsi, Budbud for jobs or other income sources and even from far beyond the border from Bangladesh many decades ago, settled at both the banks of Banka which actually are the land parcels of either Government or Eastern Railway and have been living there for generations and now refuse to vacate the land. By throwing their waste directly into the river, washing clothes and doing daily chores in the river has not only impacted the quantity and the quality of the river but it has also contributed to the river erosion very much on a local scale. Not only that, people from other wards which are not adjacent to the river come and throw the bulk of solid or liquid waste in the river water. A research work on the river, incidentally, had revealed that Banka has recorded sudden increases in its channel width upto 21 per cent against an increase in its depth by 17 per cent within the Burdwan urban area *(Siddiqui 2023).*

In this context, an attempt has been taken to measure the water depth of Banka River in three seasons namely Pre-Monsoon (March to May), Monsoon (June to September) and Post-Monsoon (October to November) to -Compare the volume of water in different seasons, especially in the monsoon which part of the rivers exceeds the mean volume of water, Guess which portions of the bank tend to get inundated first in comparison with other stations.



Roy Nagar Bridge (1)

Ichlabbad Banka Bridge (2)

Banka Bridge (*Amtala)* (3)

Birhata Clock Tower Bridge

Sailesh Setu (4)

Sudarshan Setu (5)

Alamganj Bridge (6)

Akhilesh Setu (7)

Cyphon Dam (8)

Figure No .5.3.12. The Bridges Which Were Taken as Stations for Measuring Water Depths (Source: Google Earth Pro, July,2021)

Figure No.5.3.12. The Bridges Which Were Taken as Stations for Measuring Water Depths (*Source:* Google Earth,2021)

5.3.4.1. The of Measurement of Water Depth of Banka River

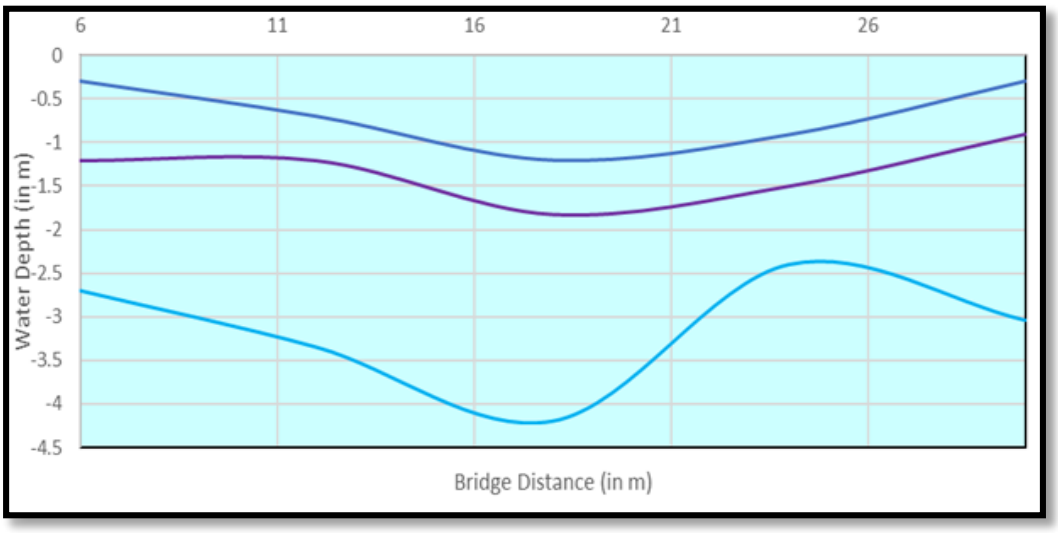


Figure No. 5.3.13A.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Roy Nagar Bridge (1)

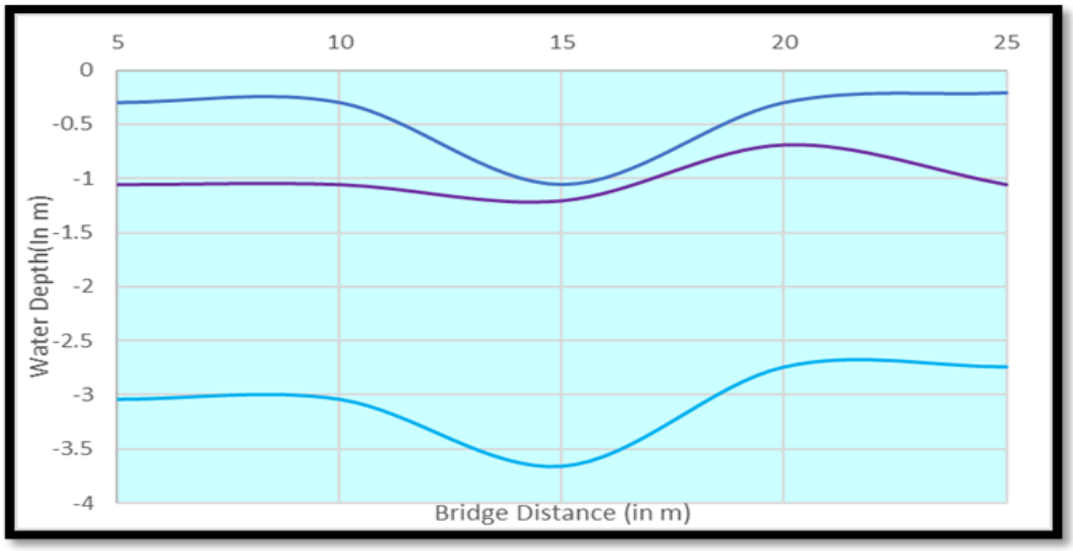


Figure No. 5.3. 13B.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at *Ichlabbad* Banka Bridge (2)

Index (level of Water Depth)	
	Monsoon
	Pre-Monsoon
	Post-Monsoon

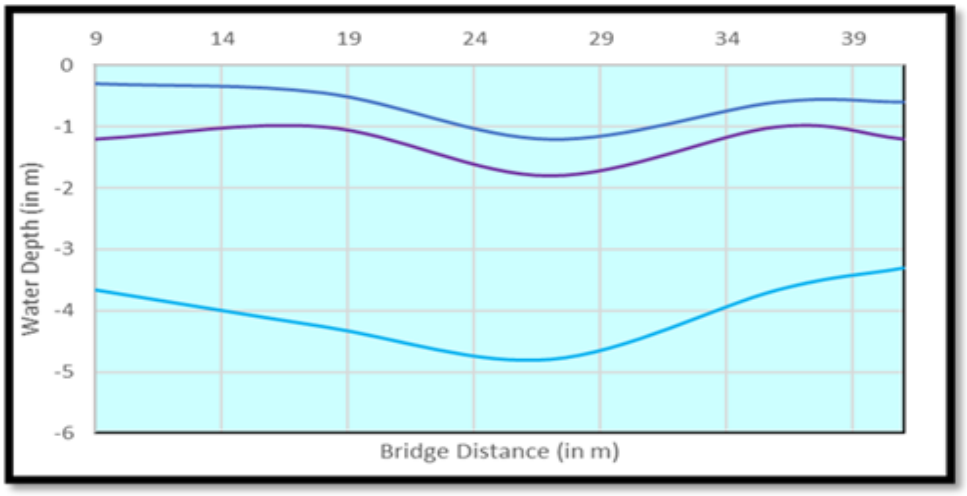


Figure No. 5.3.13.C. Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Banka Bridge (Amtala) (3)

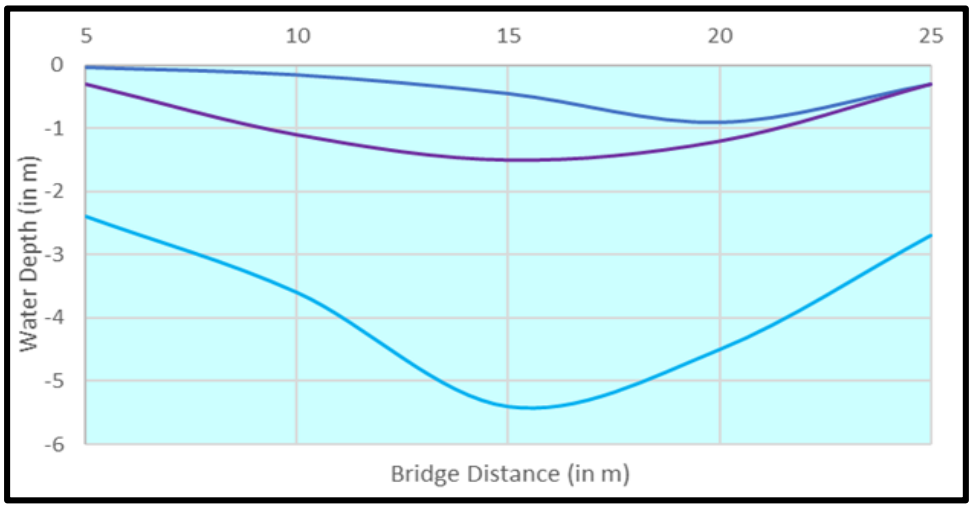


Figure No. 5.3. 13D.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Sailesh Setu (4)

Index (level of Water Depth)	
	Monsoon
	Pre-Monsoon
	Post-Monsoon

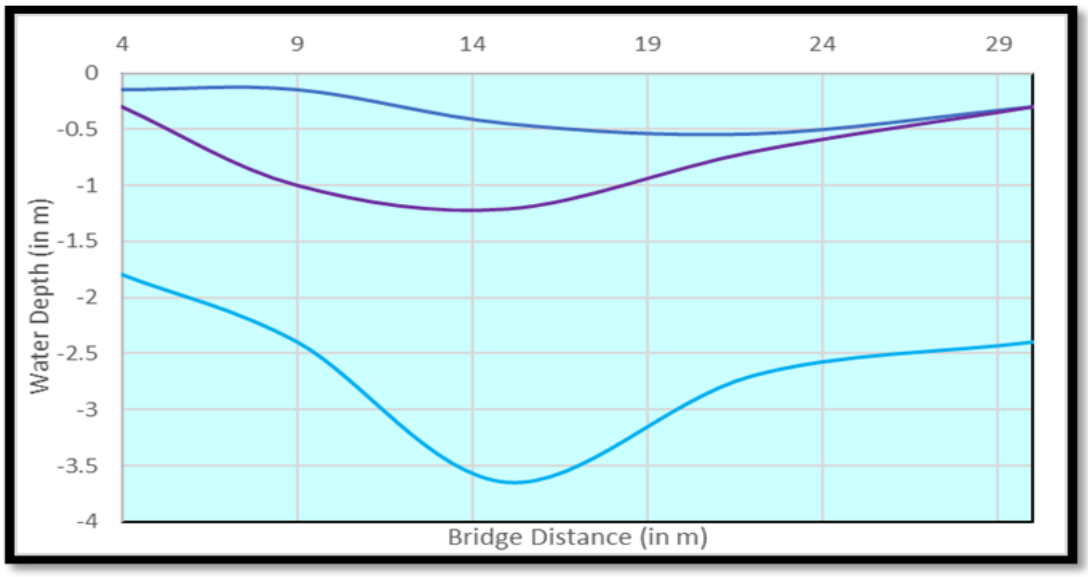


Figure No. 5.3 13E.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Sudarshan Setu (5)

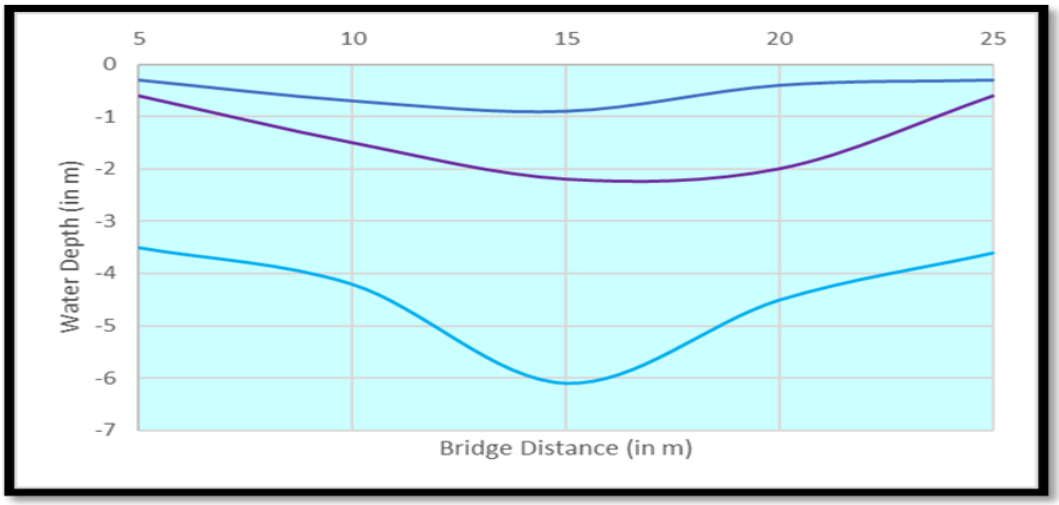


Figure No. 5.3. 13F.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Alamganj Bridge (6)

Index (level of Water Depth)	
	Monsoon
	Pre-Monsoon
	Post-Monsoon

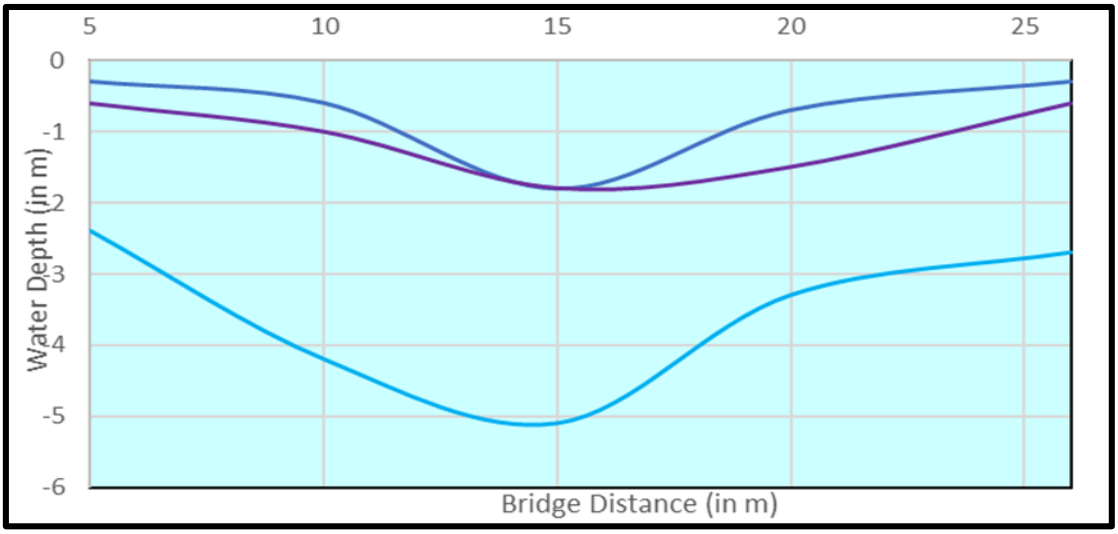


Figure No.5.3. 13G.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Akhilesh Setu (7)

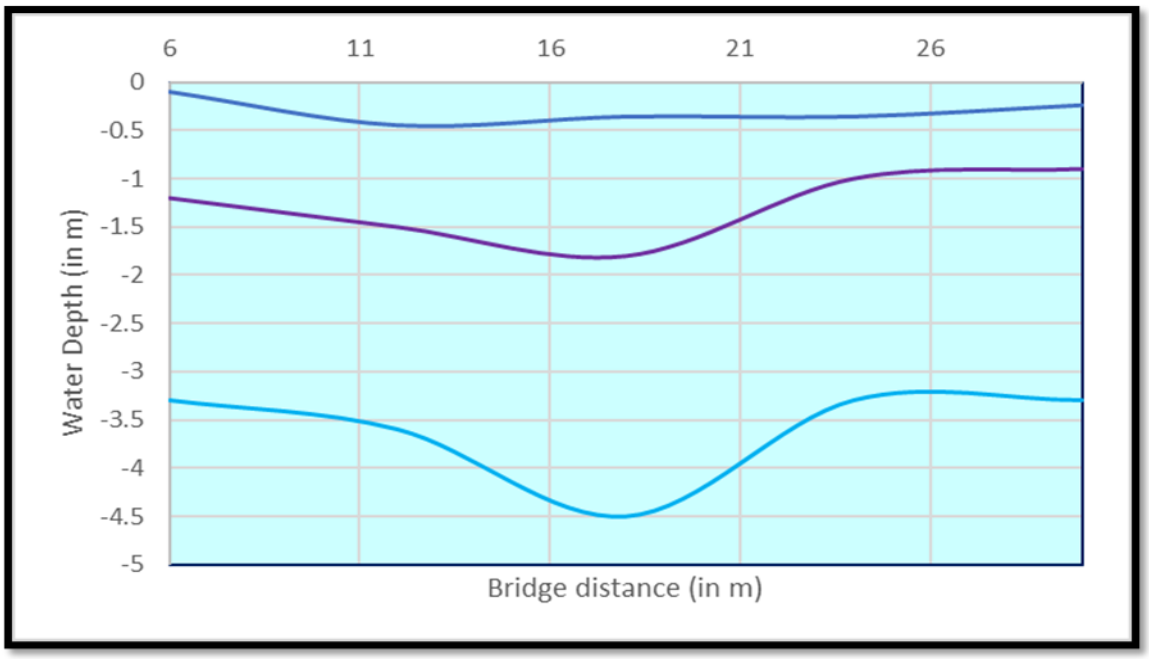


Figure No. 5.3. 13H.Pre-Monsoon, Monsoon and Post-Monsoonal Water Depth at Cyphon Dam (8)

Index (level of Water Depth)	
	Monsoon
	Pre-Monsoon
	Post-Monsoon

Table No. 5.3.8: Summary of the Water Volume at Various Stations of Banka

	Pre-Monsoon Water Volume/Running M	Monsoon Water Volume/ Running M	Post Monsoon Volume/ Running M
Cyphon Dam	17.2	98	38.4
Akhilesh Setu	19.24	92.04	28.6
Alamganj Bridge	13	109.45	34.5
Sudarshan Bridge	9.54	77.7	21.06
Sailesh Setu	9.2	93	22
Banka Pool (Near Amtala)	25.912	121.376	50.84
Ichlabad Banka Bridge	10.85	76.1	25.4
Roy Nagar Bridge	20.46	94.14	39.9
Average	14.42525	96.47575	32.5875
Total	**115.402**	**771.806**	**260.7**

Source for Figure No. **5.3.13A -13H** and **Table**. **5.3.8.**
Post- Monsoon survey was conducted in the month of Nov, 2022
Monsoon Survey was conducted in the month of April 2023
Monsoonal Survey was conducted in the month of August 2022

In the Pre-monsoon season, the water volume in all the surveyed stations seemed quite low in comparison to Monsoon and Post-Monsoon Season except Akhilesh Setu, Banka pool (Near Amtala) and Roy Nagar bridge has crossed the mean value of water volume (14.42 vol/running m). Alamgannj Bridge and Banka Pool (Near Amtala) has recorded the highest volume of water in the Monsoon period and the water is very turbulent at these stations also. These two stations can be regarded as at the bank full stages. The potential reason for this can be- might these stretches has higher cross-sectional area than others, the local slope of the river, the sudden change in the shape in the riverbed, the size and type of particles in the riverbed or the presence of obstacles or constrictions in the river. Roy Nagar Bridge, being situated outside the municipality jurisdiction holds a lesser amount of garbage into the river -this might increase the water volume in monsoon and post monsoon seasons.

The Waste Dumps Within And Around Banka Banks

Photo.5.3.30 At Adibasipara,Ward No.11 Photo.5.3.31 At Kalpataru Bridge Bank,Ward No.22

Photo.5.3.32 At Sudarshan Setu, Ward No.25 Photo.P5.3.33 At Surya Mandir Ghat, Ward No.21

Photo.P5.3.34 At Birhata, Ward No.10 Photo.P5.3.35 At Sapjola Khal (River turned Canal)

5.3.5. Impact of River Damodar on the Municipality

On the left side of Damodar river's flood plain, there are five embankments built-the main Damodar left side embankment, the Eden Canal, the Bypass and G.T. road, National Highway (NH) 2 and the Eastern Railway Line. Though it has made the city safe by protecting it from frequent and disastrous floods, the embankments have an ambiguous role when it comes to the town.

The flood plain fluvial process has been impeded by the embankments. The river Thalweg steadily rose from its flood plain due to sedimentation, and when the overall volume of flow increased, the river Damodar destroyed the embankment with its destructive attitude. Floods from the preceding century in 1913, 1916, 1935, 1956, 1978, 1995, and 2000 changed Banka was separated from Damodar by its left side embankment, which became Banka Nala or drain, but the river Bahula-Gangur was fractured at multiple spots and continued as water bodies.*(Ghosh and Guchhait 2014)*

The excess water from the Damodar River usually do not contribute in the city flooding, but, upon asking the residents of the town whether they have any flood memories of Damodar water jeopardizing their lives, they could recall the years of 1978 and 2000 when the water submerged a huge area in the town upto Lord Curzon gate which is a land mark situated in almost the central part of the Municipality. The above-mentioned years had phenomenal rainfall resulting in huge discharge and coupled with anthropogenic activities and siltation– led to embankment breaching and inundation of the city *(Banerjee 2001).* The year 1978 and 2000 has recorded the highest discharge of 10,916 m^3/s and 6387 m^3/s which is far above than the average value of 3449.767442 m^3/s if the discharge from 1975 to 2017 is taken into account.**(Table.5.3.9)** The maximum number of discharges are seen to take place in the month of September and October (Late-Monsoon**)** which aggravates the chances of raising the water le vel and consequent inundation of the bank even more**. (Figure No. 5.3.14)** The discharge data of Rhondia station has been considered because it is only discharge measuring station of lower Damodar valley and nearest to the Burdwan Town.*(Ghosh and Mistri 2013)*

Table No. 5.2.9: Highest Discharge (m^3/s) from Rhondia Station (1975 -2017)

Year	Highest Discharge (M^3/S)	Date
1975	3855	27/09/75
1976	5297	19/09/76
1977	4156	30/07/77
1978	10,919	27/09/78
1979	413	8/8/1979
1980	4210	28/08/80
1981	1635	24/07/81
1982	666	10/10/1983
1983	2098	26/06/84
1984	4518	18/10/85
1985	3317	8/7/1986
1986	3455	13/09/87
1987	4567	6/8/1988
1988	1632	5/9/1991
1989	1933	28/09/92
1990	3146	15/09/93
1991	2184	1/7/1994
1992	1443	28/09/95
1993	3816	15/09/93
1994	3298	1/7/1994
1995	6522	28/09/95
1996	3627	9/8/1996
1997	2407	15/08/97
1998	4249	13/09/98
1999	5690	25/09/99
2000	6387	23/09/00
2001	1859	2/9/2001
2002	1858	28/09/02
2003	2496	27/10/03
2004	2058	20/09/04
2005	1139	20/10/05
2006	7035	24/09/06
2007	8883	26/09/07
2008	1882	20/07/08
2009	6232	8/9/2009
2010	172	23/09/10
2011	2861	13/08/11
2012	1715	17/08/12
2013	3265	15/10/13

Year	Highest Discharge (M^3/S)	Date
2014	1480	16/08/14
2015	2565	3/8/2015
2016	2410	22/08/16
2017	4990	27/07/17

The Average is 3449.767442 (The marked cells are above the average values)

Source: (Bhattacharyya 2011) and Office of Irrigation and waterways Department, WB at Kanainatshal,2019

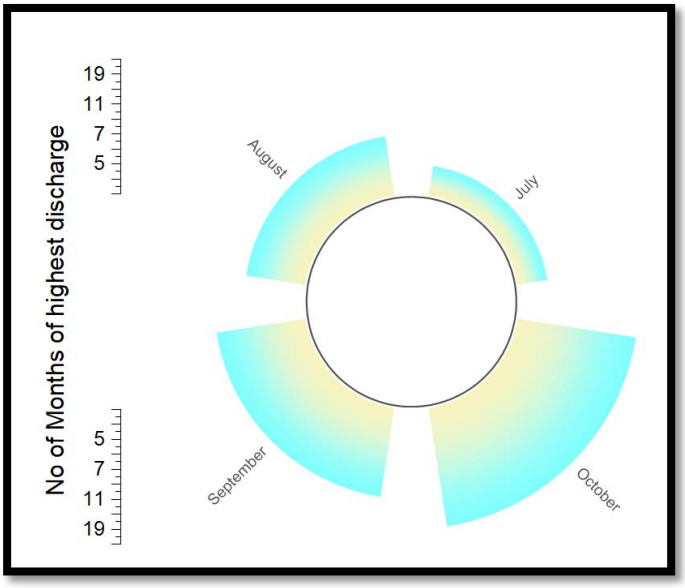


Figure No. 5.3.14. No of Months of highest discharge of Water in Damodar River

Photo.5.3.36. The Highest Flood Level Marked at the Kalna Gate Sub-Way (Source: Field Survey,2023)

5.3.6. Is There Any Contribution of Water that is Coming from Outside of The Municipal Boundary?

To find the answer of this question, a map showing Digital Elevation Model (DEM) derived from LANDSAT imagery of a broader region(that is taking 3 kilometers buffer from the Municipality boundary on each side)is drawn, which is further confirmed by the Bench Mark heights of a few railway stations around the Municipality-namely, Kshetia in the North, Galsi in the West and Shaktigarh in the Southern portion of the Municipality. The values do not actually incorporate with the DEM data , somewhere it is less or more by 1-2 m but the trend gets confirmed by checking with the actual heights of the region. So the answer is, there is almost no chance of water entering from the outside of Burdwan Municipality.**(Figure No.5.3.15)-Page.152**

List of References:

1. A.Merry, Marwa. 2017. "Experimental Study for Determine Manning'S Coefficient With Different Slopes and Channel Bed Materials." *Kufa Journal of Engineering* 8(3):76–88. doi: 10.30572/2018/kje/8031160.
2. Agrianto, F., R. Hadiani, and Y. M. Purwana. 2016. "Evaluation of Urban Drainage Network Based Geographycal Information System (GIS) in Sumenep City." *IOP Conference Series: Materials Science and Engineering* 76(1):1–6. doi: 10.1088/1742-6596/755/1/011001.
3. Banerjee, Nirmalya. 2001. "Damodar Siltation Caused Floods in Lower Bengal." *The Times of India*.
4. Bengtson, Harlan. 2017. "Manning Equation for Open Channels." (833).
5. Bhattacharyya, K. 2011. *The Lower Damodar River, India Understanding the Human Role in Changing Fluvial Environment*.
6. Brouwer, C., A. Goffeau, and M. Heibloem. 1985. "Irrigation Water Management: Training Manual No. 1 - Introduction to Irrigation." *Fao - Food and Agriculture Organization of The United Nations*. Retrieved (https://www.fao.org/3/r4082e/r4082e00.htm#Contents).
7. Bureau of Indian Standards. 1988. "Indian Standard Code of Practice for Drainage of Building Basements."

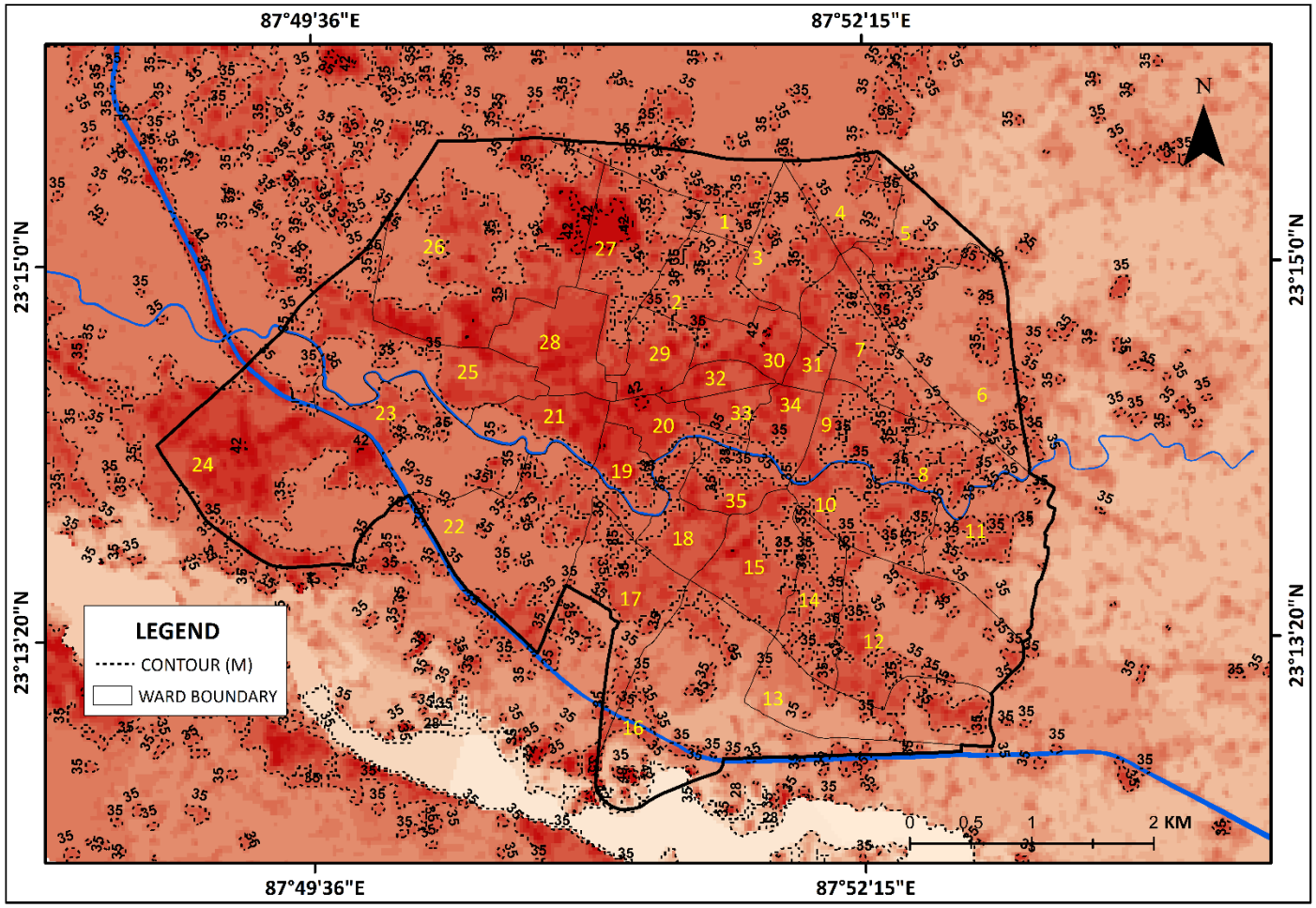


Figure No.5.3.15. Digital Elevation Map taking 3 Kms Buffer from Each Side of the Municipality

(Source: https://earthexplorer.usgs.gov)

8. Djajadi, R. 2009. “Comparative Study of Equivalent Manning Roughness Coefficient for Channel with Composite Roughness.” *Civil Engineering Dimension* 11(2):113–118.
9. DTE Staff. 2018. “Two Sides of the Same Coin: Shrinking Water Bodies and Urban Floods.”*DowntoEarth*.Retrieved(https://www.downtoearth.org.in/news/urbanisation/two-sides-of-the-same-coin-shrinking-water-bodies-and-urban-floods-72702).
10. Dutta, Shyamal, and Biswaranjan Mistri. 2016. “Solid Waste Management and Sewerage Condition in Barddhaman Municipal Area , West Bengal- An Environmental Overview. (January 2016):1–16.
11. Ghosh, Sandipan. 2020. “Reconstructing The Phases of Channel Shifting Through Identification of Palaeochannels And Historical Accounts of Extreme Floods of Damodar River In West Bengal.” (December 2012).
12. Ghosh, Sandipan, and Sanat Kumar Guchhait. 2014. “Hydrogeomorphic Variability Due to Dam Constructions and Emerging Problems: A Case Study of Damodar River, West Bengal, India.” *Environment, Development and Sustainability* 16(3):769–96. doi: 10.1007/s10668-013-9494-5.
13. Ghosh, Sandipan, and Tithy Maji. 2011. “An Environmental Assessment of Urban Drainage, Sewage and Solid Waste Management in Barddhaman Municipality, West Bengal.” *International Journal of Environmental Sciences* 2(1):92–104. doi: 10.6088/ijes.00202010010.
14. Ghosh, Sandipan, and Biswaranjan Mistri. 2013. “Performance of D . V . C . in Flood Moderation of Lower Damodar River , India and Emergent Risk of Flood.” *Eastern Geographer* XIX(1):55–66.
15. Minke, Adam G., Cherie J. Westbrook, and Garth Van Der Kamp. 2010. “Simplified Volume-Area-Depth Method for Estimating Water Storage of Prairie Potholes.” *Wetlands* 30(3):541–51. doi: 10.1007/s13157-010-0044-8.
16. Neelakantan, T. R., and K. Ramakrishnan. 2017. “Protection of Urban Water Body Infrastructure – Policy Requirements.” Pp. 1–7 in *IOP Conference Series: Earth and Environmental Science*.
17. Roy, Suvendu, and Abhay Sankar Sahu. 2013. “Effects of Urbanization on Channel

Morphology: A Case Study of Banka River in Burdwan Town, West Bengal." *Thematics Journal of Geography* 2(4):31–36.

18. Samuel, Jency. 2016. "Water Bodies Central to Urban Flood Planning." *Water & Sanitation.* Retrieved (https://www.ipsnews.net/2016/10/water-bodies-central-to-urban-flood-planning/?utm_source=rss&utm_medium=rss&utm_campaign=water-bodies-central-to-urban-flood-planning).
19. Sen, Prabhat Kumar. 1976. "A Study of the Hydrological Characteristics of the Banka Basin." *Indian Journal of Power and River Valley Development* XXVI(11):353–58.
20. Siddiqui, Kanchan. 2023. "Burdwan Wakes up for Ancient Banka River." *The Statesman*.
21. Singh, Divya. 2022. "Causes , Impacts , Risk and Mitigation of Urban Flood Management in India."

5.4.0. Foreground:

Principal Component Analysis (PCA) is a statistical technique that finds patterns and relationships in a dataset. It is widely utilized in many domains, including urban planning and flood control, to analyze and comprehend the elements that contribute to urban flooding. In the context of urban flooding, PCA can be used on a dataset including a variety of characteristics that may contribute to flooding, including rainfall intensity, land use patterns, drainage infrastructure, topography, and population density. By applying PCA to this dataset, we may find the most relevant components that lead to urban flooding and understand their relative relevance. PCA produces a set of principal components, which are linear combinations of the original variables. These components capture the greatest amount of variance in the dataset. By examining the loadings of each variable on these components, we may identify which factors have the most impact on urban flooding. Urban planners and flood management authorities can use PCA to prioritize actions and establish successful flood mitigation methods. By understanding the key factors contributing to urban flooding through PCA, decision-makers can make informed decisions and allocate resources efficiently to reduce the vulnerability of urban areas to flooding events*(Bucherie et al. 2022).*

5.4.1. Principal Component Analysis of the Criteria Related to Urbanization in Burdwan Municipality:

From the already discussed factors related to urbanization and its facets in Chapter 5, (sections 5.1 up to 5.3) all probably responsible factors have been taken into consideration- 1.Population (in numbers) 2. Population Density (persons/sq km) 3. Urban Area (in sq km)4. Water Bodies (in number) 5. Boro Pucca Drain (in number) 6. Choto Pucca Drain (in number)7. High Drain (in numbers) 8. Kutcha Drains (in number) 9. Waste Generation (gm/day) 10. Waste Collection (gm/day). For equalizing the values, removing the bias, and emphasizing the relative importance the factors are standardized by removing the units attached to them. (**Table No. 5.4.1.)**

Table No. 5.4.1. Considered Factors and Standardization of Them by Unit-Removal

Population(in number)	Population	Population Density (persons/sq km)	Population Density	Urban Area(in sq km)	Urban Area	Water Body(in number)	Water Body	Boro Pucca Drain(in number)	Boro Pucca Drain	Choto Pucca Drain(in number)	choto Pucca Drain	High Drain(in number)	High Drain	Kutcha Drain(in number)	Kutcha Drain	Waste Generation(gm/day)	Waste Generation	Waste collection(gm/day)	Waste collection
17687	1.707291	27439.6	1.033044482	0.64458	-0.179646	4	-0.719961726	13	0.592891176	48	0.530175614	0	-0.523567	12	1.486148654	2700000	-0.814814844	1350000	-0.6828271
11432	0.159466	22851.7	0.483922136	0.50027	-0.44645	11	-0.27226979	6	-0.362755785	21	-0.573383759	0	-0.523567	0	-0.36054494	2940000	-0.71027514	1470000	-0.5750721
17574	1.679328	31922.9	1.569647331	0.550514	-0.353558	12	-0.208313799	11	0.319849187	80	1.838097835	0	-0.523567	6	0.562801857	3937700	-0.275694881	1968850	-0.1271256
12126	0.331199	25551.3	0.807035256	0.474574	-0.493957	7	-0.528093753	8	-0.089713796	31	-0.164658065	0	-0.523567	1	-0.206653807	4980000	0.178312339	2490000	0.34084539
8692	-0.518557	17996.3	-0.097217087	0.482987	-0.478403	10	-0.336225781	1	-1.045360757	51	0.652793323	0	-0.523567	0	-0.36054494	2910000	-0.723342603	1455000	-0.5885415
18420	1.888674	14524.1	-0.512802128	1.26824	0.9733901	23	0.495202101	15	0.865933165	76	1.674607558	0	-0.523567	0	-0.36054494	7123187	1.111846229	3561593.5	1.30309171
14846	1.004274	20913.1	0.25189254	0.709891	-0.058898	7	-0.528093753	31	3.050269076	108	2.982529778	0	-0.523567	2	-0.052762674	7694455	1.360680343	3847227.5	1.55957914
8010	-0.687321	17204.1	-0.192034917	0.465588	-0.510571	18	0.175422146	14	0.72941217	46	0.448430476	1	0.209427	0	-0.36054494	3797998	-0.336546572	1898999	-0.1898489
7099	-0.912751	13761.9	-0.60402928	0.515845	-0.417655	13	-0.144357808	17	1.138975154	50	0.611920753	0	-0.523567	0	-0.36054494	4199720	-0.16156366	2099860	-0.0094841
9820	-0.239429	15424.3	-0.405057858	0.636659	-0.194291	17	0.111466156	2	-0.908839763	36	0.039704782	0	-0.523567	0	-0.36054494	2099250	-1.076490789	839700	-1.1410553
13842	0.75583	15684.4	-0.373926682	0.882534	0.2602882	16	0.047510165	4	-0.635797774	15	-0.818619176	0	-0.523567	0	-0.36054494	5024213	0.197570731	2009685.2	-0.0904573
19260	2.096536	14850.5	-0.473735554	1.29693	1.0264328	14	-0.080401817	1	-1.045360757	18	-0.696001467	0	-0.523567	3	0.101128459	8808702	1.846026389	3523480.8	1.26886809
13612	0.698916	14858.5	-0.47277804	0.916108	0.3223606	3	-0.783917717	2	-0.908839763	25	-0.409893482	0	-0.523567	0	-0.36054494	3377697	-0.519622163	1351078.8	-0.6818584
9044	-0.431454	17595.8	-0.145152634	0.513986	-0.421092	7	-0.528093753	5	-0.49927678	22	-0.53251119	0	-0.523567	0	-0.36054494	4068772	-0.218602265	1627508.8	-0.4336358
12850	0.510356	20642.7	0.219528565	0.622497	-0.220474	20	0.303334128	10	0.183328193	68	1.347627002	1	0.209427	0	-0.36054494	3905403	-0.289762876	1562161.2	-0.4923152
13745	0.731827	7378	-1.368113533	1.86297	2.0729402	19	0.239378137	18	1.275496148	18	-0.696001467	0	-0.523567	0	-0.36054494	2937924	-0.711179409	1175169.6	-0.8398175
12244	0.360399	16087.6	-0.325667973	0.761084	0.0357487	9	-0.400181771	18	1.275496148	7	-1.145599731	0	-0.523567	0	-0.36054494	3814205	-0.329487093	1525682	-0.525072
8036	-0.680887	19047.6	0.02861223	0.42189	-0.591361	6	-0.592049744	4	-0.635797774	27	-0.328148343	1	0.209427	0	-0.36054494	8379000	1.65885589	3351600	1.11452629
8460	-0.575967	31342.6	1.500191655	0.26992	-0.872326	3	-0.783917717	13	0.592891176	33	-0.082912926	3	1.6754156	0	-0.36054494	3299000	-0.553901167	1319600	-0.7101251
6222	-1.129768	21251.2	0.292359479	0.292784	-0.830055	6	-0.592049744	10	0.183328193	19	-0.655128898	7	4.607393	0	-0.36054494	8157100	1.562200223	3262840	1.03482351
8406	-0.589329	18869	0.007235729	0.445492	-0.547725	10	-0.336225781	12	0.456370181	65	1.225009294	1	0.209427	0	-0.36054494	6900000	1.014629967	2760000	0.58329414
10656	-0.032558	7536.17	-1.349182283	1.41398	1.2428374	22	0.43124611	7	-0.226234791	12	-0.941236884	0	-0.523567	0	-0.36054494	2468800	-0.915521425	822933.3333	-1.156111
10054	-0.181525	10962.3	-0.939111326	0.917142	0.3242722	9	-0.400181771	1	-1.045360757	24	-0.450766051	0	-0.523567	1	-0.206653807	7893500	1.447380782	2631166.667	0.46760717
15924	1.271029	7101.83	-1.401168115	2.24224	2.774143	44	1.838277909	0	-1.181881752	7	-1.145599731	0	-0.523567	21	2.87116885	6701299	0.928079369	2233766.333	0.11075823
11860	0.265377	10304.8	-1.017807013	1.15092	0.7564862	46	1.966189891	8	-0.089713796	53	0.734538461	1	0.209427	3	0.101128459	2539200	-0.884856445	846400	-1.1350389
16057	1.303941	6731.37	-1.445508198	2.3854	3.0388204	86	4.524429525	5	-0.49927678	50	0.611920753	1	0.209427	32	4.563971311	2170000	-1.045673356	1446666.667	-0.5960245
11233	0.110223	13028.3	-0.691833319	0.862201	0.2226961	24	0.559158092	9	0.046807198	75	1.633734988	0	-0.523567	1	-0.206653807	2360000	-0.962912757	786666.6667	-1.188677
5323	-1.35223	8859.23	-1.190826214	0.600842	-0.26051	18	0.175422146	7	-0.226234791	18	-0.696001467	3	1.6754156	0	-0.36054494	3870000	-0.305183789	2981369	0.78207428
7274	-0.869447	21102.3	0.274537748	0.344701	-0.734069	15	-0.016445826	4	-0.635797774	20	-0.614256329	1	0.209427	0	-0.36054494	2100000	-1.076164103	1200000	-0.8175209
5432	-1.325257	15530.9	-0.392298983	0.349755	-0.724726	5	-0.656005735	2	-0.908839763	35	-0.001167788	2	0.9424213	0	-0.36054494	2985693	-0.690372088	1706110.286	-0.3630549
5082	-1.411866	35957.1	2.052497735	0.141335	-1.110057	1	-0.911829698	1	-1.045360757	16	-0.777746606	0	-0.523567	0	-0.36054494	8798985	1.841793838	5027991.429	2.61985596
5335	-1.34926	29691.8	1.302608628	0.179679	-1.039166	6	-0.592049744	1	-1.045360757	18	-0.696001467	0	-0.523567	0	-0.36054494	2900000	-0.727698424	1657142.857	-0.4070256
7649	-0.776652	43351.1	2.937480107	0.176443	-1.045149	6	-0.592049744	4	-0.635797774	16	-0.777746606	1	0.209427	0	-0.36054494	2400000	-0.945489473	1371428.571	-0.6635852
6194	-1.136697	20130.2	0.158187821	0.307697	-0.802483	9	-0.400181771	11	0.319849187	17	-0.736874037	2	0.9424213	0	-0.36054494	2600000	-0.858373054	1485714.286	-0.5609613
8065	-0.673711	22814.5	0.479469695	0.353504	-0.717794	8	-0.464137762	28	2.640706093	1	-1.390835147	0	-0.523567	0	-0.36054494	9130400	1.986152279	5217371.429	2.78991131
10787.57		18808.54571		0.7417481		15.257143		8.657142857		35.02857143		0.71428571		2.34285714		4570634.371		2110421.826	
4041.157		8354.968677		0.5408849		15.635752		7.324880719		24.46628668		1.36426702		6.49810019		2295778.465		1113637.41	

The **Red** Columns are the standardized values, and the last two rows of the table show the total and the average respectively.
Source: Data provided by the Municipality and Computed from ARC_GIS

Table no. 5.4.2. Correlation Matrix

	Population	Population Density	Urban Area	Water Body	Boro Pucca Drain	Choto Pucca Drain	High Drain	Kutcha Drain	Waste Generation	Waste Collection
Population	1.000	.236	.650	.373	.135	.354	.422	.476	.076	-.059
Population Density	.236	1.000	.700	-.553	.028	.007	.069	.258	.053	.190
Urban Area	.650	.700	1.000	.785	.064	.018	-.253	.688	.042	-.178
Water Body	.373	-.553	.785	1.000	-.110	.149	-.056	.781	-.229	-.245
Boro Pucca Drain	.135	.028	-.064	-.110	1.000	.365	.001	-.132	.187	.289
Choto Pucca Drain	.354	.007	.018	.149	.365	1.000	.121	.088	-.043	-.035
High Drain	.422	.069	.253	-.056	.001	-.121	1.000	-.076	.070	.071
Kutcha Drain	.476	.258	.688	.781	-.132	.088	-.076	1.000	-.084	-.099
Waste Generation	.076	.053	.042	-.229	.187	-.043	.070	-.084	1.000	.907
Waste Collection	.059	.190	-.178	-.245	.289	-.035	.071	-.099	.907	1.000

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.733**
Bartlett's Test of Sphericity	Approx. Chi-Square	211.310
	df	45
	Sig.	.000

Table no. 5.4.3. KMO and Bartlett's Test

A value of at least 0.6 is required for the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO), with values closer to 1.0 being preferable.

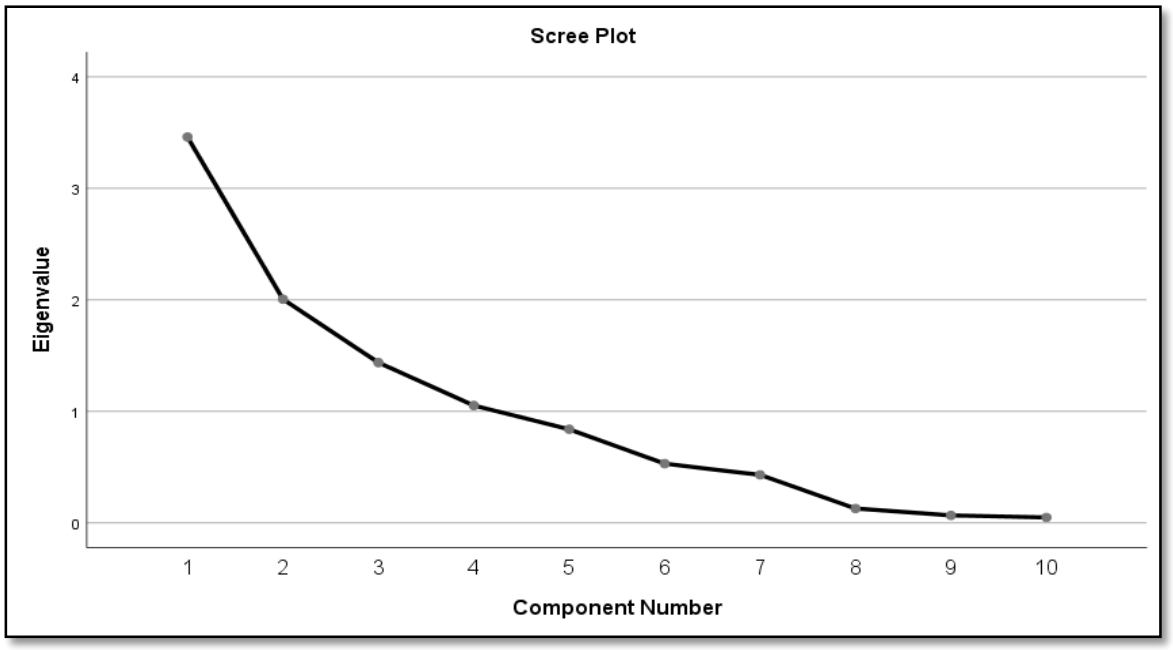


Figure No. 5.4.1 Scree Plot

Table no. 5.4.4. Rotated Component Matrix

	Component			
	1	**2**	**3**	**4**
Urban Area	**.919**			
Water Body	**.908**			
Kutcha Drain	**.811**			
Population Density	**.713**			
Waste Generation		.972		
Waste Collection		.956		
Choto Pucca Drain			.847	
Boro Pucca Drain			.785	
High Drain				-.929
Population	.510			.639
Extraction Method: Principal Component Analysis. *Rotation Method: Varimax with Kaiser Normalization.*				
Rotation converged in 5 iterations.				

Source: Calculation retrieved from SPSS 29.0.10 Version Trial Pack

There are four factors that showed up the value 1 in the scree plot for this particular analysis (**Figure No. 5.4.1)** and these four factors (**urban area, water body, kutcha drain, and population density**) clubbed under component-1 explain more than 70% of the data variance hence can be considered as the principal component for the urban flooding scenario in Burdwan Municipality.

List of References:

1. Beaumont, Robin. 2012. "An Introduction to Principal Component Analysis & Factor Analysis Using SPSS 19 and R (Psych Package)." (April).
2. Bucherie, Agathe, Carolynne Hultquist, Susana Adamo, Colleen Neely, Fernanda Ayala, Juan Bazo, and Andrew Kruczkiewicz. 2022. "A Comparison of Social Vulnerability Indices Specific to Flooding in Ecuador: Principal Component Analysis (PCA) and Expert Knowledge." *International Journal of Disaster Risk Reduction* 73(October 2021):102897. doi: 10.1016/j.ijdrr.2022.102897.
3. IDRE Statistical Consulting. 2018. "Principal Componets(PCA) & Exploratory Factor Analysis (EFA)with SPSS." *OARC Stats* 2–3. Retrieved (https://stats.oarc.ucla.edu/wp-content/uploads/2020/05/pca-efa-V12.pdf).
4. UCLA. 2021. "Principal Components Analysis | Spss Annotated Output." *Advanced Research Computing:Statistical Methods and Data Analytics* 1–2. Retrieved (https://stats.oarc.ucla.edu/).

5.5.0. Foreground:

One of the key elements influencing climate change will be shifts of rainfall or other forms of precipitation. A numerical value or graphical depiction of a particular social or environmental condition over time and space that has a significant influence on the entire system, namely the climatic system, is now a crucial component or indicator. *(Balasubramanian, 2017)* . Analyzing rainfall patterns and trends is very important as it aids the policymakers to make the decisions about cultivation schedules, building roads, and water distribution in urban and rural areas *(S, 2017)* . Also, excess rainfall is a prime reason for flooding and the increased concentration of people and property in urban areas gets more fatal (*Hammond et al. 2015).* The worldwide alteration in the pattern of rainfall may be attributed more to unplanned urbanization, excessive concretization, and the ensuing sudden shifts in land use and cover. The threats to Asian cities regarding rainfall-related disasters are even higher (*Svensson and Whitehead 2021*). Several studies have been made on the rainfall pattern of megacities are concerned but the number of research made on the municipalities, or the towns is less in numbers yet they are suffering a severe magnitude of the same problems like drainage, waterlogging, and flooding. Same goes for Burdwan Town as some parts of it get completely inundated even if it drizzles, some other places take a little longer time, but it affects every individual in the Municipal area as they must commute to school, offices, etc. The life of daily wage earners like fruit sellers, flower sellers, people related to fish and dairy distribution, Auto and Toto drivers, face a severe economic loss due to the flooding conditions. Not only the financial breakdown, it has also caused no or less access to the civic amenities like water and electricity. In some parts of the Municipality life almost stops for a few days and others struggle.

5.5.1. For Rainfall Profile of Purba Bardhaman District:

The district of Purba Bardhhaman experiences 80 % of its rainfall between June and September and every year, floods might occur because of the highly intensified South-Western monsoon's seasonal rainfall. This district categorically falls in to a tropical climatic zone followed by conditions of a moderate climate, with cold and dry winters, hot

and humid summers, and an extended period of rainy season.*(Pal, Mazumdar, and Chakraborty 2015)*

5.5.1.1. Analysis of the Spatial Distribution of Rainfall in The District:

Following the *4.2.2.1 section of Chapter – Four (Methodology)* the isohyet map is created. **(Figure No. 5.5.1)** It is evident that a significant portion of the central and Northwestern part of the map is falling under the lowest rainfall zone if the annual average rainfall counts (in mm). The study area of Burdwan Municipality also comes under this zone of less than 200 mm rainfall but if the monthly average rainfall (in mm) is considered (**Figure No. 5.5.2)** it is directing towards a higher value (more than 400 mm) from the month of May to October. The stations of Katwa and Mangalkot experience the least amount of rainfall whereas Ausgram-II has received the highest proportion of rainfall. (closer to 500 mm).

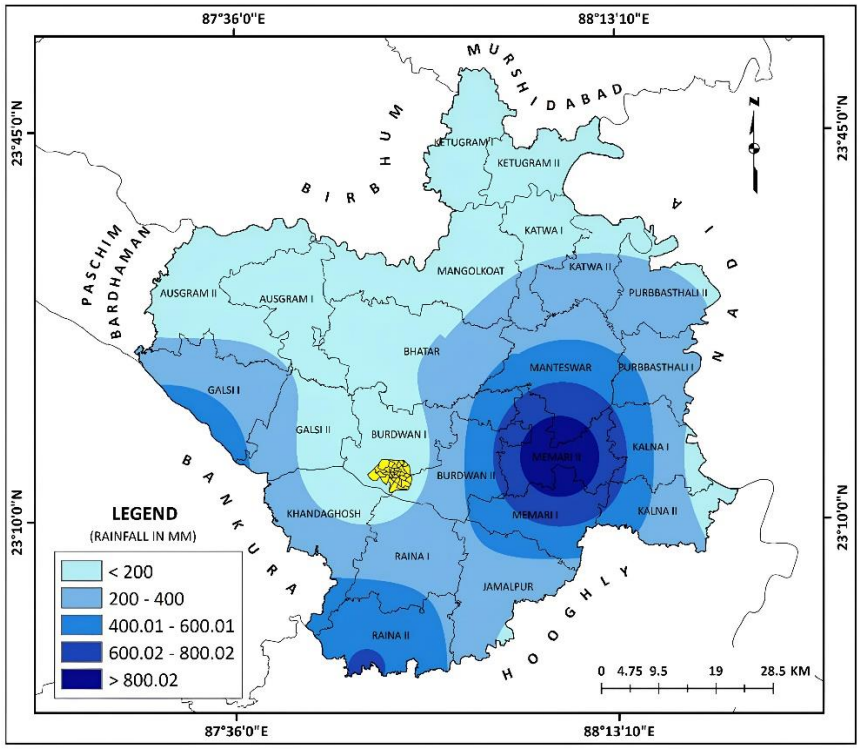


Figure No. 5.5.1. Isohyet Map of Annual Average Rainfall of District Purba Bardhaman from the years of 1979-2019(in mm)

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

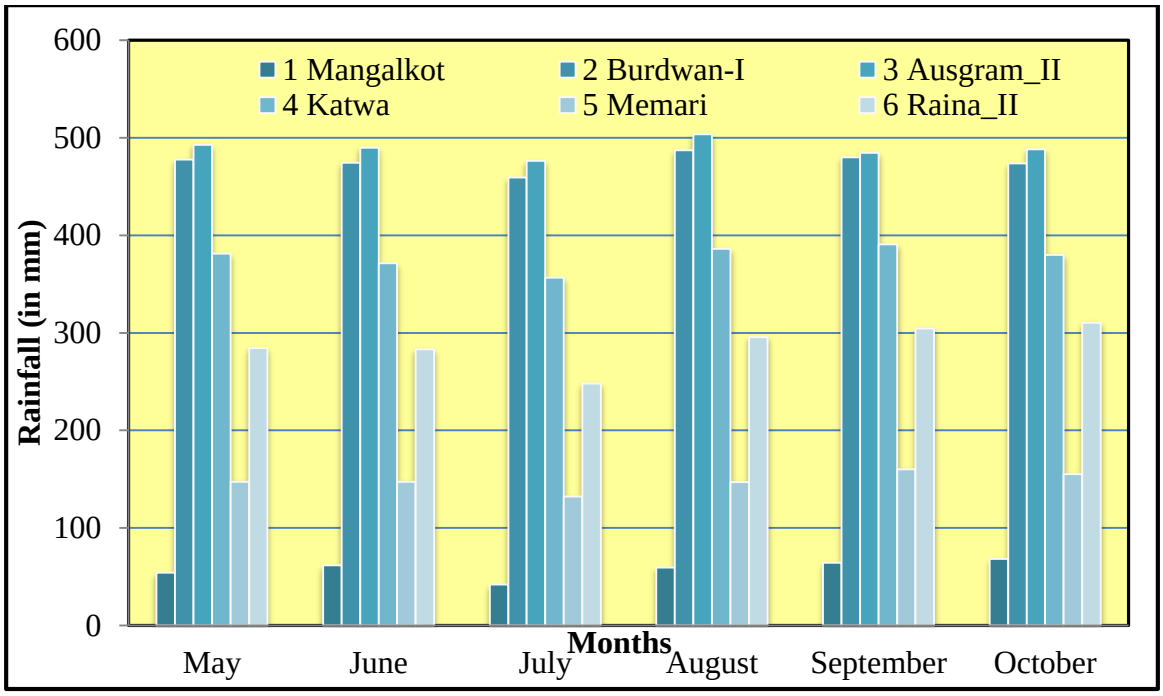


Figure No. 5.5.2. The Average Monthly Rainfall of the SWAT Stations (in mm) from the years of 1979-2019

Source: Computed with the data retrieved from the official website of SWAT Model (: https://swat.tamu.edu/data/cfsr)

5.5.1.2. Analysis of Thiessen Polygons:

Following the *section of 4.2.2.2 in Chapter-Four (Methodology)***Figure No. 5.5.3 and 5.5.4** depict that the Municipalities of Burdwan fall under the Thiessen polygon surrounding Burdwan-I block, meaning there by it is not getting influenced by rainfall of any other stations nor it is sharing its rainfall to any other stations. So, it is evident that the station near Burdwan-I which is also considered for analyzing the trend of rainfall for Burdwan Municipality, is free of any kind of rainfall influences from outside.

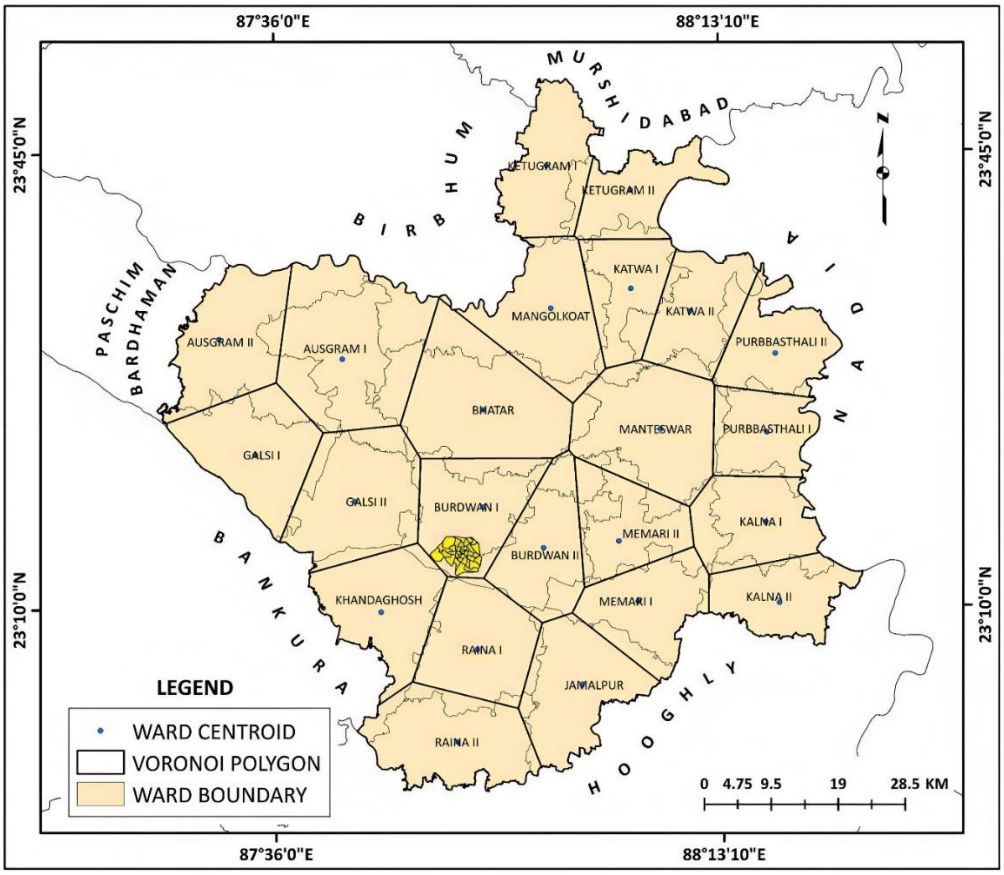


Figure No. 5.5.3. Thiessen polygons for Each Block of the District Purba Bardhaman
Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)/

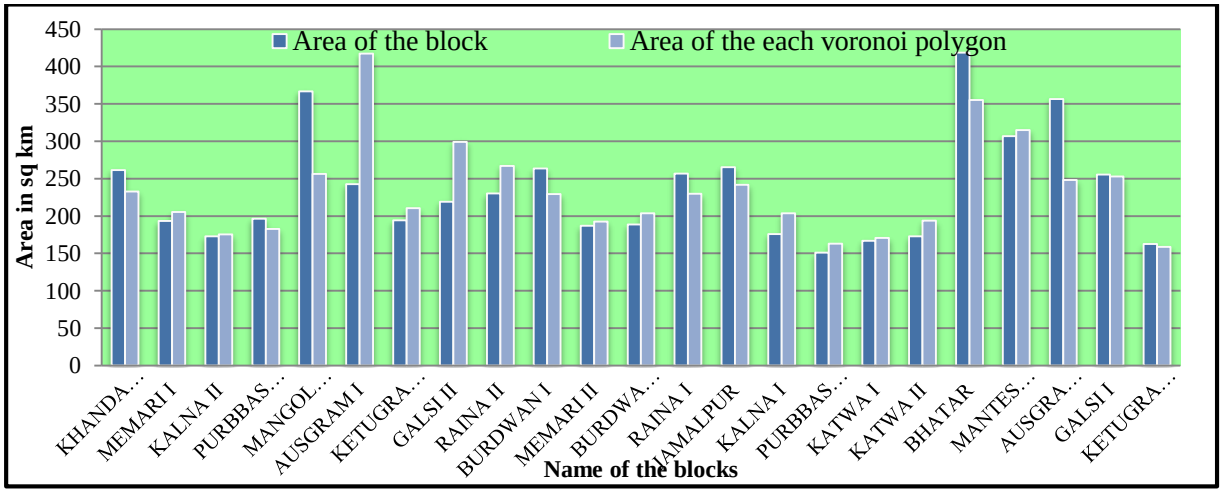


Figure No. 5.5.4. Difference in Thiessen Polygons and the Actual Block Area
Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

5.5.2. Analysis of Rainfall of Burdwan Municipality:

The analysis of rainfall involves studying various aspects of precipitation patterns, including its distribution, intensity, frequency, and duration. There are many methods of examining rainfall data, currently the statistical method is given importance for temporal analysis of the data. First, summary statistics are computed that provides a summarized result of central tendency, spread, and distribution of a dataset, allowing for a better understanding and comparison of the data, thereby describing the main characteristics and properties of the data. Measures of central tendency (such as mean, median, and mode) and measures of dispersion (such as range, variance, and standard deviation) are examples of common summary statistics. (*Yellapu 2018).*

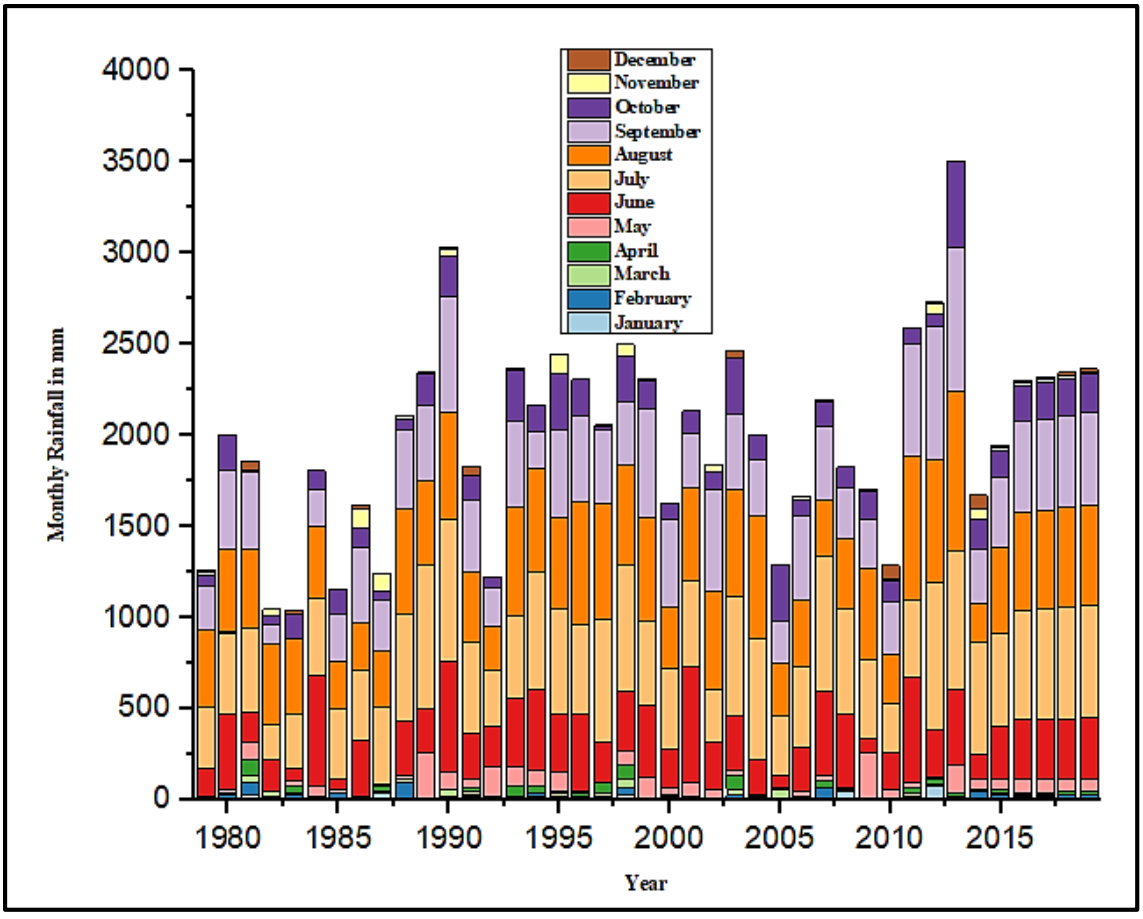


Figure No. 5.5.5. Monthly Rainfall Distribution of Burdwan Town from 1979-2019

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

Figure No. 5.5.5. shows that apart from the rainfall of the monsoonal months, which tend to be higher always, it is also noteworthy that the amount of rainfall received in the late Monsoonal month of September and October is increasing over the years. The month of July has received the highest proportion of rainfall in the monsoonal months as far as the mean is concerned (**Table.5.5.2)** while the lowest is recorded in the month of June. The standard deviation of rainfall is a statistical measure that quantifies the variability or dispersion of rainfall data around the mean. It provides insights into how much individual rainfall measurements deviate from the average value. The higher the deviation, the greater is the significant fluctuation in precipitation amounts and higher degree of uncertainty and unpredictability in rainfall *(Ayeni 2014)*. The standard deviation value for all the monsoonal months records more than 150 and it is increasing as the months pass signifying an erratic nature of rainfall.

Table.5.5.1: Summary Statistics of the Monsoonal Months of Burdwan Town from 1979-2019

	June	July	August	September
Mean	**294.7677**	**516.3211**	**485.9344**	**395.3595**
Standard Error	23.81022	24.45026	24.53605	24.90449
Median	300.1534	486.3905	492.4784	409.1875
Mode	#N/A	#N/A	#N/A	#N/A
Standard Deviation	**152.4598**	**156.558**	**157.1074**	**159.4665**
Sample Variance	23244	24510.42	24682.73	25429.57
Kurtosis	-0.05865	-0.72228	-0.1849	0.454276
Skewness	0.359437	0.069371	0.31302	0.100273
Range	620.786	610.5112	656.5766	784.1457
Minimum	9.443094	195.5318	217.0596	1.198195
Maximum	630.2291	806.043	873.6363	785.3439
Sum	12085.47	21169.17	19923.31	16209.74

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

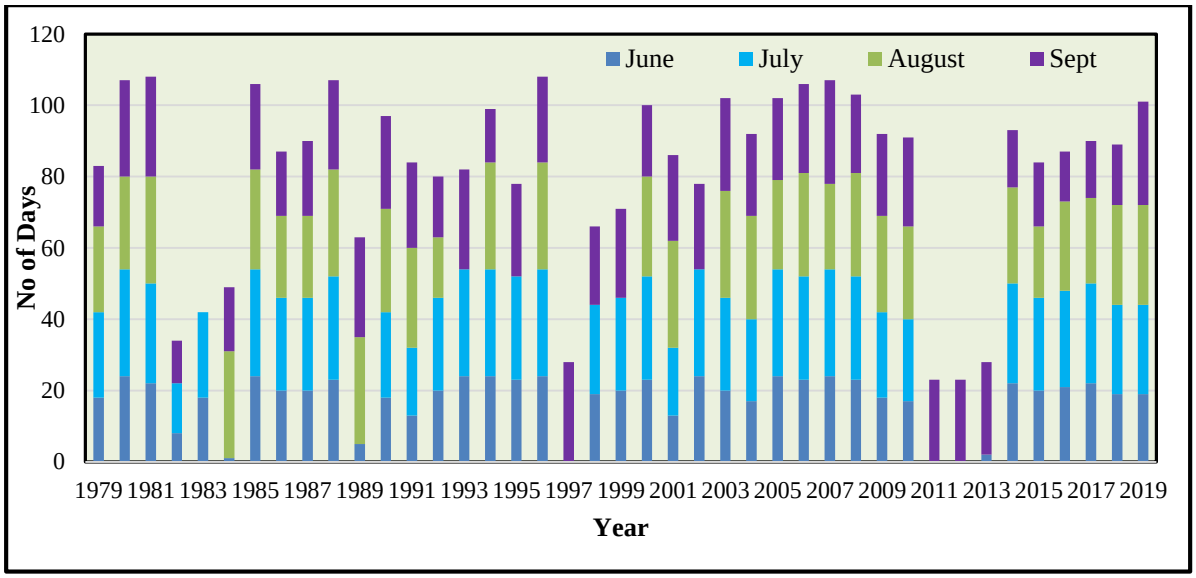


Figure No. 5.5.6. No of Days Having 2.5 mm Rainfall (Month Wise) (1979-2019)
Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

According to India Meteorological Department (IMD), a rainy day has been designated as a day with rainfall of 2.5 mm or more than that *(Nandargi and Mulye 2012).*It is always expected in any monsoonal scenario that the month of June, July and August which are of proper months of monsoon, will have much more rainy days than the other months. But surprisingly, the month of September is also having its fair and increasing portion of rainy days and the only rainy days the years like 1997, 2011, 2012 and 2013 has in the month of September. **(Figure No. 5.5.6)**

5.5.2.1. The Durbin Watson Static Test

In **Table.5.5.2**, the months of July, August, September indicate the values from 0 to 2 there by signifying a positive autocorrelation but the month of August having a close value towards 2 indicates no autocorrelation between the variables. But now if we consider the P value, only the month of July has a significant mark as the value is less than 0.05.

Table.5.5.2: The Durbin Watson Static Test for the Monsoonal Months of Burdwan Municipality

	DW Value	P Value
June	2.4898	0.924
July	**1.3325**	**0.008**
Aug	1.8555	0.262
Sept	1.553	0.052
Oct	2.4017	0.873

5.5.2.2. Change Point Detection in the Rainfall Pattern:

In the Table **5.5.3** considering the P-Value for the month of June, July, August, September- it is noteworthy that besides the month of July, there is no evidence of change-point in the rest of the months. Only the month of July has a borderline value to the level of significance. But for other months, as the P value (0.05) is greater than the chosen significance level, there are no signs of any abrupt change in the data.

Table.5.5.3: The Pettitt's Test for the Monsoonal Months of Burdwan Municipality

	U Value	P-Value	K(CP)
June	138	.3964	11
July	206	.0543	9
August	168	.1817	14
September	188	.0992	32
October	184	0.1126	10

Table.5.5.4: The Buishand Range Test for the Monsoonal Months of Burdwan Municipality

	R/sqrt(n)	P-Value	K(CP)
June	.91078	.7478	11
July	1.2724	.2293	9
August	1.0215	.5757	9
September	1.236	.2659	32
October	1.092	.4628	14

Table.5.5.5: The Standard Normal Homogeneity (SNHT) Test for the Monsoonal Months of Burdwan Municipality

	T Value	P-Value	K(CP)
June	3.2144	.6124	9
July	9.9449	0.025	9
August	5.662	0.2112	9
September	8.9175	.0357	32
October	6.0718	0.1746	10

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

- **Buishand Range Test: (Buishand,1982)**

In **Table.5.5.4** as all the P values are greater than the chosen level of significance, it might be concluded that no prominent change point is detected.

- **The Standard Normal Homogeneity (SNHT) Test: (Alexandersson 1986)**

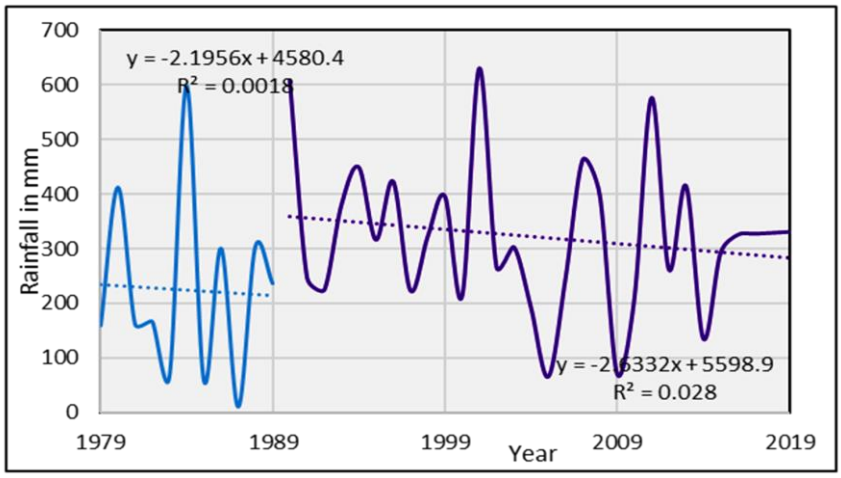
In **Table.5.5.5** lower p-values (e.g., 0.025, 0.0357) of July and September indicate stronger records against the null hypothesis, while higher p-values (e.g., 0.6124, 0.2112, 0.1746) of June, August and October suggest weaker evidence against the null hypothesis.

Considering the results of three tests of change detection, the final change point has been decided based on the number of the year those came out because of more than one test or supported by two tests among three.

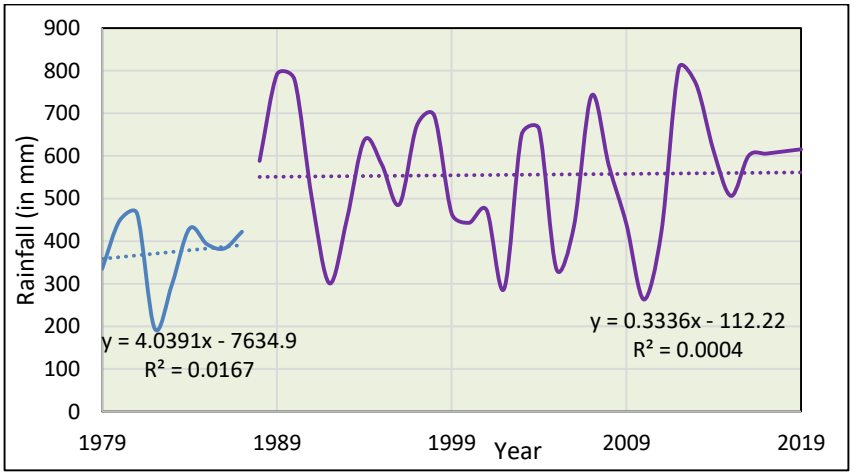
Table.5.5.6. The final year of Change Points of the Monsoonal Months

Months	**K (Change Points)**
June	11 (Backed by Pettitt and Buishand Range Test)
July	9 (Backed by three of the above-mentioned tests)
August	9((Backed by Buishand Range and SNH tests)
September	32(Backed by three of the above-mentioned tests)
October	10(Backed by Pettitt and SNH tests)

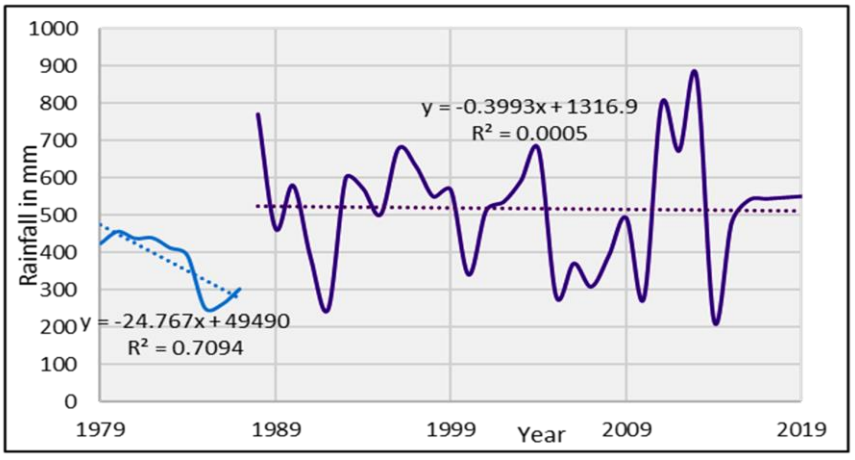
Dividing the monthly data into two halves based on the year of the change has been plotted in **Figure No. 5.5.7.** where for the month of June, both the halves are showing the declining trend where the trend is insignificant in nature. (as far as the R^2 is concerned) the first half of the month July shows an increasing trend but in the second half of the year 1987 it shows a linear trend. The trend of the second half from the year 1987 of the month August also shows a linear trend which is also insignificant in nature. The first 32 years of September show an upward pattern while the last 9 years shows a steep downward trend.in case of October, the first 10 years show a negative trend while the latter half exhibits a mild upward notion. But from the R^2 values, it is evident that all the trends of all the halves (before and after change point) are insignificant.



June

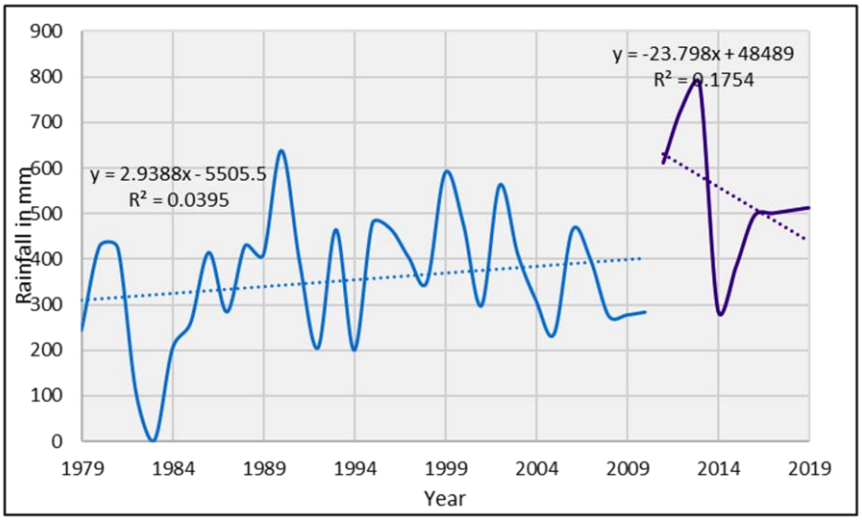


July

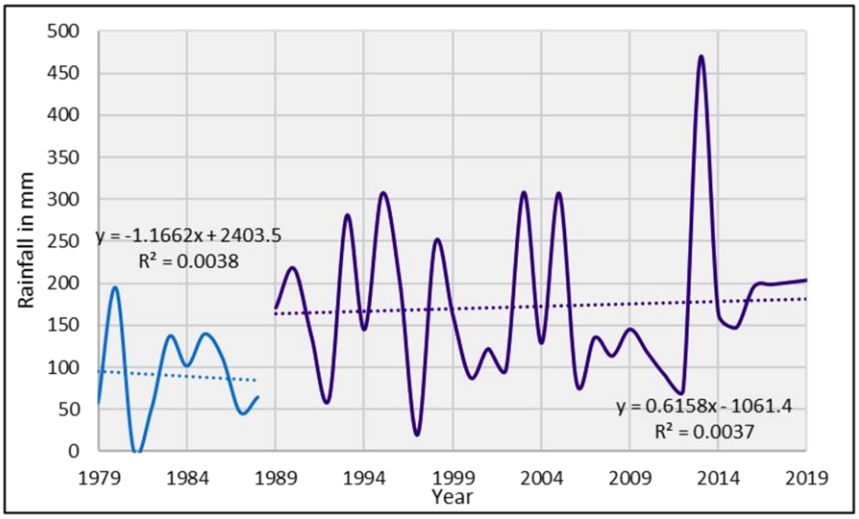


August

Contd…



September



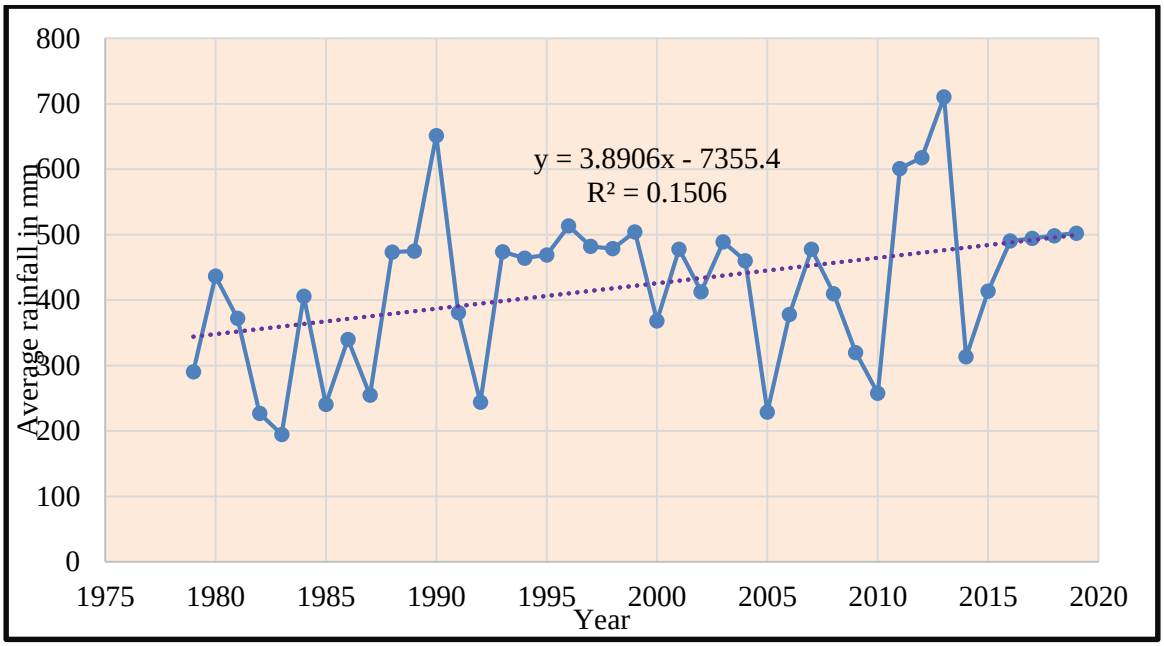
October

Figure No. 5.5.7. The Trend of Rainfall Aater Detection of Changepoint

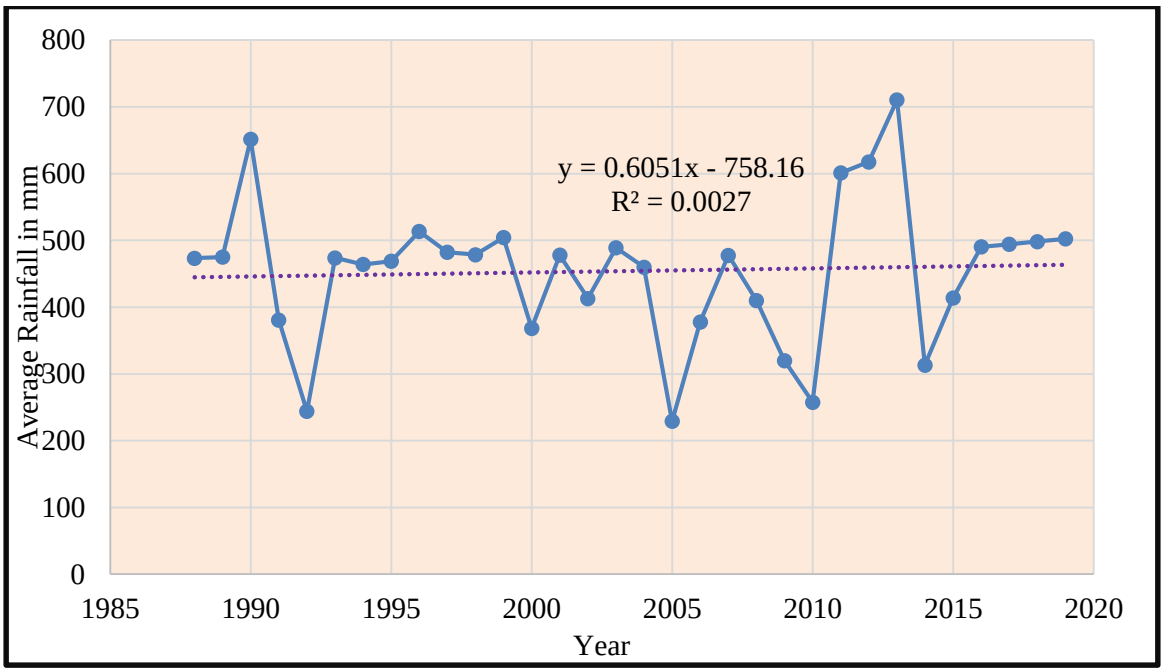
Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

Similarly, a basic method of trend analysis using the scatter plot in MS-Excel 2017 has been done to analyze the direction of annual average rainfall before and after the homogenization of the data is done. Now, considering the outcome of **Table.5.5.7.** the lowest number of years that has come up in change detection is number 9, that is the year of 1987 and the majority of the number of years where the shifts have taken place is revolving 9 only, that is 10 and 11. So, in the **Figure No. 5.5.8(i)** portrays the before homogenization scenario where there is an upward trend but insignificant in terms of R^2

value and in the **Figure No. 5.5.8(ii)**the trend gets much linear with an even more insignificant nature.



(i)



(ii)

Figure No. 5.5.8. Trend of Average Monsoonal Rainfall (1979-2019)

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

5.5.2.3. Identification of Monotonic Trend in Rainfall Data Via Mann Kendall's Test

In **Table.T5.5.8 I** apart from the month of September all other values run negative meaning thereby a negative association between the variables, suggesting that as the x-values increase, the y-values tend to decrease but in the **Table.5.5.7 II** apart from the month of June and September, all the month portray a positive value of Sen's slope but as far as the P value is concerned as all the values in **Table II** is much above the level of significance that is 0.05, that is why must be tagged as statistically insignificant. The magnitude of Kendall's tau also provides information about the strength of the relationship. The closer the absolute value of Kendall's tau is to 1, the stronger the correlation. Conversely, if the value is closer to 0, the weaker the correlation. Here also If the values of Kendall's Tau count, then also half of the values are showing negative trend of association between the ranked variables.

Table.5.5.7. Identification of Monotonic Trend in Rainfall Pattern Via Mann Kendall's Test
I-Pre-Change Point MK Test

	June	July	Aug	Sept	Oct
Z-Value	-0.3577709	-0.3711537	-2.35064038	0.20395700	-0.3127716
Sen's Slope	-12.0963407	-4.2780438	-24.23457878	0.46556662	-8.4717230
P Value	0.7205148	0.7105230	0.01874114	0.83838710	0.7544542
S	-5.0000000	-4.0000000	-20.00000000	13.00000000	-4.0000000
VAR(S)	125.000000	65.3333333	65.33333333	3461.666666 67	92.0000000
Kendal's Tau	-0.1111111	0.1428571	-0.71428571	0.02795699	-0.1111111

II-Post-Change Point MK Test

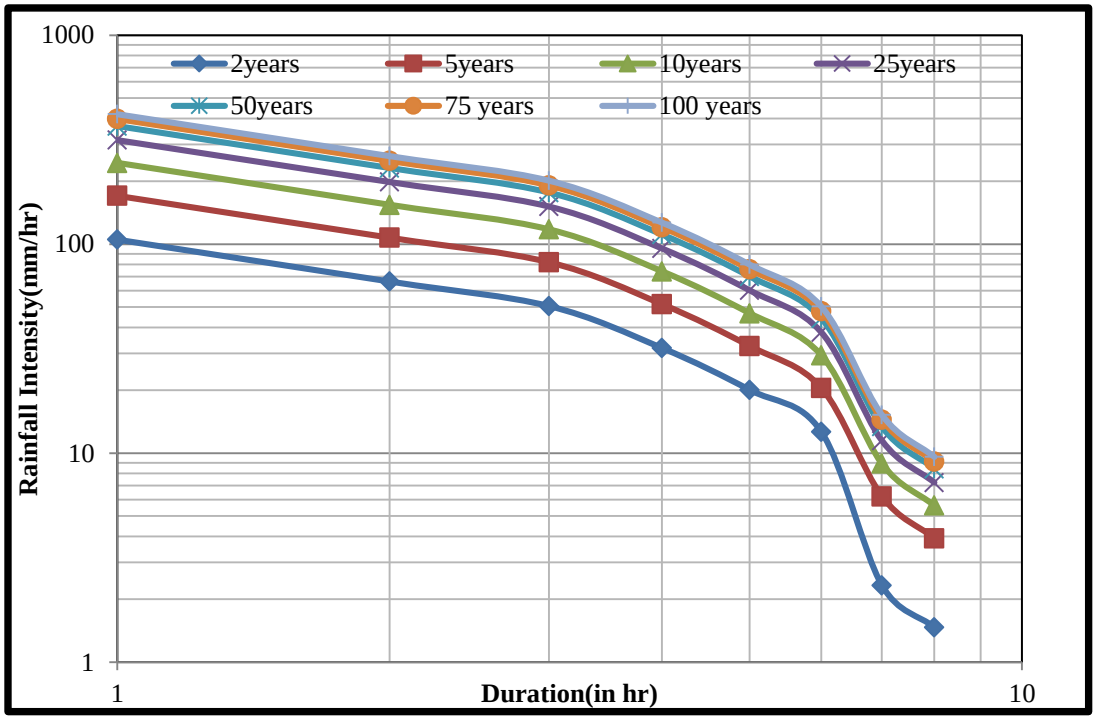
	June	July	Aug	Sept	Oct
Z-Value	-0.24385480	0.10197850	0.06798567	0.12371791	0.07136412
Sen's Slope	-0.61520789	0.79841272	0.49222644	-5.99095224	0.55131092
P Value	0.80734327	0.91877374	0.94579704	0.90153863	0.94310796
S	14.00000000	7.00000000	5.00000000	-2.00000000	5.00000000
VAR(S)	2842.00000000	3461.66666667	3461.66666667	65.33333333	3141.66666667
Kendal's Tau	-0.03448276	0.01505376	0.01075269	-0.07142857	0.01149425

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

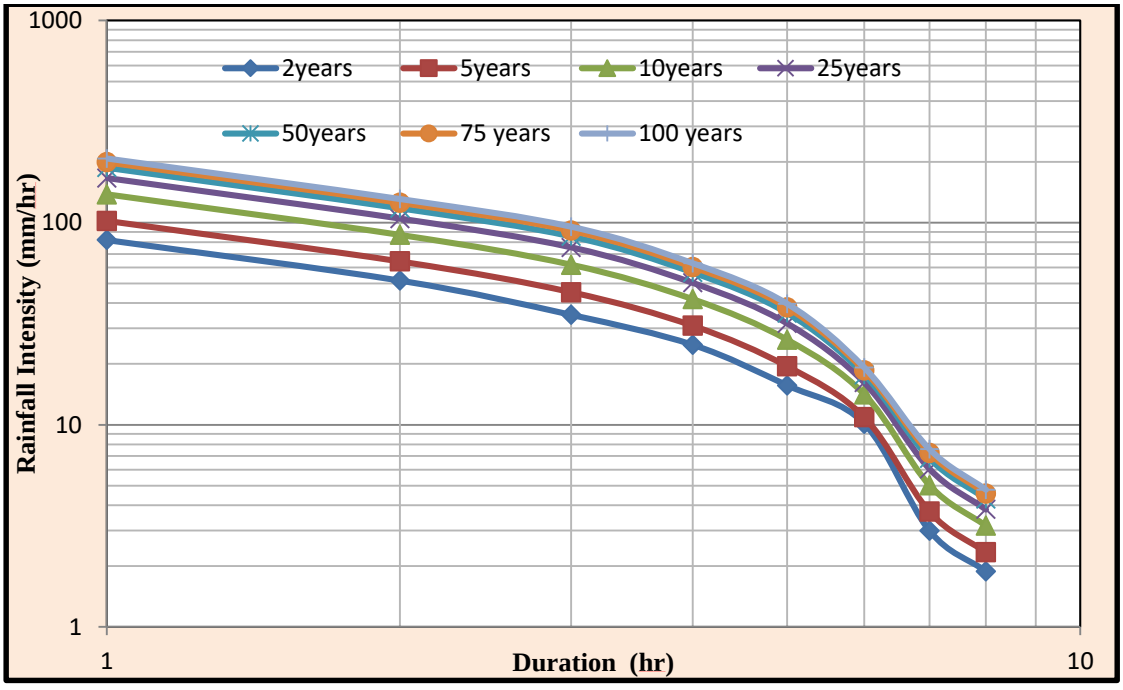
5.5.2.4. Intensity-Duration-Frequency (IDF)Curve:

A usual IDF Curve implies: **Intensity** (The vertical axis of the curve represents rainfall intensity, typically measured in millimeters per hour (mm/hr.). In general, Higher intensity indicates heavier rainfall.)**Duration** (The horizontal axis represents rainfall duration, usually measured in minutes, hours, or days. Duration indicates the length of time for which rainfall occurs) **Frequency** (IDF curves provide rainfall information for different return periods or frequencies, such as 2-year, 10-year, or 100-year events. Higher return periods indicate rarer and more extreme rainfall events.)With the help of the above-mentioned steps, the IDF Curves of the months of June, July, August, September for 49 years has been developed with the return periods of 2, 5, 10, 25, 50, 75 and 100 years. All the graphs **[Figure No. 5.5.9 (i-iv)]** exhibit the same patterns that-If the duration is fixed, with the rainfall increase from 2 years to 5 years to 100 years, the intensity increases. On the other hand, if the intensity is fixed, the duration of the rainfall increases from 2 years to 5 years to 100 years. And if the return period is fixed say for the 2-year return period as duration

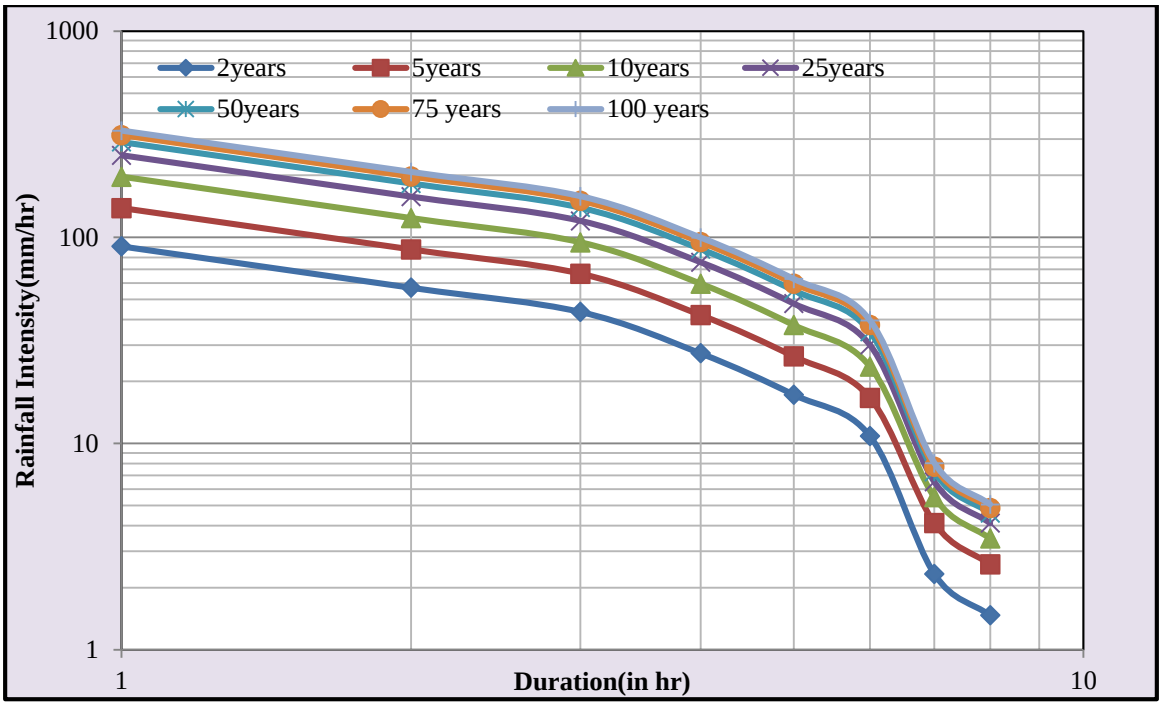
of rainfall increases, the intensity of the rainfall decreases. So, Longer rainfall events are not very intense as there is a progression in the time of return periods.



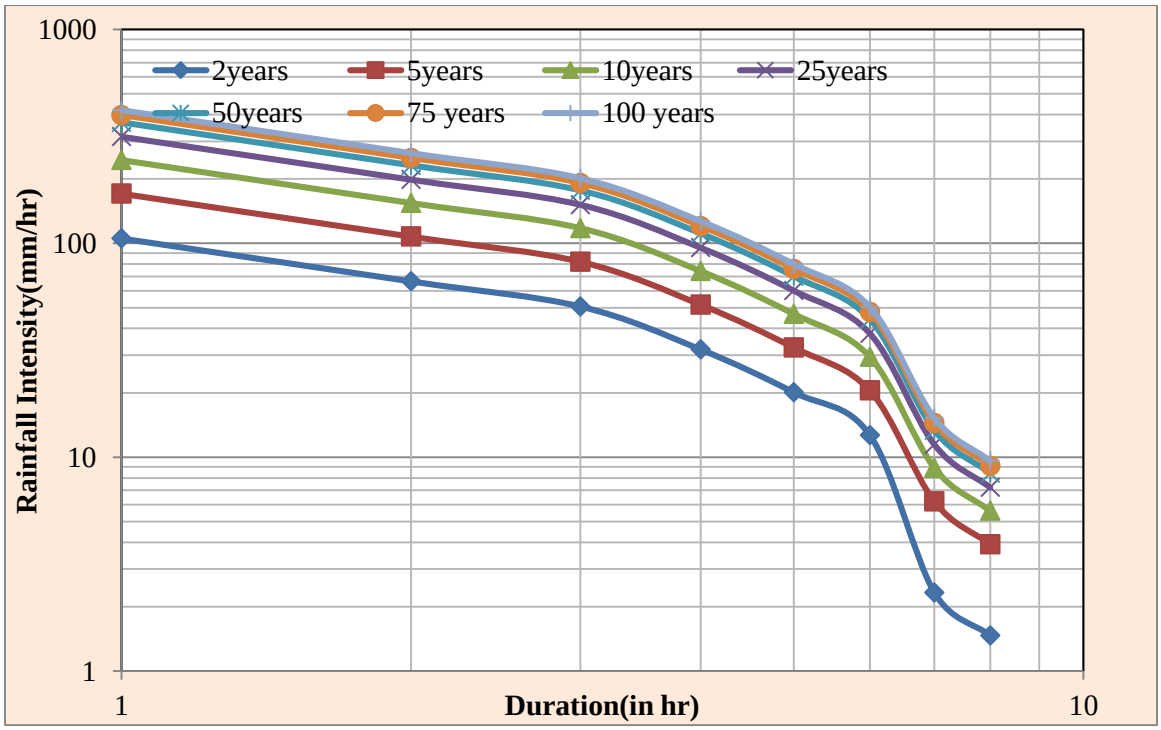
(i)June



(i) July



(iii) August



(iv) September

Figure No. F5.5.9. Intensity-Duration-Frequency (IDF) Curve (*Source:* Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

5.5.2.5 Rainfall Indices:

- **Rainfall Anomaly Index (RAI) (Van Rooy,1960)**

Figure No. F5.5.10 shows both the positive and negative anomalous years in terms of rainfall, but the negative anomaly hit much bottom (up to near about -15) than the positive ones (up to 8) has gone up like the years 2011,2012,2013 have really seen worst kind of negative rainfall anomaly.

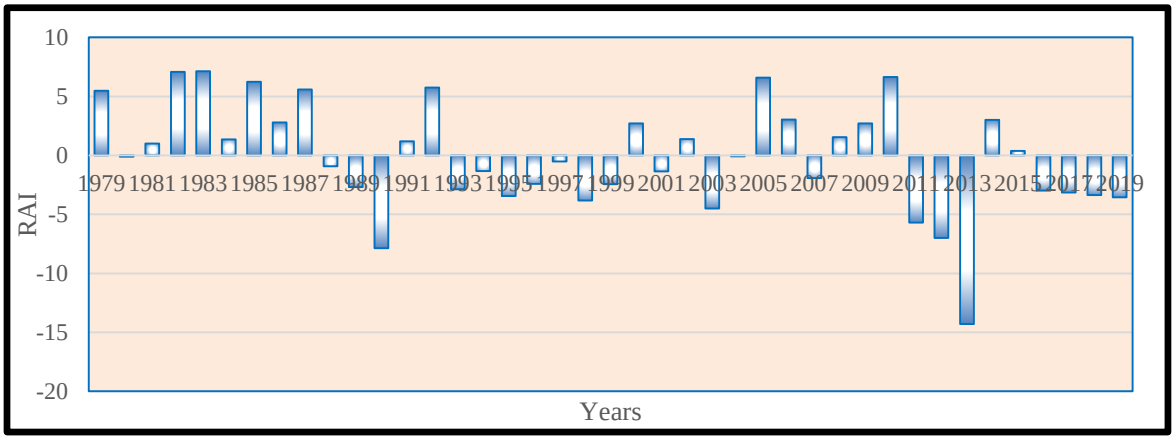


Figure No. 5.5.10. Rainfall Anomaly Index (RAI)

- **Precipitation Concentration Index (Oliver 1980)**

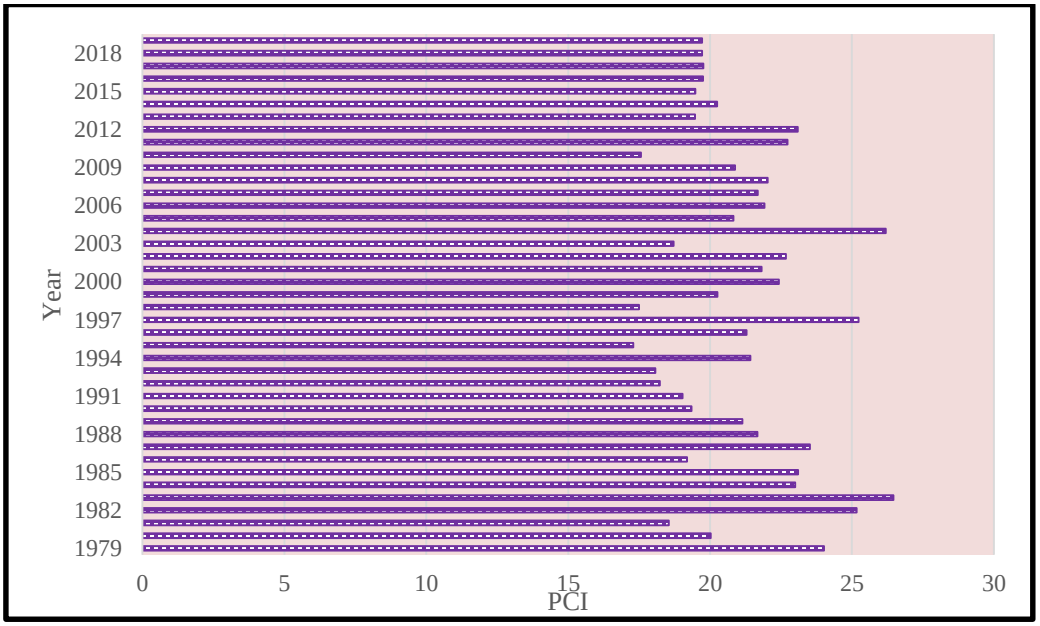


Figure No. 5.5.11. Precipitation Concentration Index (PCI)

The calculated value for PCI is **21.06,** signifying a strongly irregular concentration of precipitation.

- **Rainfall Seasonality Index (RSI) (Walsh and Lawler 1981)**

The calculated average value for RSI is **0.18** which somehow is close to having a moderate distribution of rainfall.

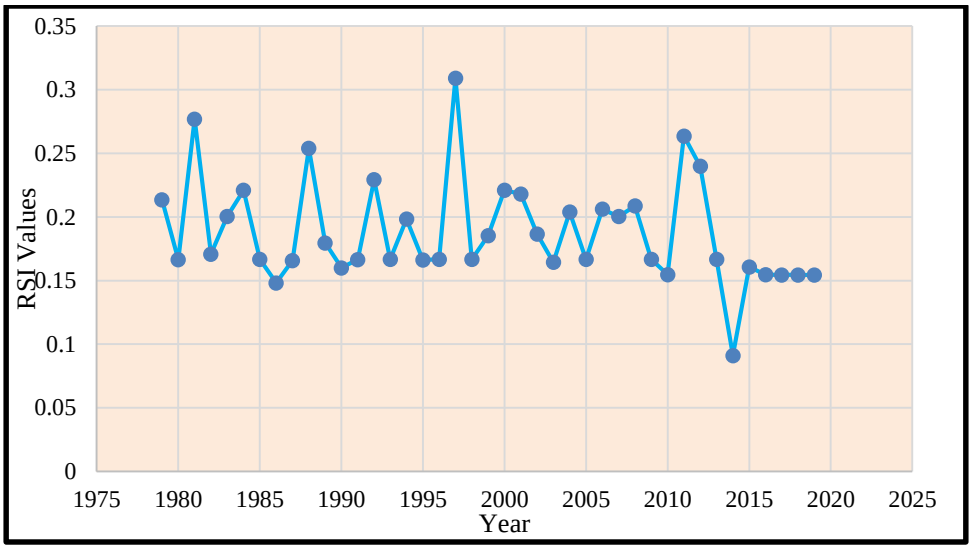


Figure No. 5.5.12. Rainfall Seasonality Index (RSI)

- **Rainfall Deviation Index (RDI):**

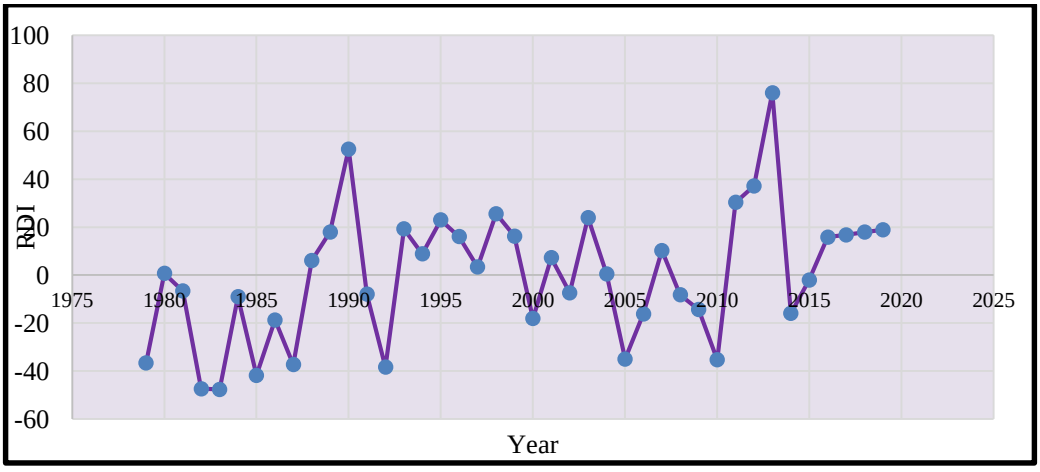


Figure No. 5.5.13. Rainfall Seasonality Index (RSI)

Source: Computed with the data retrieved from the official website of SWAT Model (https://swat.tamu.edu/data/cfsr)

The calculated value for RDI is -**0.2**, which falls under the normal category of rainfall according the category specified by IMD mentioned in the Methodology(Chapter-Four).

List of References:

1. Arif, Siti Nur Afiqah Mohd, Mohamad Farhan Mohamad Mohsin, Azuraliza Abu Bakar, Abdul Razak Hamdan, and Sharifah Mastura Syed Abdullah. 2017. "Change Point Analysis: A Statistical Approach to Detect Potential Abrupt Change." *Jurnal Teknologi* 79(5):147–59. doi: 10.11113/jt.v79.10388.
2. Ayeni, Adebanji William. 2014. "Empirics of Standard Deviation." *Empirics of Standard Deviation* (29 July):1–8. doi: 10.13140/2.1.1444.6729.
3. Bharali, B. 2015. "A Study on Frequency Analysis for Puthimari Catchment by Gumbel Distribution Method." *Journal of Civil Engineering and Environmental Technology* 2(10):19–22.
4. Champion, R., C. T. Lenard, and T. M. Mills. 1998. "Demonstrating the Durbin-Watson Statistic." *Journal of the Royal Statistical Society Series D: The Statistician* 47(4):643–44. doi: 10.1111/1467-9884.00161.
5. Dhorde, Amit G., and Mohammad Zarenistanak. 2013. "Three-Way Approach to Test Data Homogeneity : An Analysis of Temperature and Precipitation Series over SouthWestern Islamic Republic of Iran." *J. Ind. Geophys. Union* 17(3):233–42.
6. Gulap, Sonowal. 2019. "Method: A Lower Downstream of Lohit River (Dangori River)." *International Journal of Civil Engineering and Technology* 10(11):229–34.
7. Hakuba, Maria Z., Arturo Sanchez-Lorenzo, Doris Folini, and Martin Wild. 2013. "Testing the Homogeneity of Short-Term Surface Solar Radiation Series in Europe." *AIP Conference Proceedings* 1531:700–703. doi: 10.1063/1.4804866.
8. Hammond, M. J., A. S. Chen, S. Djordjević, D. Butler, and O. Mark. 2015. "Urban Flood Impact Assessment: A State-of-the-Art Review." *Urban Water Journal* 12(1):14–29. doi: 10.1080/1573062X.2013.857421.
9. Huitema, Bradley, and Sean Laraway. 2015. "Autocorrelation." (August 2006).
10. Jayasree, V., and B. Venkatesh. 2015. "Analysis of Rainfall in Assessing the Drought in Semi-Arid Region of Karnataka State, India." *Water Resources Management* 29(15):5613–30. doi: 10.1007/s11269-015-1137-1.

11. Kamal, Neel, and Sanjay Pachauri. 2018. “Mann-Kendall Test - A Novel Approach for Statistical Trend Analysis.” *International Journal of Computer Trends and Technology* 63(1):18–21. doi: 10.14445/22312803/ijctt-v63p104.
12. King, Maxwell L. 1995. “The Application of the Durbin-Watson Test to the Dynamic Regression Model under Normal and Non-Normal Errors.” *Econometric Reviews* 14(4):487–510. doi: 10.1080/07474939508800333.
13. Mayank B, Patel. 2020. “Flood Frequency Analysis Using Gumbel Distribution Method at Garudeshwar Weir, Narmada Basin.” *International Journal of Trend in Research and Development* 7(1):2394–9333.
14. Nandargi, S., and S. S. Mulye. 2012. “Relationships between Rainy Days, Mean Daily Intensity, and Seasonal Rainfall over the Koyna Catchment during 1961-2005.” *The Scientific World Journal* 2012. doi: 10.1100/2012/894313.
15. Osei, Marian Amoakowaah, Leonard Kofitse Amekudzi, Akoto Yaw Omari-Sasu, Edmund Ilimoan Yamba, Emmanuel Quansah, Jeffrey N. A. Aryee, and Kwasi Preko. 2021. “Estimation of the Return Periods of Maxima Rainfall and Floods at the Pra River Catchment, Ghana, West Africa Using the Gumbel Extreme Value Theory.” *Heliyon* 7(5):e06980. doi: 10.1016/j.heliyon.2021.e06980.
16. Pal, S., D. Mazumdar, and P. K. Chakraborty. 2015. “District-Wise Trend Analysis of Rainfall Pattern in Last Century (1901-2000) over Gangetic Region in West Bengal, India.” *Journal of Applied and Natural Science* 7(2):750–57. doi: 10.31018/jans.v7i2.678.
17. ProgrammingR. 2023. “Beginner to Advanced Resources for the R Programming Language.” Retrieved (https://www.programmingr.com/statistics/how-to-perform-a-durbin-watson-test-in-r/).
18. RESHU YADAV, S. K. TRIPATHI, G. PRANUTHI, and S. K. DUBEY. 2014. “Trend Analysis by Mann-Kendall Test for Precipitation and Temperature for Thirteen Districts of Uttarakhand.” *Journal of Agrometeorology* 16(2):164–71. doi: 10.54386/jam.v16i2.1507.
19. Roy, Sukumar, and Nabajit Chakravarty. 2021. “Rainfall Analysis by Using Mann-Kendall Trend, Sen’s Slope and Variability at Six Stations of Andaman & Nicobar Islands.”

20. Saifuddin, a K. M. 2007. “Homogeneity and Trend Analysis of Temperature for Urban and Rural Areas.” (Civil):1–6.
21. Saini, Divya, Omvir Singh, and Pankaj Bhardwaj. 2022. “Standardized Precipitation Index Based Dry and Wet Conditions over a Dryland Ecosystem of NorthWestern India.” *Geology, Ecology, and Landscapes* 6(4):252–64. doi: 10.1080/24749508.2020.1833614.
22. Salarijazi, Meysam. 2012. “Trend and Change-Point Detection for the Annual Stream-Flow Series of the Karun River at the Ahvaz Hydrometric Station.” *African Journal of Agricultural Reseearch* 7(32):4540–52. doi: 10.5897/ajar12.650.
23. Sam, Masi G., Ify L. Nwaogazie, Chiedozie Ikebude, Ubong J. Inyang, and Jonathan O. Irokwe. 2023. “Assessment of Climate Change Induced Trend, Magnitude, and Change Point Date in 24-Hourly Annual Maximum Series Rainfall Data for Port Harcourt Metropolis in Nigeria.” *International Journal of Environment and Climate Change* 13(7):118–28. doi: 10.9734/ijecc/2023/v13i71859.
24. Sasireka, K., C. R. Suribabu, and T. R. Neelakantan. 2019. “Extreme Rainfall Return Periods Using Gumbel and Gamma Distribution.” *International Journal of Recent Technology and Engineering* 8(4S2):26–29. doi: 10.35940/ijrte.d1007.1284s219.
25. Shamarti, Hasanain. 2017. “Analysis of Rainfall Seasonality Index in Iraq.” *Diyala Journal For Pure Science* 13(1):188–202. doi: 10.24237/djps.1301.158a.
26. Silva, Tarciana Rafaela Barbosa Figueiroa, Carlos Antonio Costa dos Santos, Delson José Figueiroa Silva, Celso Augusto Guimarães Santos, Richarde Marques da Silva, and José Ivaldo Barbosa de Brito. 2022. “Climate Indices-Based Analysis of Rainfall Spatiotemporal Variability in Pernambuco State, Brazil.” *Water (Switzerland)* 14(14):1–26. doi: 10.3390/w14142190.
27. Svensson, Anna, and Lizzy Whitehead. 2021. “Ipcc Report Reinforces Need for More Investment in Flood Resilience no Title.” *UNDRR*.
28. Toreti, A., F. G. Kuglitsch, E. Xoplaki, P. M. Della-Marta, E. Aguilar, M. Prohom, and J. Luterbacher. 2011. “A Note on the Use of the Standard Normal Homogeneity Test to Detect Inhomogeneities in Climatic Time Series.” *International Journal of Climatology* 31(4):630–32. doi: 10.1002/joc.2088.
29. Tuomenvirta, Heikki. 2002. “Homogeneity Testing and Adjustment of Climatic Time

Series in Finland." *Geophysica* 38(1–2):15–41.

30. Wang, Fan, Wei Shao, Haijun Yu, Guangyuan Kan, Xiaoyan He, Dawei Zhang, Minglei Ren, and Gang Wang. 2020. "Re-Evaluation of the Power of the Mann-Kendall Test for Detecting Monotonic Trends in Hydrometeorological Time Series." *Frontiers in Earth Science* 8(February):1–12. doi: 10.3389/feart.2020.00014.
31. Yellapu, Vikas. 2018. "Full Text Introduction." *Descriptive Statistics* 4(1):60–63. doi: 10.4103/IJAM.IJAM.

Following the steps and methods stated in Chapter Four (Methodology) the layers of the input data have been prosecuted in the model InVEST-UFRM.

5.6.1. The Particular Inputs for the Model:

a) The Land Use Land Cover Classification of the year 1991 and 2021:

The LULC Classification of Burdwan Municipality has already been previously discussed in chapter 5 Section- 5.1. The two years of apart 30 years have been chosen to find the differences between the run-off generation and retention as there is huge change in urban area.

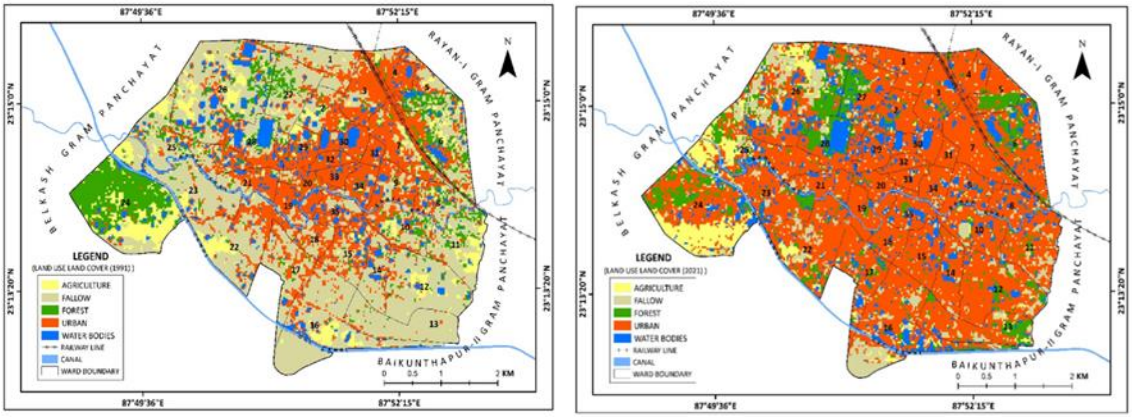


Figure No.5.6.1. The LULC Classified Images of 1991 and 2021

Source: LANDSAT Data ((https://www.usgs.gov/landsat-missions/landsat-data-access)

b) The Hydro-Soil Groups:

The hydrological soil group is made to classify soil based on its runoff potential. The United States Department of Agriculture (USDA) classified soil into four major textures, denoted by the letters A, B, C, and D, where A denotes sand, B defines sandy loam and loamy sand, C implies clayey loam and silty clayey loam, and D denotes primarily clayey soil. The classification is mostly identified by the availability of sand, loam, and clay. From lowest to highest, these four groups describe the potentiality of runoff. Burdwan

Municipality seemed to have been dominated with the HSG-D which represents high runoff potential as it is made of clay, silty clay, and sandy clay texture. with some major patches of HSG-C representing moderately high runoff potential as it is made of clay loam, sandy clay loam, loam, silty loam in Eastern, Northeastern, and Western part. In the extreme North-West and south-East corner the dual hydro soil group -C/D Prevails *(Cornell University Cooperative Extensoin 2021).*

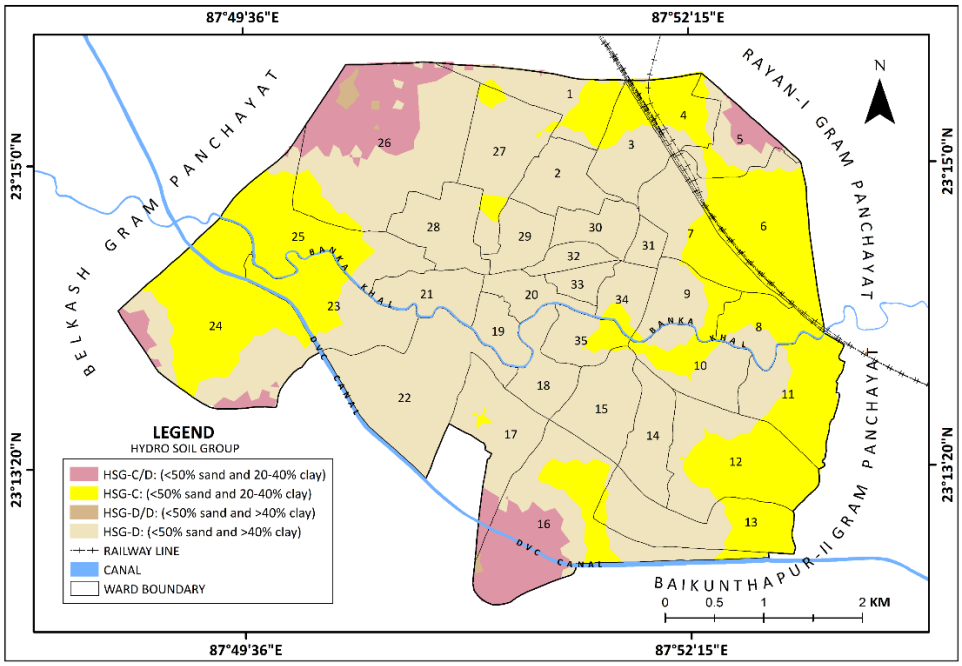


Figure No.5.6.2. The Hydro-Soil Map pf Burdwan Municipality

Source: Ear5th Data CMR Search (EARTH DATA _https://cmr.earthdata.nasa.gov/search/concepts/C2216864285-ORNL_CLOUD.html)

C)The Bio-physical Table:

The Soil Conservation Services and Curve Number (SCS- CN) technique is one of the basic and straightforward methods for predicting rainfall runoff. Land cover data is used in hydrologic modelling to predict the value of surface irregularity or friction, which impacts the velocity of water flowing overland *(Ara and Zakwan 2018)*. The runoff potential of the land is represented by CN, which is denoted by soil antecedent moisture condition (AMC), soil type, land use, and treatment value spans between 0 and 100. Higher

levels indicate a greater likelihood of runoff *(Bose and Mazumdar 2023)*. A table was constructed, and the values connected with the table were merged with specific knowledge about the study region, as well as appraising the land use categories and HSG data.

Table No.5.6.1 The Bio-Physical Properties of the LULC Classes

A	B	C	D	E	F
LUCODE	CLASSES	CN_A	CN_B	CN_C	CN_D
8	AGRICULTURE	51	57	76	86
15	FALLOW	77	86	91	94
19	FOREST	43	65	76	82
21	URBAN	98	98	98	98
42	WATER BODIES	1	1	1	1

Source: HEC_HMS Technical Reference Manual

d)Area of Interest:

The Municipal Boundary has been selected as an input for area of interest.

e) Calculation of Rainfall Depth:

Rainfall depth is taken from previously calculated Intensity-Duration-Frequency Curve (chapter no -5, Section-5.5)

5.6.2. The Results:

5.6.2.1. Run-off generation related to Rainfall:

In the year of 1991, it has been witnessed that central part or the most urbanized area of Burdwan Municipality has the runoff potentiality between 5.6 mm to 11.1 mm with some even higher runoff of 11.2 mm to 16.1mm along with the railway lines, and many places on the either side of river Banka and Damodar, after 2 hrs hours of rainfall. After experiencing 32-mm rainfall, except waterbodies and green spaces, all the other areas generate 0mm to 8 mm Potential run-off, mostly the vegetative cover and fallow. The second scenario of 1991with 46 mm describes Burdwan Municipality as a flood-prone area

and there are very few scopes of recharge except some green patches situated on the fringe of the study area, with an increased runoff up to 30.2 mm **(Figure No.5.6.3-i &ii).** In the year 2021, the pre-dominant land use is urban area covering almost all the municipal area leaving some of the Western part with 32mm rainfall it records upto 24.2 mm run-off and with 46 mm rainfall the generation of runoff increases upto 39.2 mm.

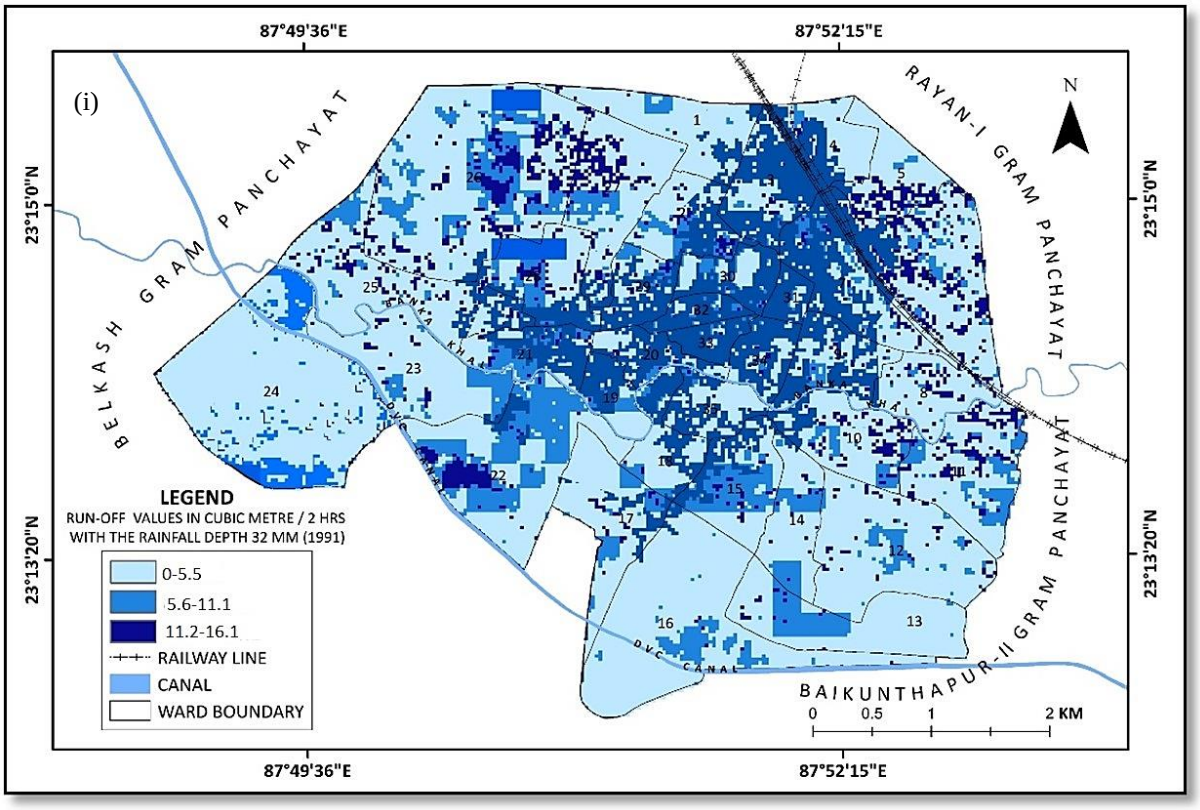
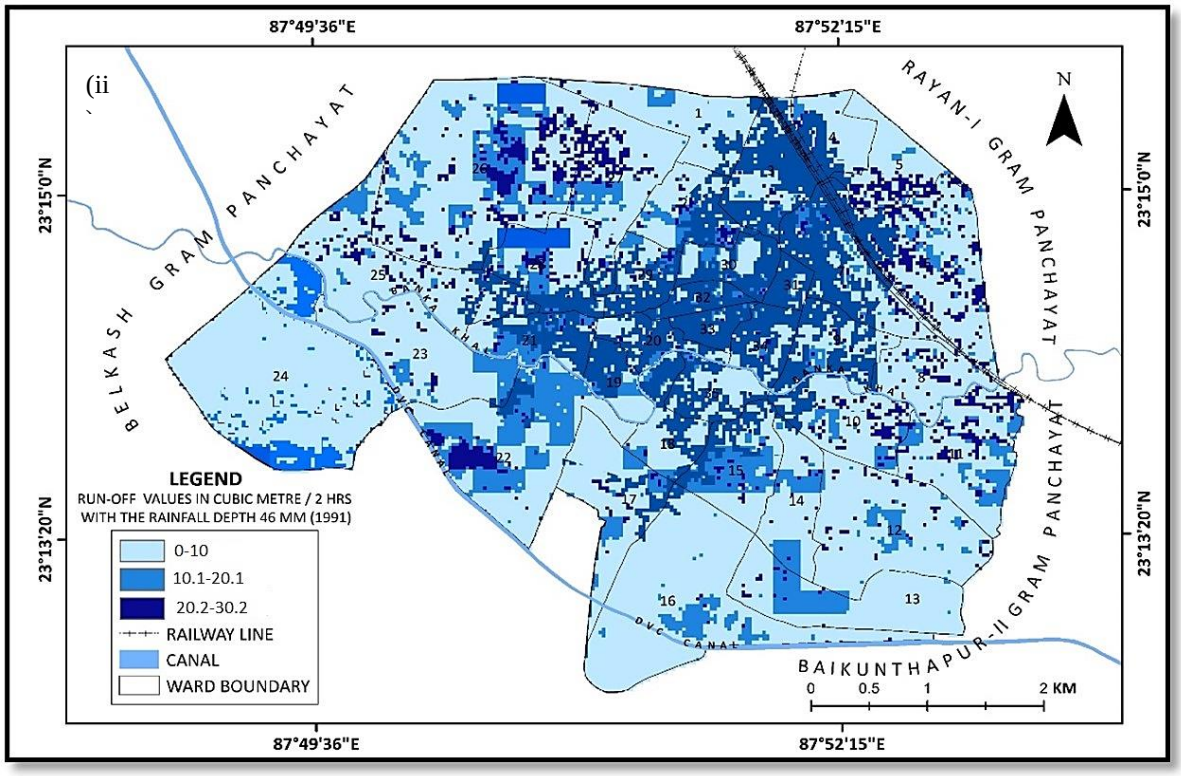
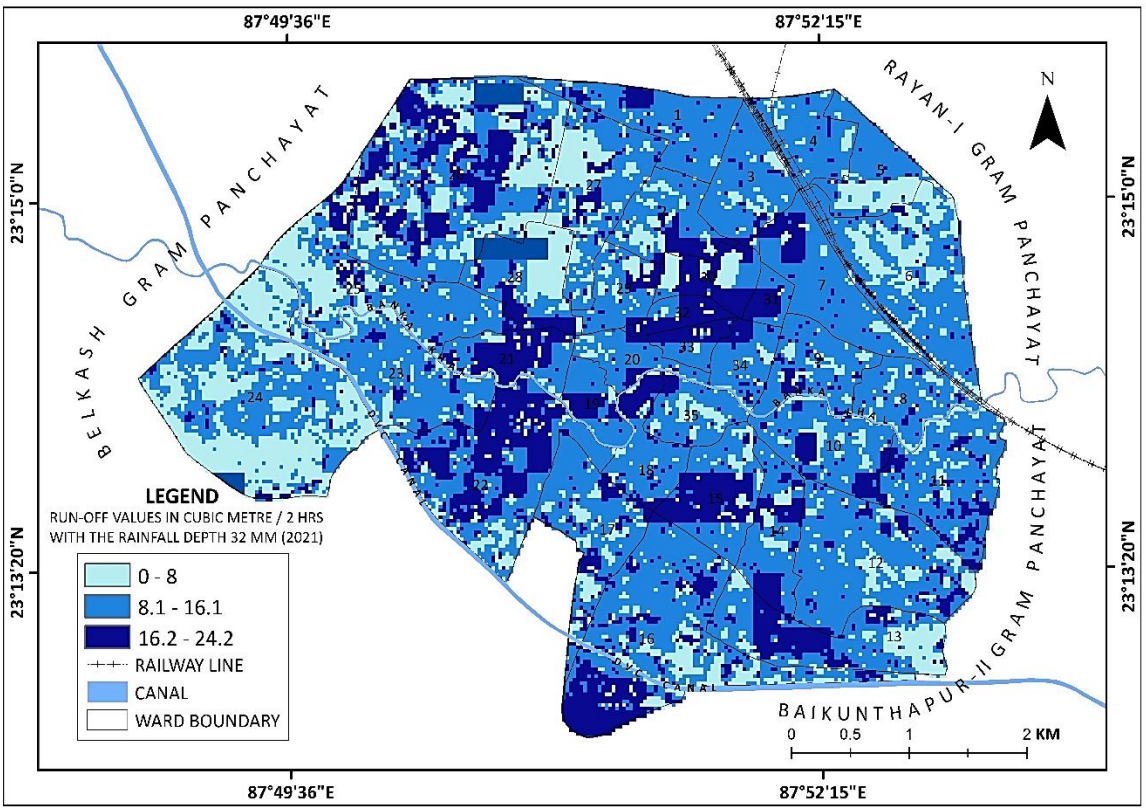


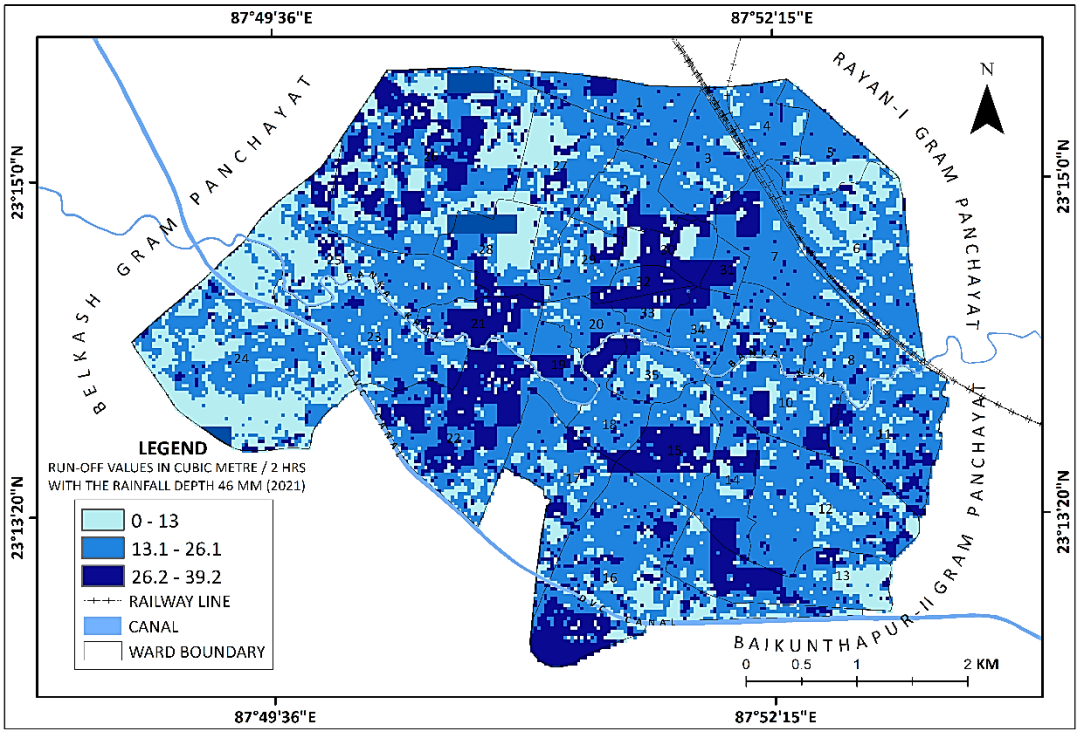
Figure.5.6.3. (i) and (ii) The Run-off Values (in Cubic metre/2hrs) with a rainfall depth of 32 mm and 46 mm in the backdrop of the year 1991

(ii) is on the next page.

(ii


87°49'36"E
87°52'15"E
23°15'0"N
23°13'20"N
BELKASH GRAM PANCHAYAT
RAYAN-I GRAM PANCHAYAT
BAIKUNTHAPUR-II GRAM PANCHAYAT
N
LEGEND
RUN-OFF VALUES IN CUBIC METRE / 2 HRS
WITH THE RAINFALL DEPTH 46 MM (1991)
0-10
10.1-20.1
20.2-30.2
RAILWAY LINE
CANAL
WARD BOUNDARY
DVC CANAL
0 0.5 1 2 KM


87°49'36"E
87°52'15"E
23°15'0"N
23°13'20"N
BELKASH GRAM PANCHAYAT
RAYAN-I GRAM PANCHAYAT
BAIKUNTHAPUR-II GRAM PANCHAYAT
N
LEGEND
RUN-OFF VALUES IN CUBIC METRE / 2 HRS
WITH THE RAINFALL DEPTH 32 MM (2021)
0 - 8
8.1 - 16.1
16.2 - 24.2
RAILWAY LINE
CANAL
WARD BOUNDARY
DVC CANAL
0 0.5 1 2 KM

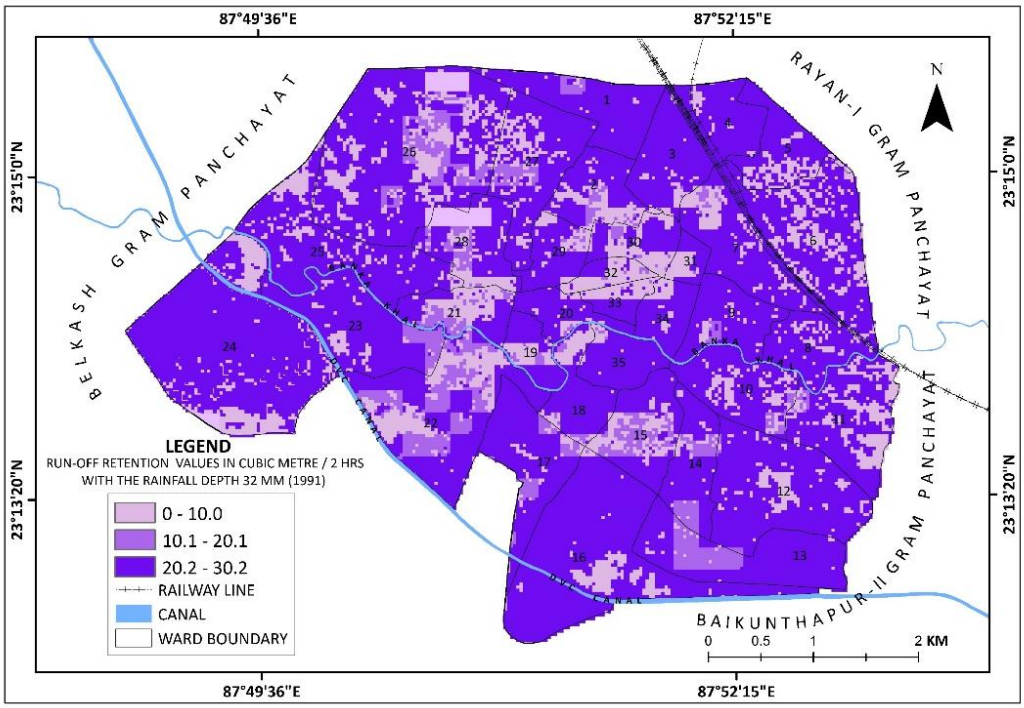


(i) is on the previous page and (ii)

Figure.5.6.4. (i) and (ii) The Run-off Values (in Cubic metre/2hrs) with a rainfall depth of 32 mm and 46 mm in the backdrop of the year 2021

5.6.2.2. Run-Off Retention in relation to Rainfall

Overall runoff retention scope has been reported to be very modest for Burdwan Municipality in the year of 1991; but it is extremely low in in the year of 2021 due to extreme extent of urbanization. The graphic illustration (Figure No.) shows that urban areas have a low capacity for runoff retention, but open green spaces have a higher capacity. For the year of 1991 as fallow was the pronounced type of landuse, recorded higher volume of run-off retentions upto 30.2 mm whereas the built up area has retained only upto 10 mm to some extent when the rainfall is recorded at 32 mm and with increasing rainfall the amount of run-off retention was marked up to 45.2mm. with the increasing urbanization in the year of 2021 it seems that only the water bodies and some patches on the bank of Damodar is holding the highest amount of run-off, that is upto 54.2 mm. majority of the municipal area has stored run-off less than 10 mm due to extensive coverage of impervious surfaces.



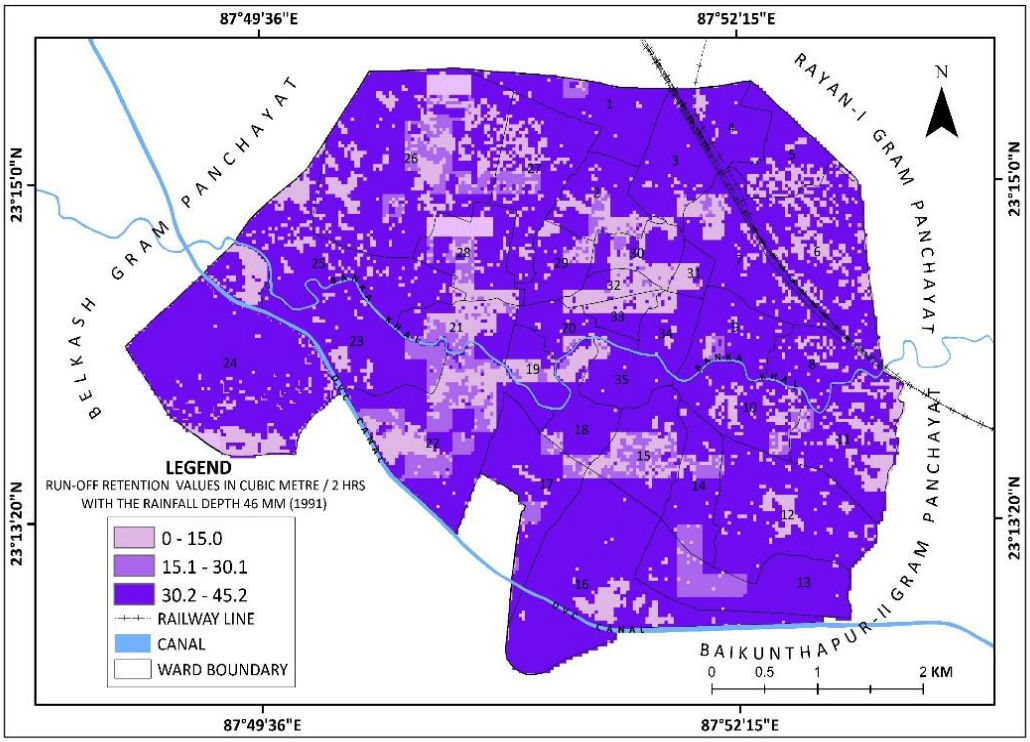


Figure.5.6.5 (i) and (ii) The Run-off Retention Values (in Cubic metre/2hrs) with a rainfall depth of 32 mm and 46 mm in the backdrop of the year 1991

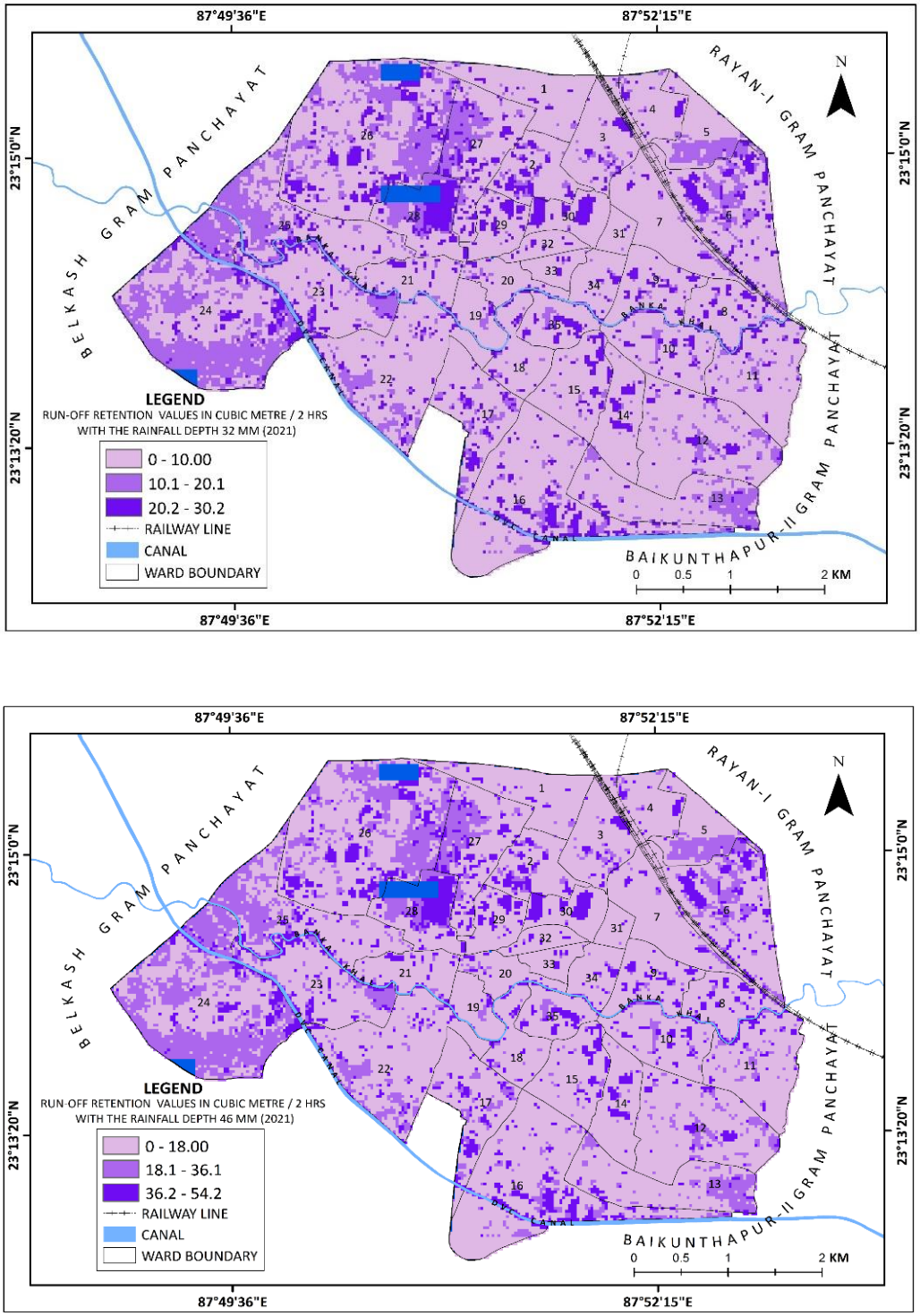


Figure.5.6.6 (i) and (ii) The Run-off Retention Values (in Cubic metre/2hrs) with a rainfall depth of 32 mm and 46 mm in the backdrop of the year 2021

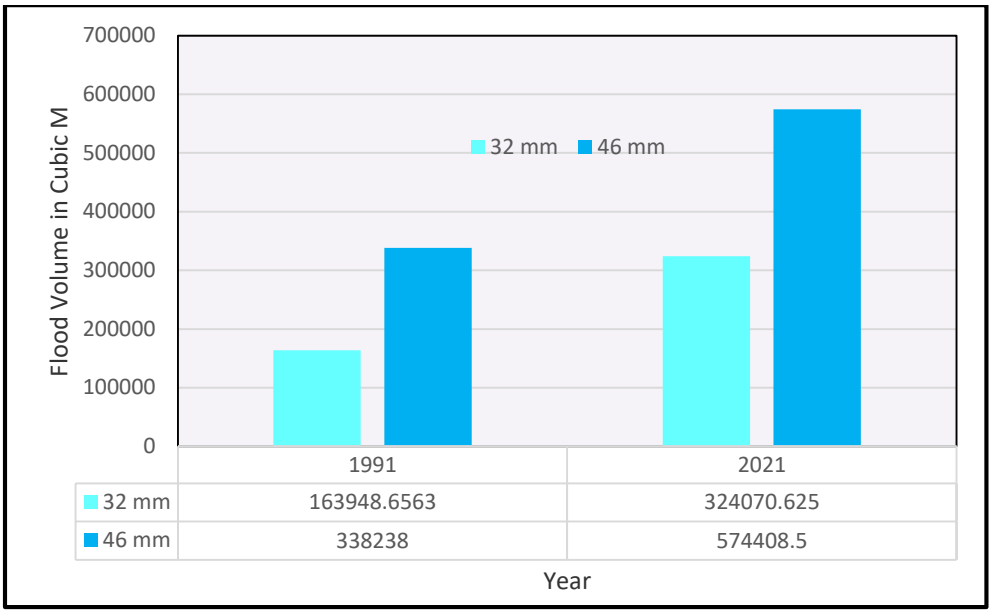


Figure No.5.6.7 Generated Flood Volume with Varied Rainfall Depth (Cubic M)

5.6.2.3. Generated Flood Volume with Varied Rainfall Depth

The volume of flood increases with the increasing amount of rainfall and ever-expanding impervious surface due to urbanization. The flood volume almost got doubled from 163948.6563 cubic m in the year 1991to 3240470.625 cubic m in the year of 2021 if the 32mm rainfall counts. And the same amount of increase in flood volume witnessed when the rainfall increased from 32 mm to 46 mm in case of both the years.

List of References:

1. Ara, Zeenat, and Mohammad Zakwan. 2018. "Estimating Runoff Using SCS Curve Number Method." *International Journal of Emerging Technology and Advanced Engineering* 8(5):195–200.
2. Bose, Suddhasil, and Asis Mazumdar. 2023. "Urban Flood Risk Assessment and Mitigation with InVEST-UFRM Model: A Case Study on Kolkata City, West Bengal State (India)." *Arabian Journal of Geosciences* 16(5):1–18. doi: 10.1007/s12517-023-11412-2.
3. Cornell University Cooperative Extensoin. 2021. "Hydrologic Soil Group for Phosphorus Index 2 . 0 and Nitrate Leaching Index Determination." *Agronomy Fact Sheet Series* Fact Sheet:1–2

5.7.0. Foreground:

Local People or the community is the first group of people that gets affected by urban floods or say any kind of floods to the highest extent (*Wolff 2021*). A perception survey could have been a helpful tool in determining how the flood affected the residents in the area. A perception survey is a research tool used in social science that gauges people's subjective views, attitudes, beliefs, or opinions on subjects. It seeks to capture people's understanding, interpretations, and evaluations of various social phenomena. Perception surveys can be conducted through questionnaires, interviews, focus groups, or other methods to collect data from a sample of individuals. The data collected through perception surveys can contribute to a deeper apprehension of human behavior, and societal dynamics, and inform decision-making processes in various fields *(Siddiqui, Elahi, and Bajwa 2017).* While there is no single "better" method for conducting perception surveys, questionnaire surveys have several advantages that make them a popular choice due to their standardized procedures, efficiency, cost-effectiveness, anonymity, and confidentiality *(Roopa and Rani 2012).*

5.7.1. Perception of People regarding Urban Amenities like Drainage, Water Bodies and Waste Management:

Citizen or the community is the backbone of any civic system-without their existence and cooperation, no programmes can achieve their goals. It is always desirable to consider one's perception, improve individuals' participation in tasks regarding betterment of urban amenities and their sense of responsibility towards it. (Alipour, Rahmati, and Akbarbeyki 2015)

5.7.1.1. Regarding Urban Drainage:

Majority of the most affected areas have only choto pucca drains thereby enhancing the chance of water logging and flooding. (**Figure No. 5.7.1.)** In the case of Ward 13, near Becharhat, the roads here are very low-lying and in height almost parallel to the drains.

The water clogging starts even with the discharge of the daily household water- bathing, washing clothes etc. and as the days pass till the evening the water level rises and enters the ground floor. The local people are elevating the roads by dumping rubbish which they are buying at a cost of 15 Rs. Everyday. Despite several complaints the Municipality did not pay any attention. In addition, extremely bad odors and continuous spread of diseases by mosquitoes are alarming threats to the kids. If the drains get blocked in one ward or the dump sites get filled the adjacent wards find it difficult mostly to accommodate the troubled Ward. Plastic and glass bottles are the main components that clog the drainage lines. **(Figure No. 5.7.2.**) The frequency of cleaning these silts in the affected areas are also irregular mostly. People residing in ward No.6, Railway Loco Colony, they have said the drains get cleaned when the higher official of railway visits. There are no workers who clean the drains and waste regularly. The drains overflow in the rainy season. (**Figure No. 5.7.3.)** A respondent woman of 60-62 years who has seen the era of coal engine railways was telling how the wastewater was put used efficiently at that point of time. The last 10 to 12 years have witnessed a huge population rise and with that the water inundation problem has risen. But there are some low-lying areas like Ward No.10, Khosbagan is a low-lying area but as the drainage condition is better means the cleaning of the drainage is done regularly, even if the water accumulates but also recedes in 10-15 minutes. The same condition is witnessed in GT Road, Mehedibagan, Punjabi bagan, Curzon gate, DM office. In many areas, the drainage lines seem to be covered to broaden the roads but as it prohibits further percolation to the excess and creates a rush of overland flow.

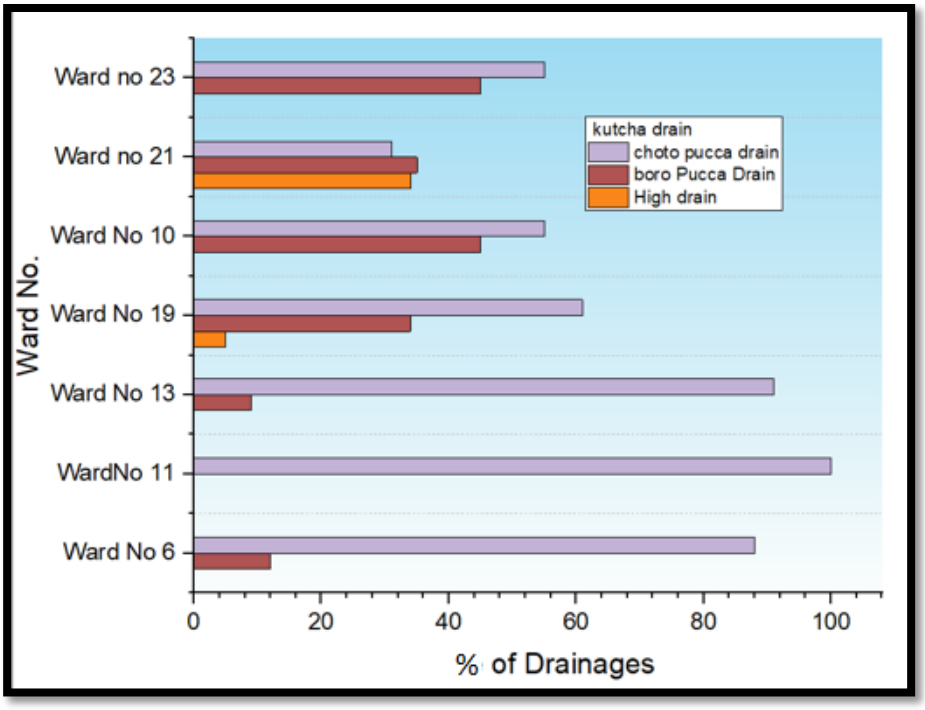


Figure No. 5.7.1. The Type of Drainages the Respondents Have in their Vicinity

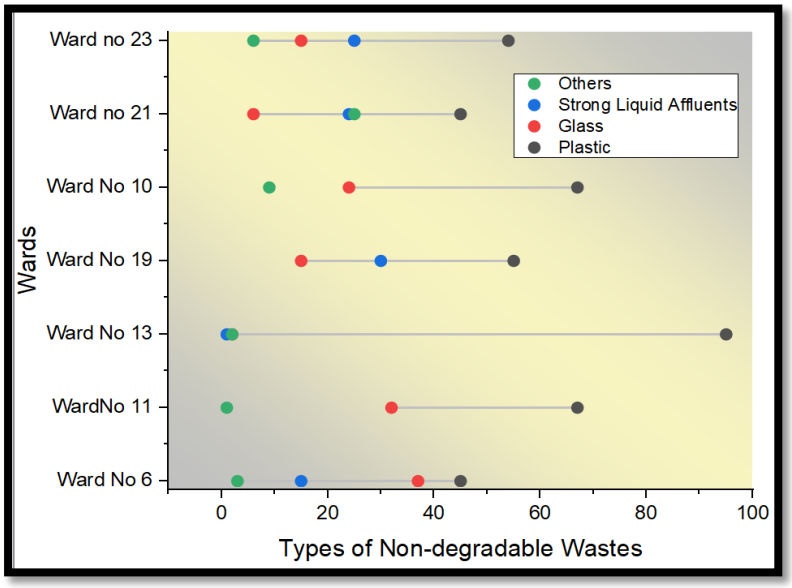
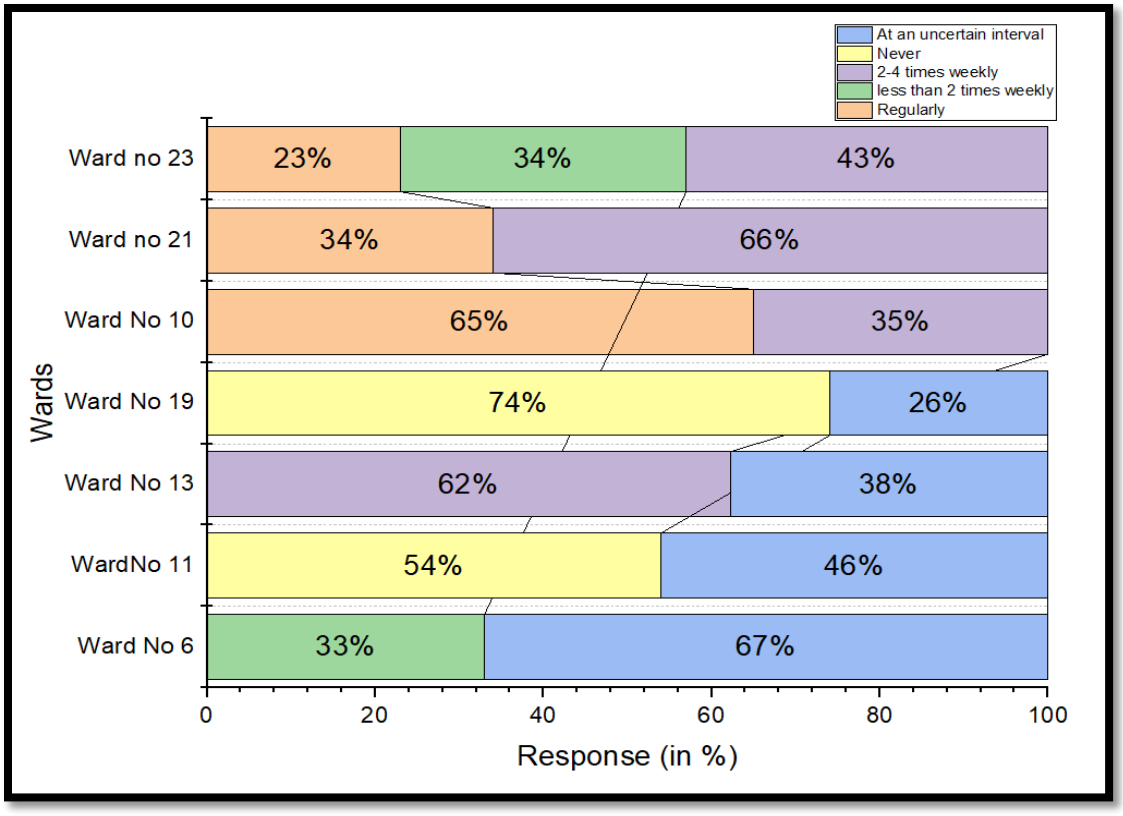


Figure No. 5.7.2. The Composition of Wastes in the Respondents' Localities



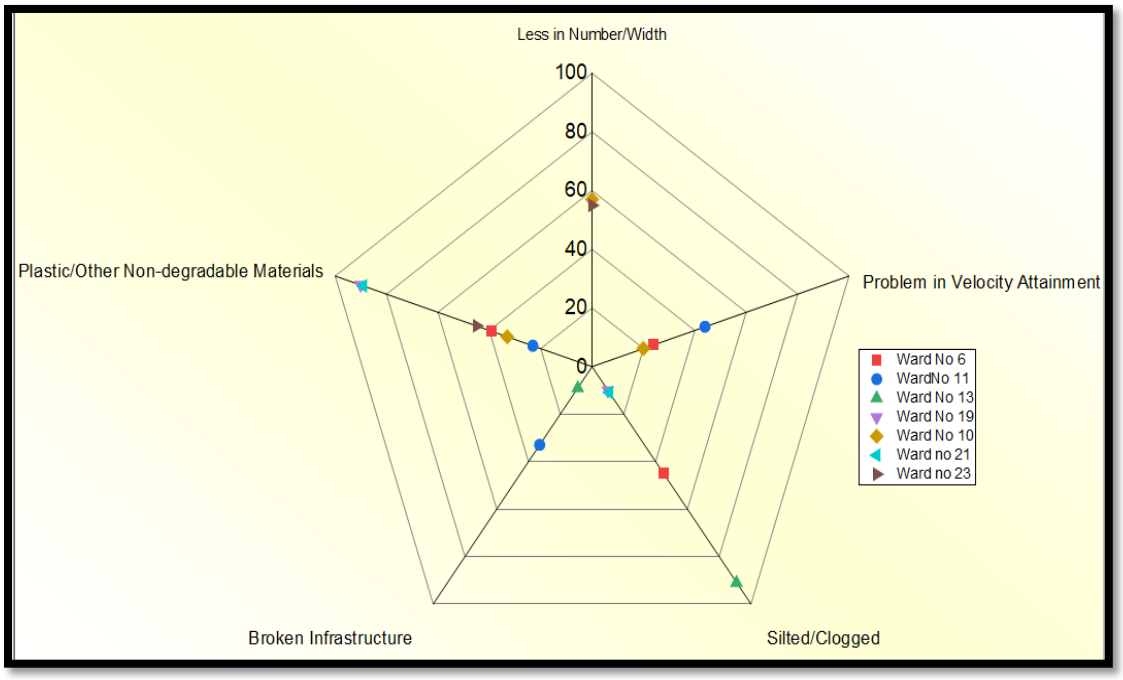


Figure No. 5.7.3 (Top)and 5.7.4.(Bottom) Regularity of Cleaning Drains and Issues in Drainage Network (*Source:* Primary Survey,2022-23)

5.7.1.2. Regarding Urban Water Bodies:

Burdwan Municipality is blessed with nearly 500 water bodies. So, most of the respondents have been living close to one or another water bodies (**Figure No. 5.7.5.)** But they have reported that they have witnessed many waterbodies to be encroached primarily to build high rises in their wards or the adjacent wards. **(Figure No. 5.7.8)** Neither the local citizens nor the Municipal authority has taken any steps against these incidents. Not only that, but the water bodies also which come under the legal properties of the Municipal Authority, do not get cleaned regularly. There are no restrictions on such restrictions on not littering the water- that is why the famous water bodies, around which parks or playgrounds are built like Krishna Sayer, they are found to accumulate trash into them. This is the scenario we are talking about the developed wards which are centrally located, so one can imagine the scenario of the peripheral wards. At times, the small ponds are so silted or covered with water plants, that it gets hard to make a difference between a water body and a field from a distance.

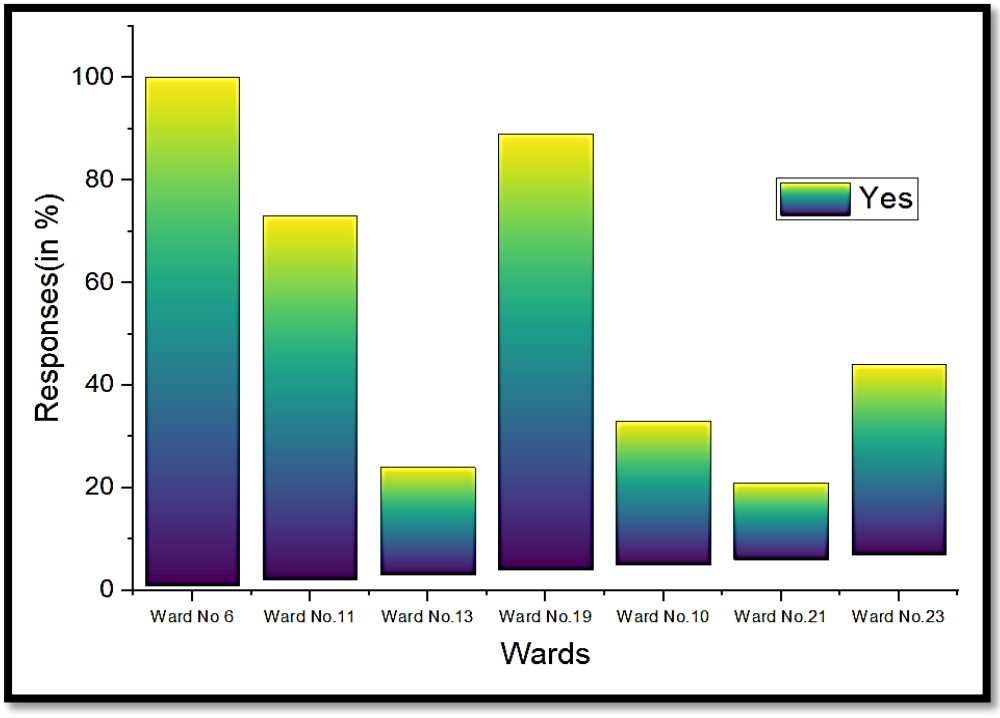


Figure No. 5.7.5. Whether the Respondents Have Water Bodies Nearby Their Place

(*Source:* Primary Survey,2022-23)

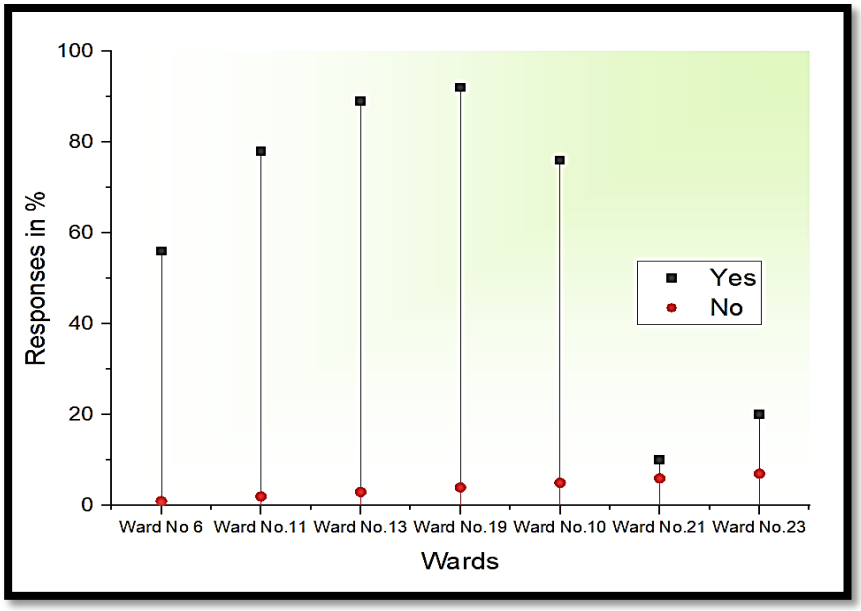


Figure No. 5.7.6. Whether They Have Witnessed Any Encroachment of Water Bodies

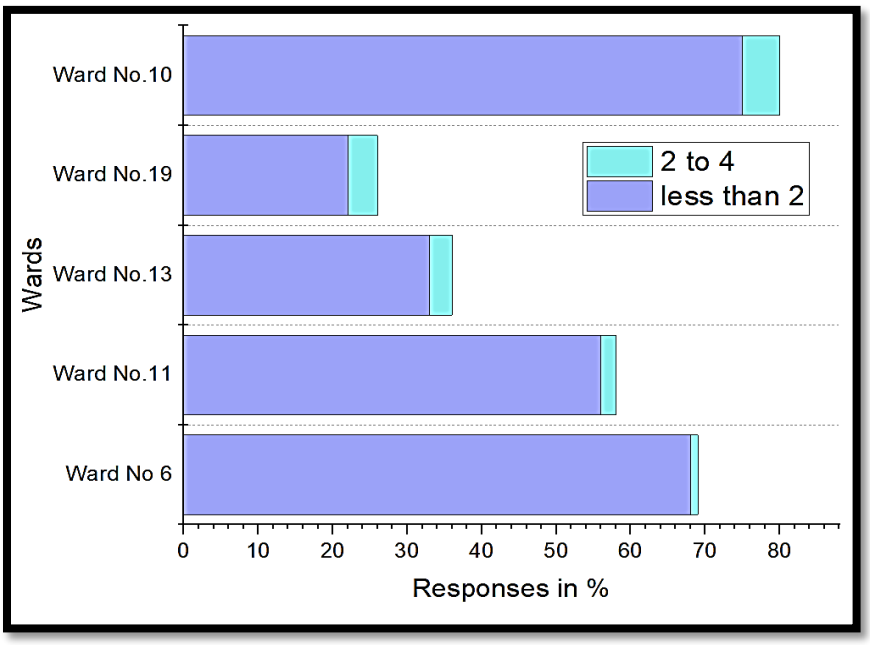


Figure No. 5.7.7. The Number of Waterbodies the Respondents Seen to Disappear

(*Source:* Primary Survey,2022-23)

5.7.1.3: Regarding Urban Solid Waste Management:

Urban solid waste has been also a menance for maintaing a healthy environment in the Municipal Area. One can easily find heap of waste lying on both side of the roads open and along drainage line, even in the nearest water bodies while paying a visit in any wards. While conversing with the citizens, it was clearly appeared that cleaning of the wards do not take place regularly, mostly in the wards which seem to be flood prone, there the waste removal happens at an irregular intervals. **(Figure No. 5.7.8)** Even if they sweep the main roads regularly, they do not do it for the side lanes. Very unfortunately, the fellow citizens lack the basic civic senses, at times they dump larger wastes like mattresses, chairs coming from farway wards. The people who live nearby the water bodies or river Banka, they throw the wastes directly intothe water, compleely avioding the Vats or dustbins.(**Figure No. 5.7.9)** On the other hand,there are several parcel of lands owned by individuals, who do not stay in the Municipality area anymore, eventually those lands has become dumpyards. And as they are personal propertiies there is a continuos tiff goes on between the local people and waste workers that who would be the cleaning authority in absence of owner. The wet silts are picked up from the drains and is left as it is at the side of the drains for much longer period of time than it should have been. The dumped wastes spread pungent odur and are breeding grounds for mosquitoes- thereby causing threats to the children especially. Despite several complaints to the Municipal authority, Nobody paid the attention to this severely threatened scanrio.The situation of Khosbagan (Ward No 10) and Rath Tala (Ward No.23) is a little bit better –possibly there might be two reasons: firstly, Khosbagan being the medical centre of the Municipality area (all well-equipped nursing homes, clinics, pathological labs are located)it needs to be cleaned regularly and secondly, both the areas are being locationally famous and geographically centralized. There is a sharp contrast distribution of conservancy facilities in the centrally positioned wards and the peripheral ones, which can be easily interpreted with the variation of the existing open and haphazard garbage dumps.

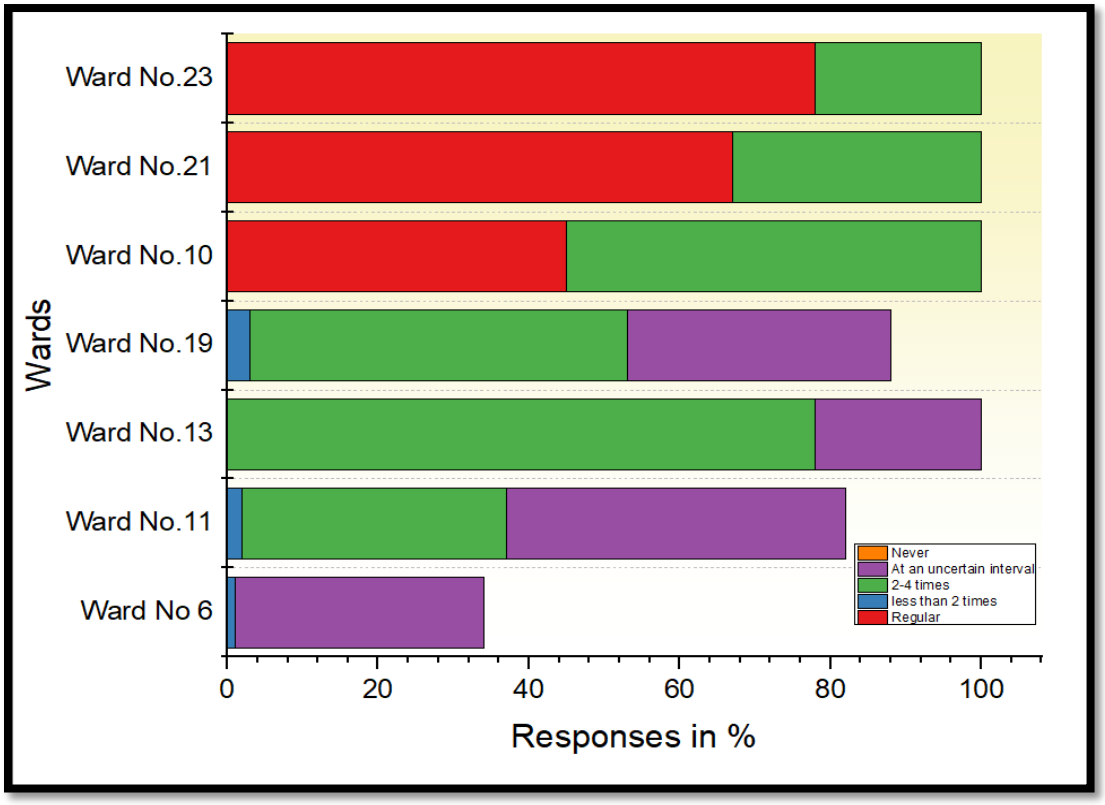


Figure No. 5.7.8 The Frequency of Cleaning the Wastes in the locality

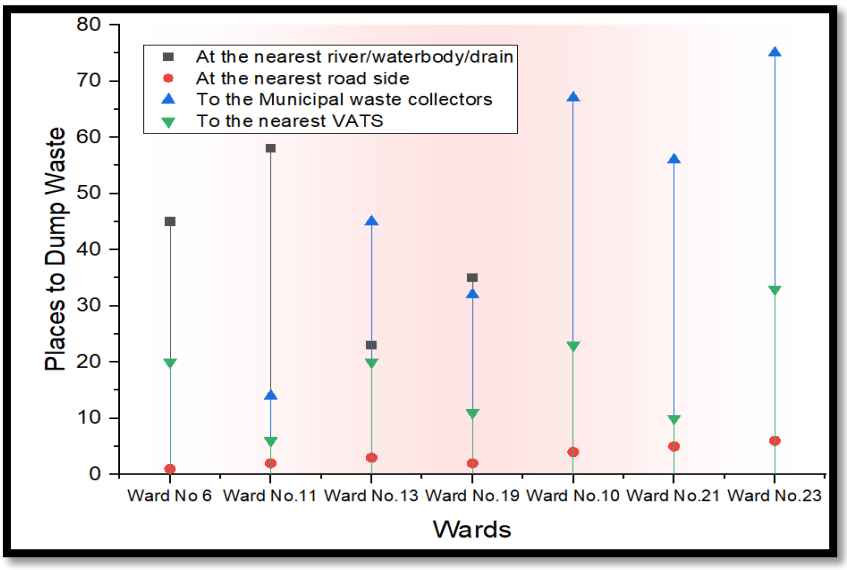


Figure No. 5.7.9 Places to Dump the Regular Waste (*Source:* primary Survey,2022-23)

5.7.2. The Causes behind the Urban Flooding Scenario According to the Citizens:

For the cause analysis scenario, the economic groups have been given priority as the objective was to find out the impact that urban flooding poses on the citizens. But before that, the causes should be understood. From the pilot survey done at the beginning of the study, some causes were identified and later developed while surveying with questionnaires. The options are given codes like 1,2,3 up to 11 and then they have been put in important order as responded by the surveyed people based on their experience of where they live and what they do for a living. (**Table No.5.7.1)**

Table No.5.7.1: The Causes of Urban Flooding as per the Citizens (Codes Given)

Codes	Causes
1	Poor Condition of Drainage network (Silted / Blocked)
2	Absence of regular drainage maintenance
3	Not Cleaning Banka River and dumping waste
4	Dumping of Waste here and there
5	Water Release by DVC
6	Lesser number of Waste workers
7	Low lying area
8	Low road heights in respect to drainage heights
9	Conflict and non-cooperative attitude from the citizens
10	No/less monitoring from municipality regarding drainage and waste
11	less number of campaigns/ awareness programs

Most of the respondents, who are permanent inhabitants of the municipality, agreed primarily on the poor condition of the drainage network, which is the result of a lack of regular drainage maintenance. Similar opinions have been given by the vegetable vendors of the surveyed markets also. On the contrary, the Municipal waste workers have focused on the carelessness and the non-cooperation of the citizens as they dump garbage here and there without following the basic civic guidelines of dumping wastes in the designated areas. (**Table No.5.7.2)**

Table No.5.7.2: The Causes of Urban Flooding as per the Citizens (as per importance order)

	Importance Order										
Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Service/Businessman of the Household (Ward No.11)	**1**	**5**	**2**	**10**	**4**	**3**					
Ward No.13	**7**	**8**	**1**	**2**	**4**	**10**	**11**				
Ward No.6	**2**	**4**	**1**	**10**							
Ward No.19	**3**	**10**	**1**	**2**	**1**	**4**					
Waste Workers (Ward No.13)	**6**	**4**	**9**	**10**	**11**						
Ward No.29	**4**	**1**	**6**								
Daily Wage Earners (Ward No.13)	**2**	**4**	**7**	**8**	**1**						
Ward No.31	**1**	**2**	**4**	**6**	**9**						

Sources: Primary Survey,2022-23

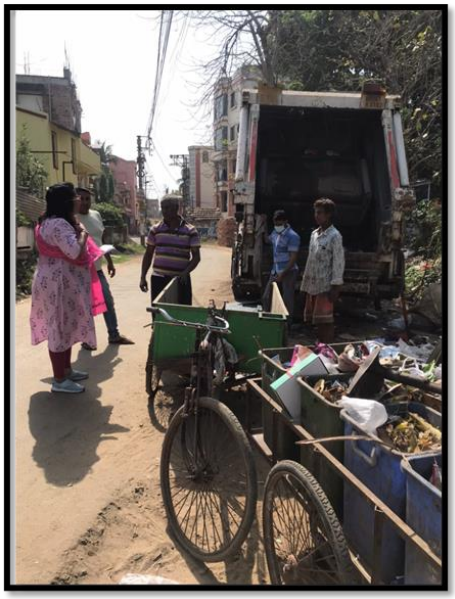


Photo. 5.7.1 and 5.7.2 (Left and Right) Conversation with the Municipal Waste Workers at the Ward No.13, Burdwan Municipality (*Source*: Primary Survey,2023)

5.7.3. The Impact of the Urban Flooding Scenario According to the Citizens:

The impact of the flooding is also analyzed like the causes have been studied. It seems that the daily wage earners and the Municipal waste worker gets impacted to a greater extent than the servicemen sectors. The vegetable vendors and the fish sellers talked about how

they need to stop to do their shops or how they face difficulties collecting the products they sell. Even if they have some things left from the previous days, those get perished, and the economic loss gets double for them. Their shops get closed for a consecutive 2-3 days if the situation persists. The permanent residents of ward no.13 in the Municipality talked about how even an untimely short-lived rain make the school closed where their children go. The Municipal On the contrary, there is a problem of transport for commuting jobs and even if they are available, they charge an extreme price for availing them. Some roads got closed, so it is not always that a diversion of roads could be possible which makes the traffic scenario the worst. **(Table No.5.7.4)**

Table No.5.7.3: The Impacts of Urban Flooding as per the Citizens (Codes Given) According to their Socio-Economic Condition

Impact	Codes
Impact (Service Men)	
Can not get out of home	1
Delay in commuting	2
Unavailability of the transport	3
extreme hike in toto/rickshaw fare	4
shortage of urban amenities	5
water pollution (tap water gets polluted)	6
Shifted to School buildings	7
Impact (Waste Workers)	
Stop working during rain	1
gets sick as the municipality does not provide measures	2
Impact (Daily wager)	
Daily in flowing of goods	1
Temporary Price hike	2
Uncertainty of the sale	3
shutter-down state of the shop	4
Perishing of the goods due to damp	5

(Source: Primary Survey, 2023)

Table No.5.7.4: The Impact of Urban Flooding as per the Citizens (as per importance order)

Respondents	Importance Order						
	1st	2nd	3rd	4th	5th	6th	7th
Service/Businessman of the Household (Ward No.11)	1	3	5	4	2		
Ward No.13	3	1	2	4	5		
Ward No.6	1	2	3				
Ward No.19	1	2	3				
Waste Workers (Ward No.13)	2	3	4				
Ward No.29	1	2	5	6			
Daily Wage Earners (Ward No.13)	4	5	6	3	2		
Ward No.31	3	5	6				

(*Source*: Primary Survey,2023)

When an overall assessment on the Municipal Services is prepared based a 5 Point Scale, it is seen that the group of daily wage earners are extremely dissatisfied with the current performance of the Municipality regarding drainage maintenance, followed by their hopeless attitude towards the basic facilities provided by the authorities. Same goes for the Waste Workers also as they think that the work, they are doing needs more manpower and equipment and a proper training of the dwellers. They said that they are trying their level best to provide the services timely, but it is also true that everything is not in their hands. On the contrary, the common people express their griefs about waste management as the wastes clog both the drainage and the roads. **(Table No.5.7.5)**

Table No.5.7.5. Assessment of the Municipal Service on 5 Point Scale by the Respondent's Groups

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am not satisfied with the drainage maintenace					
I am not satisfied with the Waste management					
I am not satisfied with the Overall Urban Amenties					
I doubt the Role of Municipal Authority					
I doubt the Role of neighbours					

By the Daily Wagers

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am not satisfied with the drainage maintenace					
I am not satisfied with the Waste management					
I am not satisfied with the Overall Urban Amenties					
I doubt the Role of Municipal Authority					
I doubt the Role of neighbours					

By the Municipal Workers

Statements	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am not satisfied with the drainage maintenace					
I am not satisfied with the Waste management					
I am not satisfied with the Overall Urban Amenties					
I doubt the Role of Municipal Authority					
I doubt the Role of neighbours					

By the Service Men

INDEX (in %)

75-100

50-75

25-50

0-25

Source: Primary Survey, 2022-23

List of References:

1. Alipour, Shadi, Fatemeh Rahmati, and Mina Akbarbeyki. 2015. “The Role of Citizenship Education and Participation in Waste Management.” *Science Journal* 36(3).
2. Roopa, S., and MS Rani. 2012. “Questionnaire Designing for a Survey.” *Journal of Indian Orthodontic Society* 46(4_suppl1):273–77. doi: 10.1177/0974909820120509s.
3. Siddiqui, Kamran Ahmad, Muhammad Ather Elahi, and Ishtiaq Ahmad Bajwa. 2017. “Heuristics of Designing Perception Surveys in Social Science.” *The Social Sciences* 12(12):2249–51.
4. Wolff, Erich. 2021. “The Promise of a ‘People-Centred’ Approach to Floods: Types of Participation in the Global Literature of Citizen Science and Community-Based Flood Risk Reduction in the Context of the Sendai Framework.” *Progress in Disaster Science* 10:100171. doi: 10.1016/j.pdisas.2021.100171.

CHAPTER: SIX

MAJOR FINDINGS

6.0. Foreground:

The major findings of the current research study are the key results or outcomes discovered through the investigation. These findings hopefully would be capable of answering the research questions mentioned in *Chapter Three* and the Objectives also. Let us have a look at the important outcomes objective wise.

6.1. Findings related to Objective.1:

- Urban areas are expanding, and the highest rise has been recorded in the decade of 2011 to 2021. If the same rate continues till 2051, each decade will be adding some 2 to 3 sq km urban area.
- The central part of the Municipality is mostly urbanized.
- Mostly the fallow part followed by the greeneries is mainly occupied by the encroaching urban area.
- The mean center of urbanization is shifting towards the southwestern part of the Municipality so is the sphere of influence.
- The directional growth of the urban area is also pointing toward the same inferences that the Western front of urban areas is expanding, and the South-Eastern part is being intensified.
- The previously discussed four types of drains are found in the Municipality-which is dominated by *choto* pucca drains and high drains are the least in the numbers.
- The primary survey says that the condition of the drainages is not that functional in every part of the Municipal Area.
- There are 61 water bodies lost in the last 13 years.
- There is a huge difference between waste accumulation and collection in most of the wards creating excess waste.
- All the facilities tend to be amassed in the central part of the municipality and the Western Part especially seems to be deprived of development.

- There are four factors -expanding urban area, diminishing water body, presence of kutcha drain, and increasing population density, which could be held responsible for the current situation of urban flood.

6.2. Findings related to Objective.2:

- The town of Burdwan lies in the low rainfall zone, and it does not share any influence with other stations or blocks.
- The annual rainfall is increasing but in an insignificant manner.
- The month of September has rainy days almost like July and August have.
- With the change point model, it is found that no halves of rainfall show any trend of increase.
- The trend of rainfall (increase or decrease) is statistically insignificant.
- Rainfall indices show a fluctuating pattern of rainfall.
- The pattern of short-lived high intensity rainfall is found in the months of July, August, and September.
- After running INVEST-UFRM model for generating the run-off volume, it is found that the run-off value and the flood volume both have increased in 2021 since 1991 while the run-off retention has significantly decreased.
- As far as the impact of the Damodar River is concerned the water entered to a greater extent in the town in the years 1978 and 2000 as the peak discharge was higher(much above the average value).
- The Monsoon water volume is usually higher than the usual days, as DVC has released water 2/3 days prior to the survey.
- In the monsoon season, the bridges near Amtala and Alamganj tend to show water volume above the average, may be due to higher cross-sectional area.

6.3. Findings related to Objective.3:

- Upon asking about the general conditions of Urban Drainage, Water Body, and waste management, mostly they have opined that they live in the vicinity of Choto Pucca drains, which might be incapacitated for flood management.

- Plastics and non-degradable items are mostly the components that have contributed to the bottle-neck situation of the drainages.
- The Wards which are on either bank of Banka River, have complained about the drainages not getting cleaned by the waste workers.
- The composition of the waste is quite like drainage as far as the plastic material is concerned.
- The discussion about the causes and impacts was very much ward-specific, so no general inferences could have been drawn.
- As far as the assessment of the Municipal services counts, people showed their dissatisfaction with the drainage and waste management activities.

These profound outcomes will help to formulate some regular and practical guidelines for the management of the urban flooding in Burdwan Town.

CHAPTER: SEVEN

RECOMMENDED MAJOR GUIDELINES & CONCLUSION

CHAPTER SEVEN:
RECOMMENDED MAJOR GUIDELINES AND CONCLUSION

7.0. Foreground:

As far as the urban surface drains are concerned, the Indian Government has stringent schemes on regular drainage cleaning with heavy machinery, its inspection and monitoring where it is lucidly written about the frequencies of drainage cleaning and maintenance procedures (CPHEEO, 1999) .To support municipal solid waste management, the Central Government granted the 12th and 13th Finance Commission Grants and Funds for Municipal Solid Waste Management. From 2005 onwards, programmes such as UIDSSMT (Urban Infrastructure Development Scheme for Small and Medium Towns) and JNNURM (Jawaharlal Nehru National Urban Renewal Mission), as well as the most recent Swachh Bharat Mission called SBM, were implemented. *(Mani and Singh 2016)* We discovered that, except for the Segregation of Wastes at the Source and Plastic-Ban policies (which are not effectively checked regularly), no additional efforts have been implemented in Burdwan Municipality. There is a significant discrepancy between the regulations on paper and the reality on the ground. *Experiencing some consecutive days in the field area, some of the suggestions can be incorporated into already implemented plans to make the urban management practices sustainable.*

7.1. Site-Specific Recommended Urban Flood Management Measures:

Mostly any kind of disaster comes with two kinds of management strategies- Structural and Non-Structural. Structural measures of disaster management refer to physical interventions and measures designed to lessen the impact of a disaster and Non-structural measures of disaster management focus on planning, policies, and practices that aim to mitigate the impact of disasters. Here also, the suggestions are formulated likewise.

7.1.1. Structural Measures:

- As it is very hard or next to impossible to cease the growth of urban areas, the first thing that needs to be done is to build drainage systems at par with the population and urbanization growth in terms of numbers, infrastructure, and capacity.
- The Existing drainage should be cleaned regularly so that it stops the huge amount of siltation from occurring and functions the drainage system properly in the wards like 6,11,13,14, and Banka River adjacent wards like 18,19,21 so that no waste can be floated to the river.
- The broken drains or the kutcha drains found in wards like 24,10 should be concretized immediately otherwise, there is a chance of being washed out in the rainy seasons causing further drainage blockages.
- The Municipality is dominated by choto pucca drains. Wherever possible, the depth and the width should be increased to transform it into a boro pucca drain to retain more water, especially in the flood prone zones of 6,7,10,11,13,14,16,19.
- The municipality should install covered manholes finding suitable bedding material and pipeline connections at least at the road junctions of the inundated roads at a nearer interval of distance especially in the low-lying areas of ward no 13,14. This way it would not consume any extra place and will serve the purpose. Manhole is quite absent in the Municipality area.
- There are long stretches of road even in the central wards of the municipality (where the growth is the highest) like in the ward like 18,35,15,28,29 almost everywhere-where the drains on both sides are covered by concretes. It is time to get introduced with the percolative drainage blocks which will keep the broadened road intact yet again give the water to flow downward.
- The town has no separate drainage system for collecting wastewater and stormwater like most other old Indian cities. Efforts should be made to make some underground drainages at least in the affected areas and designate them as wastewater collecting channels, especially needed in ward no 11 and 13.
- Resurrection of the Banka River by cleaning and dredging is of paramount urgency. Also, the dumping of waste on the Banka banks, under the bridges over Banka should be strictly prohibited and imposed on the citizens with a monetary fine.

- There are many drains (boro pacca drains) in the wards like 11,21,23 those once were connected to Banka but now due to siltation and broken sidewalls they get detached. The links should be immediately established to avoid flooding situations.
- Though the people dwelling on the banks of Banka demand the concretization of the banks, in the monsoon, this even does not help. Rather shaping the banks with percolative tiles or small grasses could have been installed to avoid the flood-like situation and as well as for beautification.
- Nature-based solutions (NBS) should be introduced at a community level like Rain-Water Harvesting, green roofing, green corridors around residential buildings, converting open spaces into parks or recreational places, etc. Introduced.
- The concept of ' Reuse, Reduce, and Recycle' should be endorsed even at the minute level as plastic is a complete menace and somewhat responsible for the current situation. Though the Municipal Authority informed that plastics are being sent to nearby cement factories, but the impact is yet to be known.
- A proper waste water collection system and a waste -water treatment/ sewage treatment plant (STP) following the Indian Governmental standards, covering the need of the town should be installed immediately in somewhere near the municipality as it needs a huge space for materialization and also dependent on the size of the city and its population.
- More bigger and frequent dustbins should be permanently installed on the roadsides and in public places especially in the busiest places of the town- like the localities of universities, government colony, Birhata etc.
- There is no such significant dewatering flood pump station to carry out the excess water into the nearest water body or river except a mini pump near the Kalna Gate sub-way. At least one major pump should be installed keeping the parameters like distance from the flood areas, flood severity, elevation, power consumptions, and debris handling capabilities in mind.
- City Master Plans including Drainage Master Plan should be framed with a proper time-bound vision to manage the flooding situation. Proper Planning of Land Use is needed to keep the water bodies and the open spaces intact in terms of quantity and quality both.

7.1.2. Non-Structural Measures:

- Risk Mapping- the areas with strong chances of inundation should be demarcated officially to mark the current situation and also to predict the future scenario. Right now, no such data is available in this regard.
- Awareness missions are expected to be held on the issue of flooding along with the training of aspects like waste management, and drainage maintenance for both the Municipal workers and the citizens.
- Citizen's Health campaigns, especially prior to the rainy seasons, seem to be mandatory.
- Community involvement within the flood management framework and their relationship with the Governing body should be strong so that the monitoring processes can be regular and easier.
- The citizens' willingness and the Municipal official's readiness to live in a sustainable environment is of the utmost importance to consider.

7.2. The Immediate Stake Holders and Their Duties:

There is no general consideration of the stake holders in terms of urban flood management as it depends on the location and context. Here, the most active responsible parties are seen to be the local people and their government- where Government is responsible for quick response to the alarming water logging or flooding and the local people can strengthen their stand to overcome.

Table No. 7.1. The Role of Stakeholders in the Flooding Situation

Stake holders	Level of Stake holders	The Responsible Authorities	Roles and Responsibilities
Governmental Bodies	Immediate Tier	Burdwan Municipality	1. Building knowledge of the Risk 2. Hydrological Monitoring and Risk assessment 3. Communication to the next tier and Dissemination of knowledge to the public 4. Awareness and capacity building
		Burdwan Development Authority	

	Next Tier	State and National Government	Taking proper financial and planning measures
Citizens	Immediate Tier	Drainage and Waste Workers	Performing their duties to the town and its denizens
	Next Tier	All other residents	Collaboration toward fellow citizens and environmental consciousness toward the city

Source: Compiled by author.

7.3. Conclusion:

Since prehistoric times, urbanization has been a part of Burdwan's evolution as a center of attention. The city's development began during the time of the Burdwan Raj and continued under the Municipal Authority after that. This town has always had an advantage over the other planned communities in the District in terms of administration, education, and medical facilities, even if it was never able to compete with them. However, the urban amenities did not grow at par with the population and urban growth. Consequently, the problems of unplanned urbanization like water logging, and flooding emerged.

It is a common scenario and a perennial phenomenon whenever it rains due to the infrastructural drawback, degeneration of river and water bodies, inefficient planning and policy action, and negligence from the citizens and the municipal drainage/waste workers, etc. Flood Management does not only call for its management alone but rather a holistic sustainable approach which will include a strategy to achieve ecologically sustainable land use in coming years that would create a balance between the two seemingly opposing aims of increasing land demand brought on by urbanization and the protection of natural resources. and centralized decision-making. However, changing patterns of risk probabilities have led to a shift in the way floods are managed, with a greater emphasis on flood mitigation, preparedness, and resilience. The town of Burdwan should adopt this kind of decentralized framework to give the citizens a fair chance to be vocal about their issues.

List of References:

1. CPHEEO (1999). *Manual on Water Supply and Treatment*. New Delhi: Ministry of Urban Development.
2. Shyamala. M, and Satpal Singh b.2016. Sustainable Municipal Solid Waste Management in India: A Policy Page - *Procedia Environmental Sciences* (35) pp150-157.

ANNEXURE-1

QUESTIONNAIRES

For

Assessing the Impact of Urban Flood

On Various Socio-Economic Groups

Questionnaire

For

The Perception Study of the People in the Flood Affected Wards of Burdwan Town

Questionnaire No:

Ward No:

Sample Size:

Sampling Method:

A. Respondent's Identity:

1. Name:

2. Age:

3. Sex: □Male □Female □Others

Age Group	No. of Persons
0-14	
15-29	
30-45	
46-60	
Above 60	

4. Religion:□ Hindu □Muslim □Others

5. Educational Qualification: □ *Up to Primary* □ *up to secondary* □ *up to higher* □*secondary* □ *Graduate* □*postgraduate* □ *higher than PG*

6. Are you a permanent dweller of this block? *Yes No*

A) If yes, since how many years have you or your family is living here?

□*Less than 10years* □ *10-20 years* □*20-50 years* □*more than 50 years*

B) If No, where are you from? (*specify the ward or block*)

…….

C) Why did you come here? □ *For work* □*others(specify)*

D) Since when you are commuting to this place?

□ *Less than 2 years* □*2-5 years* □ *more than 5 years*

7A). The material of your house built: …….

B) The material of the floor built:……...

C) The material of the roof built:…….

8. Is the house owned by you or rented? (*Specify the years)*

9. Occupational Status :(Salary if possible) □*Service- Government/Private* □*Business- Own/Work for other*

10. Are you an employee or by anyhow linked to the Burdwan Municipality or Burdwan Development Authority? □ Yes □ *No.* If Yes: *How?*

B. Questionnaire:

I. Regarding Flooding and Water logging Conditions

11. How many times do you experience rainfall annually?

□ *Only in rainy Season* □*Post rainy season* □ *Prior to rainy season*

□*Rainy and post-rainy* □*rainy and prior to-rainy season* □ *All of them*

12. What is the duration? *(in terms of hours-days)*

□In case of Monsoon-

□In case of Pre-Monsoon-

□In case of post-monsoon-

13. How is the intensity? *(High/Medium/Low)*

□In case of Monsoon-

□In case of Pre-Monsoon-

□In case of post-monsoon-

14. Is there any way out so that the water can get an outlet?

□*Yes* □*No*

If yes *where and how?*

If not, when exactly does it starts to get accumulated or rise?

□*After raining of one hour* □*one-three hours* □*three-five hours more than five hours*

15. Can you provide the height of rise?

□*Just topples over the drains* □ *half of one story* □ *one story* □*more than that*

16. What do you do when it inundates a few portions of your house?

□*Move to other portions of the house* □*move to relatives' house* □ *others*

17. How long does it takes the water to go back its previous stage if the rain stops?

□*An hour* □ *One-two Hours* □ *More than two hours* *Or*

A) If the rain does not stop for how many days will the water stay at the same level?

□*One day* □ *One-two days* □ *More than two days*

18.Is it the scenario of only rainy season or whenever the rain occurs?

□ *Rainy Season* □*Whenever the rain occurs*

19. Have you ever faced any consequences regarding the release of the Dam or Barrage water in your town? □ *Yes* □*No*

A) How frequent is that?

□*Once a year* □ *once in three years* □ *once in five years*

20. Whenever rainwater gets accumulated there is a high chance of getting affected by rainwater borne diseases. Have you faced any?

If yes. Please mention:

If not, what precautions do you take for wellness?

23. Does the municipality take any actions regarding this?

□*Yes* □*No*

A) If yes, When/How many times and how?

II. **Urban Drainage and Sanitation**

24. What is the condition of the drainage nearby?

□*Pucca* □*Kaccha* □*Semi-pucca* □*others*

25. Does it get cleaned up regularly? □*Yes* □ *No*

A) If yes, how? (Mention the process or instruments)

B) How many people are engaged in this job at a time according to you?

□*One* □*One-two* □*more than two*

26. How many times you have seen cleaning a person underground drainage system?

□*Once in a month* □*once in three months* □*More frequent than this*

28. Do you have any idea about the sub-surface drainage system in your area?

□*Yes* □ *No*

29. Does your place have separate outlets for storm water and wastewater drainage? □*Yes* □*No*

30. Do you think that this categorization is needed? □*Yes* □*No*

31. You have any pumping station here? □*Yes* □ *No*

32. Is there any plan of doing so by the Municipality that you have heard of?

□ *Yes* □*No*

A) If Yes, Specify the location:

33. Do you see waste materials also in the water? □*Yes* □*No*

33. What are they? □*Garbage* □*Excreta* □*Others*

34. Do they also enter your house when inundated? □*Yes* □*No*

35. What is the status of the waste collection by the municipality?

□*Very Good* □*Good* □*Moderate* □*Poor*

36. How frequently does it get cleaned up?

□ *Everyday* □*Once in three days* □*once in a week* □*less frequent than that*

37. What is the method of your in-house waste collection? How do you deal with non-degradable stuff?

38. Can you show me a dump yard nearby? □ *Yes* □*No*

A) If Yes, Specify the location:

39.Where do they usually accumulate the garbage?

40. Have you ever lodged any complaint against this condition to the Municipality? □*Yes* □*No*

A) If yes, what was their reply?

41. What do you think as the possible causes for this situation?

□ *Heavy Rainfall* □ *Faulty Drainage* □*Unplanned Growth of urban area*

□*Concretization* □ *Others*

42. Have you ever thought of moving to higher areas in terms of altitudes or out of town? □*Yes* □*No*

44. Do you think that there is a discrepancy of distribution of benefits between the ward near Municipality and Peripheral Wards? □*Yes* □ *No*

A) If yes, why so?

III. Regarding Urban Amenities:

45. During the heavy consecutive rains, how do you go to work?

A) Do you use public transport? □*Yes* □*No*

B) If yes, which mode? □ *State Bus* □*Private Bus* □*Auto* □*Shuttle cars* □ *Others*

46. Do you have your personal vehicle? □*Yes* □*No*

A) If Yes, Specify: □*Two-Wheeler* □ *Four Wheeler*

B) Do you feel safe to take your vehicle out when the area is heavily waterlogged? □*Yes* □ *No*

47. What is your normal time taken for going to work?

□*Less than 30 minutes* □*30 Minutes to 1 hour* □*more than 1 hour*

48. How many extra hours does it take at time of rain?

□*Less than 30 minutes* □*30 Minutes to 1 hour* □*more than 1 hour*

49. What is the condition of the local flower or vegetable market?

50. Does the supply get affected? □*Yes* □*No*

51. Does the price get affected? □*Yes* □*No:* if yes, how much?

52. What is the condition of electricity at that point of time?

□*Fully shut down* □ *intermittent supply* □*good condition of supply*

53. How do you manage the water for daily household work at that time?

54. Have you noticed the condition of the street vendors or pavement dwellers?

A) If Yes, where do they shift?

55. Any difficulties you face regarding medical service:

A) if yes, Specify:

56. Any difficulties you face regarding banking service:

A) If yes, Specify:

57. What are the assets you have in your household?

□*TV* □*Fridge* □*AC* □*washing machine* □*Personal Vehicle Others*

A) Have they got damaged ever? □*Yes* □*No*

58. Any other difficulties you want to mention:

59. Do you have any suggestions for the Municipal Authority?

60. Do you have any suggestions to local people or your neighbor for the betterment of this area?

61.Have you heard about any control room or shelter during the extreme events by the Municipality? □*Yes* □*No*

Date: ----------

Place: Signature of the Surveyor

Questionnaire

For

Interviewing the Municipal Workers related to Urban Drainage Cleaning and Waste Collection

Questionnaire No:

Ward No:

Sample Size:

Sampling Method:

A. Respondent's Identity:

1. Name:

2. Age:

3. Sex: □*Male* □*Female* □*Others*

Age Group	No. of Persons
0-14	
15-29	
30-45	
46-60	
Above 60	

4. Religion: □*Hindu* □*Muslim* □*Others*

5.Are you a permanent dweller of this block? □ *Yes* □*No*

E) If yes, since how many years have you or your family is living here?

□*Less than 10years* □*10-20 years* □ *20-50 years* □ *more than 50 years*

F) If No, where are you from? (specify the ward or block)

G) Why did you come here? □ *For work* □ *others(specify)*

H) Since when you are commuting to this place?

□ *Less than 2 years* □ *2-5 years* □ *more than 5 years*

B. Questionnaire:

6. How many times do you clean the urban drainage channel in a month or at the nearest interval to one month?

□*Less than two times* □ *2-4 times* □*more than 4 times*

7. How many times do you think that it should be cleaned?

□*Less than 4 times* □*4-6 times* □*more than 6 times*

8. Kindly specify the nature of your employment: □*permanent* □ *contractual*

9. What are the usual stuffs or garbage you get while cleaning the drains:

□*Degradable waste* □ *non-degradable waste*

10. Could you please highlight the process afterwards: like where you dump or how you process?.....

11. What are the precautions you take before the monsoon arrives?

12. Are there any monitoring services for the work done by the workers?

13. Do you know about the existence of sewage canals separately? *If yes where?*

14. What extra care do you perform during Monsoon or rainy season?

□No means of care □change the shoe □gloves □others

15. What is the condition of the drains in the post monsoon time?

16. Have you ever engaged yourself in the cleaning of '*Banka*'Khal?

17. Do you think that if the canal had existed in a better condition, it could worsen the situation of the town less?

25. What is the status of the waste collection by the municipality?

□ *Very Good* □*Good* □*Moderate* □*Poor*

26. How frequently you do this clean up?

□*Everyday* □ *Once in three days* □ *once in a week* □*less frequent than that*

27. What is the method of the in-house waste collection as per your experience?

28. Do you have a dump yard nearby? □ *Yes* □*No*

A) If Yes, Specify the location:

29. Where do you usually accumulate garbage? Could you please specify the method?

30. Any Suggestions you want to give to the Authority:

31. Any suggestion you want to give to citizen:

Date: …….

Place: Signature of the Surveyor

Questionnaire
For
Interviewing the Daily Wage Earners

Questionnaire No:

Ward No:

Sample Size:

Sampling Method:

A. Respondent's Identity:

1.Name:

2. Age:

Age Group	No. of Persons
0-14	
15-29	
30-45	
46-60	
Above 60	

3. Sex: □ *Male* □*Female* □*Others*

4. Religion: □ *Hindu* □*Muslim* □ *Others*

5.Are you a permanent dweller of this block? □ *Yes* □*No*

A) If yes, since how many years have you or your family is living here?

□*Less than 10years* □ *10-20 years* □ *20-50 years* □ *more than 50 years*

B) If No, where are you from? (specify the ward or block)

C) Why did you come here? □ *For work* □ *others(specify)*

D) Since when you are commuting to this place?

□ *Less than 2 years* □ *2-5 years* □ *more than 5 years*

B. Questionnaire:

6. What do you sell?

□*Fish* □*Dairy Products* □*Flowers* □*Newspaper* □*Others*

7. What is the condition of the local flower or vegetable market?

□*Poor* □ *Very Poor* □*gets closed* □ *Some of the shops remains opens*

8. Kindly specify the nature of your shop*:* □*permanent* □*temporary*

9. Does the supply get affected? □*Yes* □*No*

10. Does the price get affected? *Yes No:* if yes, how much

11. How is your living getting affected?

□*Supply gets reduced* □ *need to increase the price* □*No sale* □*Others*

12. What is the prime cause you think is responsible for this situation?

□*Heavy Rainfall* □*Drainage Condition* □*Heap of waste* □*others*

13. Is it already a low-lying area? □ *Yes* □*No*

14. Have you ever thought about shifting to some other places to sell?

□*Yes* □*No* If no, Why?

15. Do you see cleaning of waste/ drains here regularly?

□*Yes* □*No*

If not, then what is the frequency of cleaning?

□*Less than two times* □ *2-4 times* □ *more than 4 times in week*

16. To combat this situation what steps do you think should be taken?

17. What extra measure do you perform during Monsoon or rainy season?

□Purchase waterproof sheet □try not to invest more □others

18. Any Suggestions you want to give to the Authority:

19. Any suggestion you want to give to citizen:

Date: …….

Place: Signature of the Surveyor

ANNEXURE-2

CALCULATION TABLE

Annexure.2.1. Kappa's Co-efficient Classification for the Satellite Images of 1991,2001,2011,2021

Classified Data	Water	Forest	Urban	Fallow	Agriculture	Row Total	Commission Error	User Accuracy	Producer Accuracy	Overall Accuracy	Observed Accuracy	Change Agreement	kappa
Water	603	0	48	0	10	661	58	0.91225416	0.990147783	0.875056724	38244635	11113157	**0.83**
Forest	0	1185	5	0	442	1632	447	0.726102941	0.905963303				
Urban	5	0	1496	0	222	1723	227	0.868253047	0.823335168				
Fallow	0	35	20	563	231	849	286	0.663133098	0.992945326				
Agriculture	1	88	248	4	1938	1746	341	1.109965636	0.681674288				
Column Total	609	1308	1817	567	2843	6611							
Omission Error	6	123	321	4	905								

Classified Data	Forest	Agriculture	Water	Urban	Fallow	Row Total	Commission Error	User Accuracy	Producer Accuracy	Overall Accuracy	Observed Accuracy	Change Agreement	kappa
Forest	13	14	0	0	0	27	14	0.481481481	0.325	0.929843433	65095260	40120403	**0.84**
Agriculture	12	293	0	0	6	311	18	0.942122186	0.74744898				
Water	0	0	350	265	0	615	265	0.569105691	0.956284153				
Urban	0	0	13	5946	2	5961	15	0.997483644	0.931536895				
Fallow	15	85	3	172	1178	1453	275	0.810736407	0.993254637				
Column Total	40	392	366	6383	1186	8367							
Omission Error	27	99	16	437	8								

Classified Data	Water	Forest	Agriculture	Fallow	Urban	Row Total	Commission Error	User Accuracy	Producer Accuracy	Overall Accuracy	Observed Accuracy	Change Agreement	kappa
Water	625	0	0	0	350	975	350	0.641025641	0.920471281	0.931894034	85668780	60354416	0.80
Agriculture	0	857	10	6	56	929	72	15.30357143	0.567174057				
Forest	0	17	282	43	0	342	60	0.824561404	0.918566775				
Fallow	14	617	15	1333	1373	3352	2019	0.397673031	0.904341927				
Urban	40	20	0	92	5838	6990	152	0.835193133	0.766443482				
Column Total	679	1511	307	1474	7617	9588							
Omission Error	54	654	25	141	1779								

Classified Data	Water	Agriculture	Forest	Fallow	Urban	Row Total	Commission Error	User Accuracy	Producer Accuracy	Overall Accuracy	Observed Accuracy	Change Agreement	kappa
Water	468	0	0	0	77	545	77	0.858715596	0.930417495	0.933373818	124018993	72450526	0.85
Agriculture	0	109	0	2	42	153	44	0.712418301	0.990909091				
Forest	10	1	83	0	45	139	56	0.597122302	1				
Fallow	10	0	0	299	537	846	547	0.353427896	0.906060606				
Urban	15	0	0	29	9800	6844	44	1.431911163	0.933244453				
Column Total	503	110	83	330	10501	11527							
Omission Error	35	1	0	31	701								

Annexure.2.2. Calculation of Intensity-Duration- Frequency Curve (For June)

	YEAR	JUNE		5min	10min	15min	30min	60min	120min	720min	1440 min
1	1979	49.81		7.54	9.50	10.88	13.71	17.27	21.76	39.54	49.81
2	1980	30.39		4.60	5.80	6.64	8.36	10.53	13.27	24.12	30.39
3	1981	28.91		4.38	5.52	6.31	7.96	10.02	12.63	22.95	28.91
4	1982	24.52		3.71	4.68	5.35	6.75	8.50	10.71	19.46	24.52
5	1983	102.32		15.49	19.52	22.35	28.15	35.47	44.69	81.21	102.32
6	1984	12.73		1.93	2.43	2.78	3.50	4.41	5.56	10.10	12.73
7	1985	49.08		7.43	9.36	10.72	13.50	17.01	21.44	38.95	49.08
8	1986	2.46		0.37	0.47	0.54	0.68	0.85	1.07	1.95	2.46
9	1987	34.17		5.17	6.52	7.46	9.40	11.85	14.93	27.12	34.17
10	1988	45.62		6.91	8.70	9.96	12.55	15.82	19.93	36.21	45.62
11	1989	87.42		13.24	16.68	19.09	24.05	30.31	38.18	69.38	87.42
12	1990	66.25		10.03	12.64	14.47	18.23	22.97	28.94	52.59	66.25
13	1991	75.24		11.39	14.35	16.43	20.70	26.08	32.86	59.72	75.24
14	1992	38.89		5.89	7.42	8.49	10.70	13.48	16.99	30.87	38.89
15	1993	50.63		7.67	9.66	11.06	13.93	17.55	22.12	40.19	50.63
16	1994	38.71		5.86	7.39	8.45	10.65	13.42	16.91	30.73	38.71
17	1995	83.78		12.69	15.98	18.30	23.05	29.04	36.59	66.49	83.78
18	1996	34.13		5.17	6.51	7.45	9.39	11.83	14.91	27.09	34.13
19	1997	37.37		5.66	7.13	8.16	10.28	12.95	16.32	29.66	37.37
20	1998	78.99		11.96	15.07	17.25	21.74	27.39	34.50	62.70	78.99
21	1999	31.62		4.79	6.03	6.91	8.70	10.96	13.81	25.10	31.62
22	2000	61.16		9.26	11.67	13.36	16.83	21.20	26.72	48.55	61.16
23	2001	52.09		7.89	9.94	11.38	14.33	18.06	22.75	41.35	52.09

YEAR	SEPT		5min	10min	15min	30min	60min	120min	720min	1440 min	
24	2002	36.06		5.46	6.88	7.88	9.92	12.50	15.75	28.62	36.06
25	2003	28.49		4.31	5.44	6.22	7.84	9.88	12.45	22.61	28.49
26	2004	27.00		4.09	5.15	5.90	7.43	9.36	11.79	21.43	27.00
27	2005	47.58		7.21	9.08	10.39	13.09	16.50	20.78	37.77	47.58
28	2006	145.93		22.10	27.84	31.87	40.15	50.59	63.74	115.82	145.93
29	2007	48.74		7.38	9.30	10.64	13.41	16.90	21.29	38.68	48.74
30	2008	35.59		5.39	6.79	7.77	9.79	12.34	15.54	28.24	35.59
31	2009	32.91		4.98	6.28	7.19	9.06	11.41	14.38	26.12	32.91
32	2010	188.28		28.51	35.92	41.12	51.81	65.27	82.24	149.44	188.28
33	2011	59.03		8.94	11.26	12.89	16.24	20.46	25.78	46.85	59.03
34	2012	43.77		6.63	8.35	9.56	12.04	15.17	19.12	34.74	43.77
35	2013	28.91		4.38	5.52	6.31	7.96	10.02	12.63	22.95	28.91
36	2014	24.52		3.71	4.68	5.35	6.75	8.50	10.71	19.46	24.52
37	2015	38.71		5.86	7.39	8.45	10.65	13.42	16.91	30.73	38.71
38	2016	13.50		2.04	2.58	2.95	3.71	4.68	5.90	10.71	13.50
39	2017	61.16		9.26	11.67	13.36	16.83	21.20	26.72	48.55	61.16
40	2018	52.09		7.89	9.94	11.38	14.33	18.06	22.75	41.35	52.09
41	2019	56.64		8.58	10.81	12.37	15.59	19.64	24.74	44.95	56.64
			Mean	**7.70**	**9.70**	**11.11**	**13.99**	**17.63**	**22.21**	**40.37**	**50.86**
			STD DEV	5.16	6.50	7.44	9.37	11.81	14.87	27.03	34.05

	2 yrs	5 yrs	10 yrs	25yrs	50 yrs	75 yrs	100 yrs
YT	0.366512921	1.499939987	2.250367	3.198534261	3.901938658	4.310784	4.600149
KT	-0.154775677	0.842608225	1.502963	2.337323356	2.956299417	3.316072	3.570705

Sn	1.1364
Yn	0.5424

Contd…

					2 yrs		5 yrs		10yrs
time (hr)	time(min)	Mean	STD	Rainfall(mm)	rainfall(mm/hr)	Rainfall(mm)	rainfall(mm/hr)	Rainfall(mm)	rainfall(mm/hr)
0.08333	5	7.70	5.16	6.90	82.82	10.84	130.04	15.46	185.47
0.1666	10	9.70	6.50	8.69	52.18	13.65	81.93	19.47	116.86
0.25	15	**11.11**	7.44	9.96	39.83	15.63	62.52	22.29	89.17
0.5	30	13.99	9.37	12.54	25.08	19.68	39.37	28.07	56.15
1	60	17.63	11.81	15.80	15.80	24.81	24.81	35.38	35.38
2	120	22.21	14.87	19.91	9.95	31.24	15.62	44.56	22.28
12	720	40.37	27.03	27.98	2.33	56.79	4.73	81.00	6.75
24	1440	50.86	34.05	35.25	1.47	71.55	2.98	102.04	4.25

						25		50	
time (hr)	time(min)	Mean	STD	Rainfall(mm)	Rainfall(mm)	rainfall(mm/hr)	Rainfall(mm)	rainfall(mm/hr)	Rainfall(mm)
0.08333	5	7.70	5.16	6.90	19.76	237.14	22.95	275.47	24.81
0.1666	10	9.70	6.50	8.69	24.89	149.42	28.92	173.57	31.25
0.25	15	**11.11**	7.44	9.96	28.50	114.00	33.10	132.42	35.78
0.5	30	13.99	9.37	12.54	35.89	71.78	41.69	83.38	45.06
1	60	17.63	11.81	15.80	45.23	45.23	52.54	52.54	56.79
2	120	22.21	14.87	19.91	56.97	28.48	66.17	33.09	71.52
12	720	40.37	27.03	27.98	103.55	8.63	120.28	10.02	130.00
24	1440	50.86	34.05	35.25	130.45	5.44	151.52	6.31	163.77

The Calculation Process is same for the other monsoonal months also.

For the Month of July:

2 yrs	5 yrs	10yrs	20yrs	50Yrs	75Yrs	100 Yrs
82.8196	130.0365	185.4709	237.1365	275.4651	297.7431	313.5106
52.18462	81.93429	116.8623	149.4154	173.5651	187.6018	197.5365
39.83388	62.52153	89.16818	113.9987	132.4195	143.1263	150.7042
25.0795	39.36666	56.14553	71.78144	83.38105	90.12319	94.89501
15.8021	24.80639	35.37999	45.23379	52.5439	56.79281	59.80003
9.954243	15.62196	22.27953	28.483	33.08509	35.75999	37.65319
2.331443	4.73265	6.749591	8.628988	10.02323	10.83362	11.40718
1.468717	2.981078	4.251496	5.435244	6.313416	6.823844	7.185104

For the Month of August:

2 yrs	5 yrs	10yrs	20yrs	50Yrs	75Yrs	100 Yrs
90.47156	138.5587	196.6574	250.1021	289.7503	312.7954	329.1059
57.01404	87.31798	123.931	157.6112	182.597	197.1197	207.3984
43.49245	66.60943	94.53924	120.2317	139.2919	150.3704	158.2113
27.39853	41.96131	59.55599	75.74124	87.74838	94.72738	99.66686
17.25999	26.43397	37.51792	47.71399	55.27801	59.67451	62.78619
10.87311	16.65236	23.63481	30.05793	34.82297	37.59259	39.55282
2.331443	4.113393	5.499342	6.523876	7.283935	7.72571	8.038381
1.468717	2.591275	3.464368	4.109785	4.588591	4.866892	5.063863

For the month of September:

2 yrs	5 yrs	10yrs	20yrs	50Yrs	75Yrs	100 Yrs
105.3206	170.6639	244.8874	315.133	367.2452	397.5349	418.9727
66.37172	107.5502	154.3249	198.5928	231.4333	250.5215	264.0313
50.63084	82.04335	117.7249	151.4941	176.546	191.1072	201.413
31.89543	51.68407	74.16201	95.43529	111.217	120.39	126.8822
20.09286	32.55892	46.71914	60.12047	70.06234	75.84093	79.9308
12.65771	20.51084	29.43121	37.87352	44.13651	47.77679	50.35325
2.331443	6.211777	8.913344	11.47013	13.36689	14.46937	15.24965
1.468717	3.913174	5.615055	7.225727	8.420615	9.11513	9.60668

Annexure 2.3. Rainfall Indices

Year	RAI	PCI	RSI	RDI
1979	5.483083	24.01142	0.213574	-36.6505
1980	-0.09927	20.01938	0.166447	0.663541
1981	0.996489	18.5478	0.276993	-6.66082
1982	7.090948	25.16574	0.17078	-47.398
1983	7.127795	26.46808	0.200497	-47.6443
1984	1.357035	23.00383	0.220954	-9.07081
1985	6.253001	23.1035	0.166667	-41.7969
1986	2.802344	19.19016	0.14826	-18.7317
1987	5.585042	23.52338	0.165835	-37.332
1988	-0.91153	21.6697	0.253988	6.092906
1989	-2.68494	21.1384	0.17961	17.94693
1990	-7.86036	19.35036	0.160063	52.54092
1991	1.189099	19.03479	0.166554	-7.94828
1992	5.743212	18.23411	0.229327	-38.3893
1993	-2.87442	18.0763	0.166667	19.21346
1994	-1.31877	21.42307	0.19838	8.815013
1995	-3.43482	17.29626	0.166335	22.95936
1996	-2.40165	21.28474	0.166667	16.05333
1997	-0.49937	25.23371	0.309144	3.337906
1998	-3.82962	17.49675	0.166667	25.59831
1999	-2.43222	20.25895	0.185298	16.25765
2000	2.708542	22.42841	0.22105	-18.1047
2001	-1.35614	21.81674	0.218103	7.212364
2002	1.389413	22.67179	0.186699	-7.38931
2003	-4.50834	18.71521	0.164443	23.97669

Annexure 2.4. No. the Rainy Days in the Monsoonal Months from 1979-2019

Year	June	July	August	Sept
1979	18	24	24	17
1980	24	30	26	27
1981	22	28	30	28
1982	8	14		12
1983	18	24		
1984	1		30	18
1985	24	30	28	24
1986	20	26	23	18
1987	20	26	23	21
1988	23	29	30	25
1989	5		30	28
1990	18	24	29	26
1991	13	19	28	24
1992	20	26	17	17
1993	24	30		28
1994	24	30	30	15
1995	23	29		26
1996	24	30	30	24
1997	0			28
1998	19	25		22
1999	20	26		25
2000	23	29	28	20
2001	13	19	30	24
2002	24	30		24
2003	20	26	30	26
2004	17	23	29	23
2005	24	30	25	23
2006	23	29	29	25
2007	24	30	24	29
2008	23	29	29	22
2009	18	24	27	23
2010	17	23	26	25
2011				23
2012				23
2013	2			26
2014	22	28	27	16
2015	20	26	20	18
2016	21	27	25	14
2017	22	28	24	16
2018	19	25	28	17
2019	19	25	28	29

Annexure.2.5. Seasonal Water Depth in River Banka

Roy Nagar Banka Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.3	2.7	1.21
2nd	0.7	3.35	1.21
3rd	1.2	4.2	1.82
4th	0.91	2.4	1.5
5th	0.3	3.04	0.91

Ichlabad Banka Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.3	3.04	1.06
2nd	0.3	3.04	1.06
3rd	1.06	3.66	1.21
4th	0.3	2.74	0.69
5th	0.21	2.74	1.06

Banka Pool (Near Amtala):

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.3	3.66	1.2
2nd	0.45	4.26	1
3rd	1.21	4.8	1.8
4th	0.6	3.66	1
5th	0.6	3.3	1.2

Burdwan Clock Tower Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.12	0.24	0.03
2nd	0.12	0.24	0.03
3rd	0.12	0.24	0.03
4th	0.12	0.24	0.03
5th	0.12	0.24	0.03

Sailesh Setu:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.03	2.4	0.3
2nd	0.15	3.6	1.1
3rd	0.45	5.4	1.5
4th	0.91	4.5	1.2
5th	0.3	2.7	0.3

Sudarshan Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.15	1.8	0.3
2nd	0.15	2.4	1
3rd	0.45	3.65	1.21
4th	0.54	2.7	0.7
5th	0.3	2.4	0.3

Alamganj Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.3	3.5	0.6
2nd	0.7	4.2	1.5
3rd	0.9	6.09	2.2
4th	0.4	4.5	2
5th	0.3	3.6	0.6

Kalpataru Ground Bridge:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.1	2.7	0.9
2nd	0.3	3.6	1
3rd	0.3	5.7	1.5
4th	0.9	4.2	0.6
5th	0.45	3.04	0.3

Akhilesh Setu:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.3	2.4	0.6
2nd	0.6	4.2	1
3rd	1.8	5.1	1.8
4th	0.7	3.3	1.5
5th	0.3	2.7	0.6

Cyphon Dam:

Points	Pre-Monsoon Water Depth (in m)	Monsoon Water Depth (in m)	Post Monsoon Water Depth (in m)
1st	0.1	3.3	1.2
2nd	0.45	3.6	1.5
3rd	0.36	4.5	1.8
4th	0.36	3.3	1
5th	0.24	3.3	0.9

Annexure.2.6. The Type of Drainages the Respondents Have in their Vicinity in %

		Ward No.						
		6	10	11	13	19	21	23
Kutcha Drain	Choto Pucca Drain	88	56	100	92	62	32	56
	Boro Pucca Drain	12	44	-	8	30	38	44
	High Drain	-	-	-	-	8	40	-

Annexure.2.7. The Composition of Wastes in the Respondents' Localities in %

		Ward No.						
		6	10	11	13	19	21	23
Types of Non-degradable Wastes	Plastic	45	70	69	96	54	47	55
	Glass	38	22	30	-	16	9	15
	Strong Liquid Affluents	15	-	-	1	30	23	24
	Others	2	8	1	4	-	21	6

Annexure.2.8. Regularity of Cleaning Drains in %

		Ward No.						
		6	10	11	13	19	21	23
Response	Never	-	-	54	-	74	-	-
	At an uncertain interval	67	-	46	38	26	-	-
	Less than 2 times weekly	33	-	-	-	-	-	34
	2-4 times weekly	-	35	-	62	-	64	43
	Regularly	-	65	-	-	-	34	23

Annexure.2.9. Issues in Drainage Network in %

		Ward No.						
		6	10	11	13	19	21	23
Issues in Drainage Network	Less in Number / Width	-	50	-	-	-	-	58
	Problem in Velocity Attainment	21	20	45	-	-	-	-
	Slitted / Clogged	39	-	-	92	10	10	-
	Broken Infrastructure	-	-	33	8	-	-	-
	Plastic / Other Non-degradable Materials	40	30	22	-	90	90	42

Annexure.2.10. Whether They Have Witnessed Any Encroachment of Water Bodies in %

		Ward No.						
		6	10	11	13	19	21	23
Response	Yes	58	94	80	90	95	12	18
	No	2	6	3	3	5	9	10

Annexure.2.11. The Number of Waterbodies the Respondents Seen to Disappear in %

		Ward No.				
		6	10	11	13	19
Response	2 - 4	69	78	58	36	26
	Less than 2	1	4	2	3	4

Annexure.2.12. The Frequency of Cleaning the Wastes in the Locality in %

		Ward No.						
		6	10	11	13	19	21	23
Response	Never	-	-	-	-	-	-	-
	At an uncertain interval	36	-	40	20	35	-	-
	Less than 2 times weekly	2	-	5	-	5	-	-
	2-4 times weekly	-	56	30	80	50	30	25
	Regularly	-	44	-	-	-	70	75

Annexure.2.13. Places to Dump the Regular Waste in %

		Ward No.						
		6	10	11	13	19	21	23
Places to dump the waste	Nearest river / waterbody / drain	45	-	58	28	35	-	-
	Nearest roadside	3	5	4	5	3	5	5
	Municipal waste collectors	-	68	15	47	32	57	75
	Nearest Vats	20	27	6	5	12	11	35

ANNEXURE-3

PLAGIARISM CHECKING REPORT

GENESIS OF URBAN FLOOD IN BURDWAN TOWN

ORIGINALITY REPORT

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