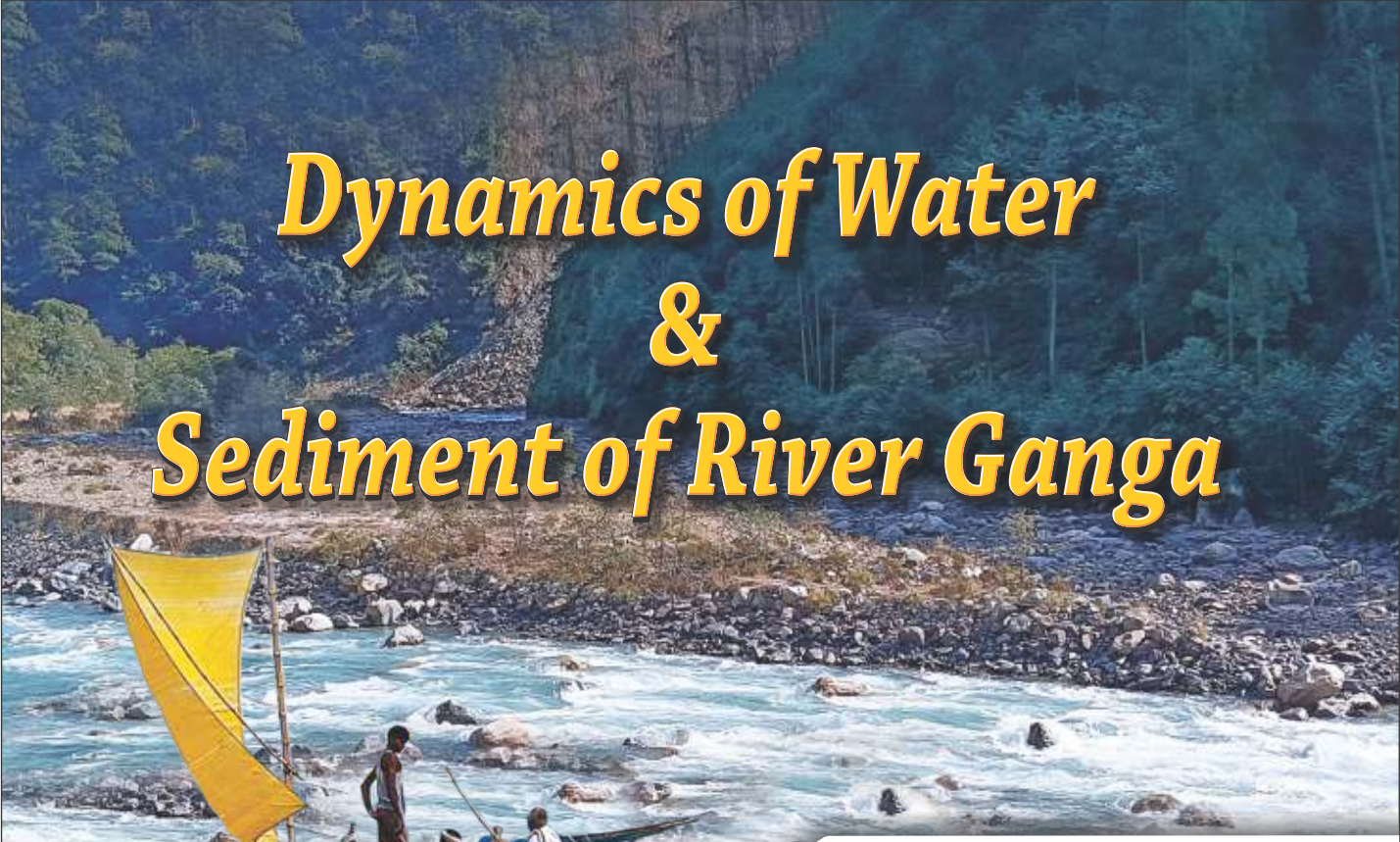
Dynamics of Water & Sediment of River Ganga



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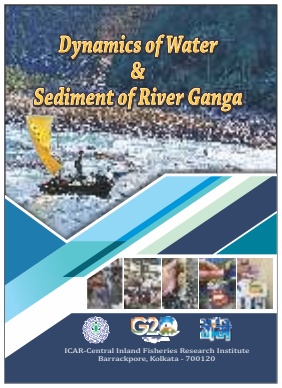

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FOREWORD

The river Ganga, with a stretch of 2525 km, constitutes the lifeline of Indian civilization covering about 33% of the Indian plateau with more than 43% of the total population of the country. Apart from being an essential source of drinking water, agriculture, navigation route, industrial need, and several other uses- it also provides livelihood to thousands of nearby fisher folks and riparian residents. With the growth of civilization and advancements in the processes of industrialization in the country, people have exploited the river for their benefit by establishing several grossly polluting industries on the bank of the river and constructing numbers of dams and barrages over it, hindering the lotic regime and adversely affecting, thereby, the natural riverine ecosystem. In fact, uncontrolled discharge of industrial effluents, coupled with indiscriminate release of city sewage, has been grossly deteriorating the river water quality since long. Under the 'Namami Gange' program of Govt. of India, ICAR-CIFRI has regularly monitored the water as well as sediment quality of river Ganga during the period 2016-2020 at 20 sampling stations covering the entire stretch of the river from Harshil to Fraserganj, besides studying different aspects related to fish and fisheries of the river. This study has generated a vast volume of data for understanding the changes in the water and sediment quality of river Ganga. The salient features of this study have been meticulously scanned and compiled in this volume. The publication highlights station-wise changes in different limno-chemical parameters of water as well as sediment on time scale, mainly in graphical form, which clearly describe several interesting transformations of various water and sediment quality attributes in this river due to the anthropocentric interventions. The information is extremely important and would be of immense help to the students, researchers, policymakers, and other stakeholders for formulating any future work plan leading to better management of this unique riverine system.

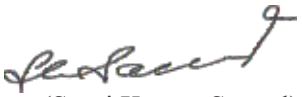
I am sure this book will be immensely useful to everybody related with this field and I congratulate the authors and the entire project team for bringing out such a valuable publication.

(Prof.G.N.Chattopadhyay)

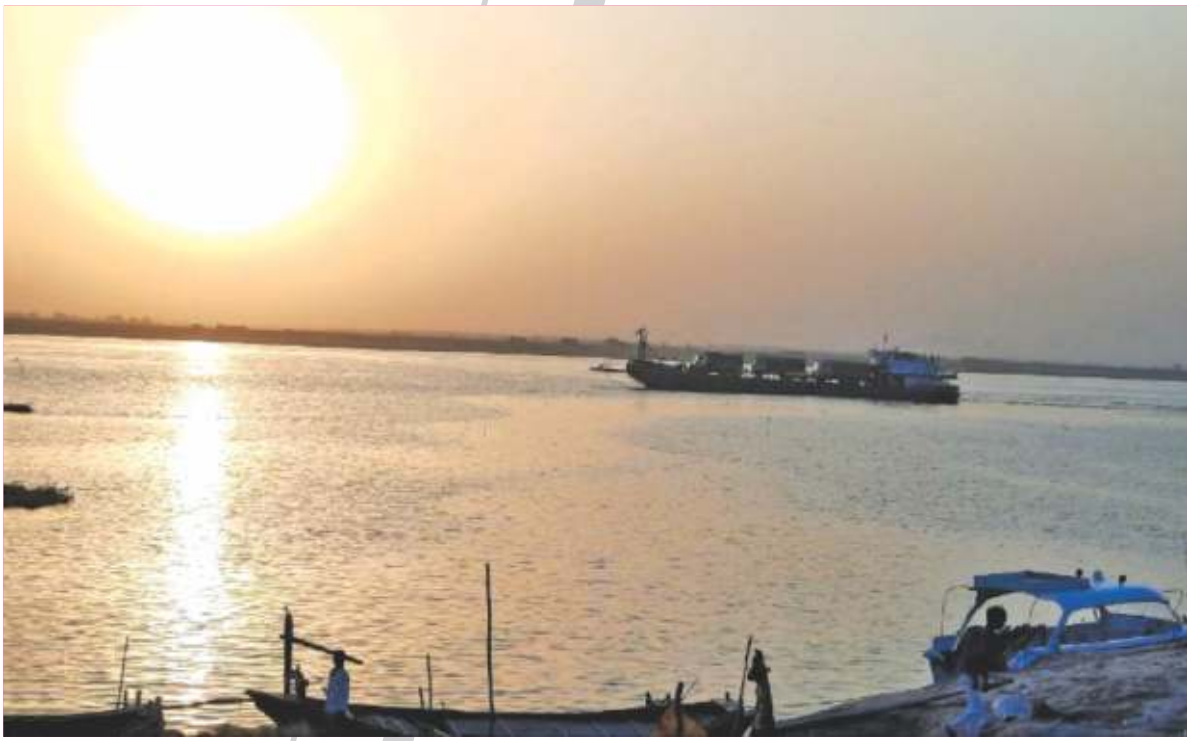
18th August, 2023

FOREWORD

River Ganga is one of the most sacred water bodies of the Hindu religion and is worshipped as the mother Ganga. It is also believed to cure health alignments. The river flows with highly nutrient-enriched sediment and deposits the same on the fertile soil along its shoreline. The river has allowed civilization to develop and prosper for several centuries. Today, millions of people live around the bank of rivers and collect fresh water for drinking purpose as well as other household activities. Also, the river water is used for fishing and providing irrigation to the standing crops along its bank. A large number of cities are located along the bank of the river Ganga. Untreated city and urban sewage are released into the river. Besides receiving a high volume of domestic sewage and industrial effluents, runoff water from the adjoining agricultural farm also renders the water eutrophic. To improve the quality of water, Government of India launched several programmes, viz. Ganga Action Plan (1985), the Namami Gange Project (2014), and so on. Continuous monitoring of the water as well as sediment quality of the river Ganga is undertaken by several National Organizations like the Central Pollution Control Board (CPCB), Central Water Commission (CWC), and others. However, most of the monitoring is done keeping a view of the use of river water for drinking purposes or other human uses. Since the inception of ICAR-Central Inland Fisheries Research Institute (CIFRI) in 1947, the river Ganga has always remained one of the study areas from a fisheries point of view, keeping fish as the eco-biotic indicator. Along with the study of different aspects of fish and fisheries, the study of the water quality of river Ganga in perspective of its suitability for healthy living of aquatic organisms is always an integral part of most of the studies conducted by ICAR-CIFRI under the project **"National Mission for Clean Ganga"**. The book **"Dynamics of water & sediment of river Ganga"** highlights station-wise time-scale changes of different physicochemical parameters of water and sediment, mostly in graphical form, which illustrates the changes in riverine conditions. The latter is believed to help the students, researchers, policymakers, and other stakeholders decide future policies towards better management of this very important riverine system. I believe this book will be helpful to everybody, and I congratulate the authors and the entire project team for bringing out this valuable book.



(Saroj Kumar Sanyal)
August 9, 2023



PREFACE

River Ganga is endowed with rich aquatic biodiversity resources but is getting destructed day by day with the increasing population which resulted in the enhancing pollution load to the river. Humans are responsible for the same as they enhance anthropogenic activities for their benefit. With the advancement in society and increased rate of industrialization, the load on industries has also increased resulting in the release of polluted water and harmful chemical contaminants to the river and which subsequently resulted in increased pollution in one of the major country's most important aquatic biota. As the river is also an ecological niche of millions of organisms and with this, it is a source of bread and butter to the millions of resident populations.

The water and sediment quality reveal the practical facts of the river i.e., whether the river is good for aquatic biodiversity and other dependent organisms or not. So, for the investigation, the sediments and water quality of the river have been monitored in all four seasons i.e., Winter, Pre-Monsoon, Monsoon, and Post Monsoon, all across the river Ganga at 21 different sampling points i.e., starting from the hills of Uttrakhand to the lowlands of Uttar Pradesh, Bihar, Jharkhand, and West Bengal. In which the timescale comparison has been made from 2016 to 2020.

The Present Book **"DYNAMICS OF WATER AND SEDIMENT OF RIVER GANGA"** will give a clear picture of the changing status of the river Ganga which will make them compatible significance to the policymakers and all the stakeholders who are directly or indirectly dependent on the river.

ACKNOWLEDGEMENT

The authors are thankful to National Mission For Clean Ganga (NMCG), Ministry of Jal Shakti, Department of water resources, River Development and Ganga Rejuvenation, Government of India (Project No. T-17/2014-15/526/NMCG-Fish and Fisheries), New Delhi for their financial assistance to ICAR- Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Kolkata, West Bengal for the project entitled "Assessment of fish and fisheries of the Ganga River system for developing suitable conservation and restoration plan". The authors are also thankful to the CIFRI team of the NMCG project of its regional centre at Prayagraj, Uttar Pradesh for their efforts. The authors also extend their gratitude towards Sri Amarnath Prasad and Sri. Umasankar Ram for their help and support in Field sampling. Thanks are also due to the local fishers, who have rendered their full support as and when required.

Authors

CONTENTS

INTRODUCTION

1.1 The Ganga

The sacred river Ganga covers a total path length of 2,550 Km^2 (22° 18' 6.43" N to 31° 2' 49.31" N and 77° 58' 47.44" E to 88°30' 37.89" E) endeavoring its glorious beauty from the hills of Uttarakhand to the lowland of West Bengal covering 5 major states of the country i.e., Uttarakhand (110km), Uttar-Pradesh (1,450km), Bihar (445km), Jharkhand and West Bengal (520km)). Making an impressive impact on religious activities, tourism, and fisheries sectors influencing the bread and butter of thousands of nearby residents and fishers by providing drinking water and livelihood source. Ecologically, River Ganga contributes more than 2000 aquatic organisms, with diverse species composition which balances the riverine ecology and ecosystem. The river starts its journey from 6000 M high altitude at Gangotri moves in the western direction. After that cut by Siwaliks and enters Haridwar with a 750m width. From here it flows first to the south, then to the southeast and east before splitting into two distributaries, namely Bhagirathi and the Hooghly. The river Bhagirathi flows through Berhampur, and kawa then flows about 150km and joins with the Hooghly estuary at Nabadwip. River Hooghly flows through Kolkata and Diamond Harbour after that it meets with the Bay of Bengal in the east. Bhagirath-Hooghly is one of the major distributaries, which forms the biggest marshy delta in the world, called Sunderban (2340 km^2). It covers a basin area of approximately 861,40404 km^2 (K. K. Vass et al. 2010). The river basin drains waters more than one-fourth (26.3%) of the country's total geographical area and is also treated as the biggest river basin in India (CPCB report, July 2013) and supports 43 percent of its population (M. P. Sharma). The river receives an exorbitant amount of water 142.6 million m^3 that mainly comes from Gangotri glacier, which is situated 4100 meters above sea level (CPCB report), and monsoon rainwater. The whole river system covers cool upland streams and warm water stretches, including deltaic habitats. The river Ganga has numerous tributaries, namely, Kali, Ramganga, Yamuna, Gomti, Ghaghara, Gandak, and Kosi. The river Yamuna, although a tributary of the Ganga, is a river basin in itself. Its major tributaries are

Chambal, Sindh, Betwa, and Ken. The main plateau tributaries of the Ganga River are Tons, Son, Damodar, and Kangsabati-Haldi (M. P. Sharma). Adding to this fact of immense biodiversity, the hydrological parameters act as an influencing factor for the riverine health and its ecosystem. The Ganga carries 616 x 106 tons of suspended solids to the Hooghly estuary (CIFRI, Bulletin 152).

Ecological Status of The River

The ecological status of any aquatic habitat determines the density and diversity composition of species. Among the major water quality parameters, i.e., the water temperature varies with a very comprehensive range, i.e., from 7.22 °C to 29.52°C. The river Ganga is well known for its strong buffering capacity and thus is having little fluctuations in the pH in the entire stretch (7.7-8.07). The average dissolved oxygen status in the entire stretch was found to be in the optimum range. Higher values were in the upper stretch of the river while comparatively lower dissolved oxygen values were observed in the estuarine stretch of the river. Alkalinity, conductance, total dissolved solids, calcium, magnesium, and hardness had shown considerable variations. The values of specific conductivity, salinity, total dissolved solid, chlorinity, calcium, magnesium, and total hardness had increased gradually and reached very in the estuarine stretch of the river. The nutrient status of the river in respect of nitrate and phosphate showed minimum values in the entire stretch of the river. But having comparatively higher values at Kanpur and Bhagalpur due to deceased riverine flow signifies its eutrophic condition. The silicate values were found higher in Patna to Jangipur. The riverine flow which is one of the most important deciding factors of riverine health was found (0.1 m/sec to 1.8 m/sec), to have lower values at Farraka and Tehri due to the impact of Barrages which hinders the riverine flow. While higher riverine flow was observed in the tidal zone of the river.

The objective of the present investigation

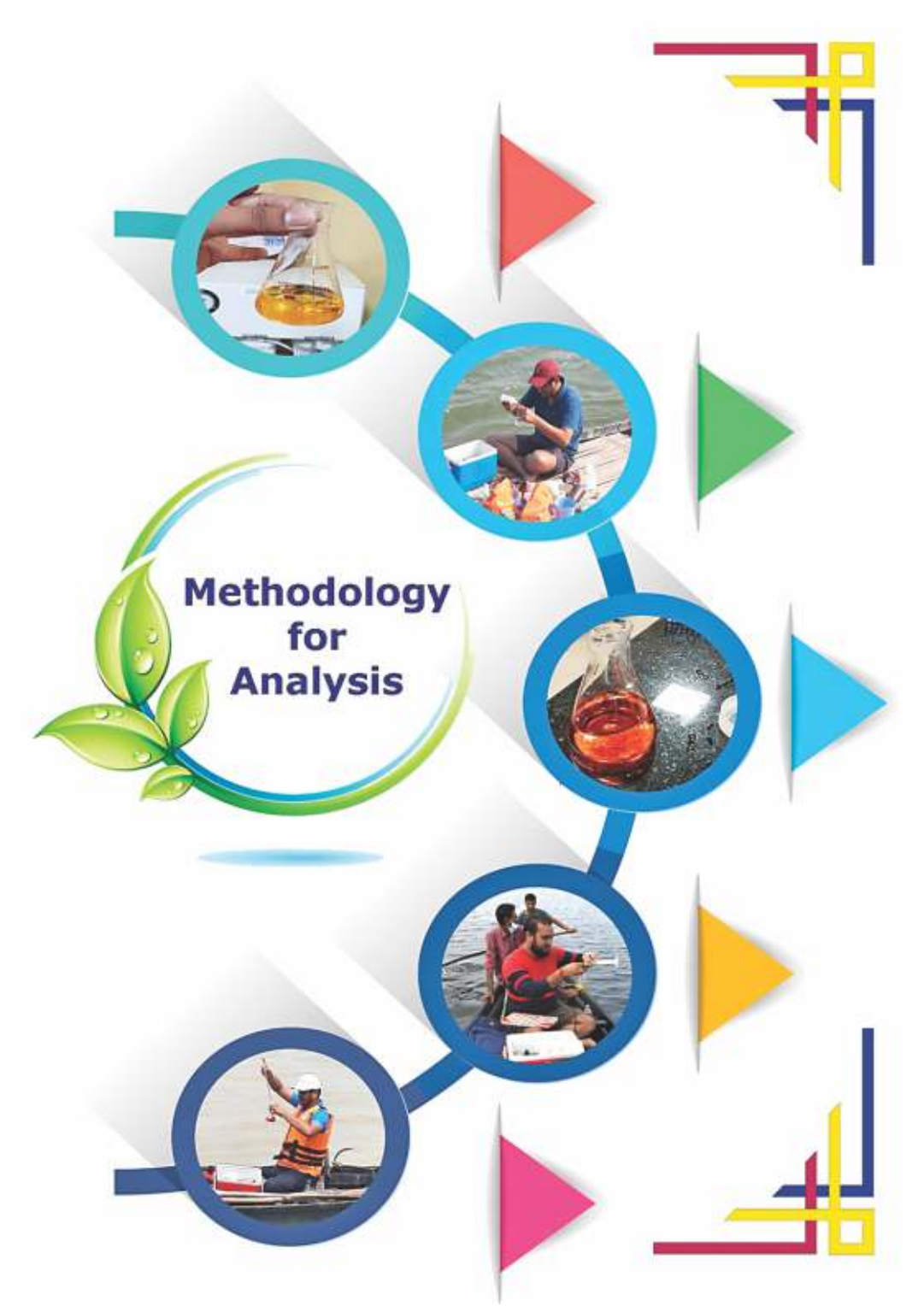
The present investigation was carried out under the project *Assessment of fish and fisheries of the Ganga River system for developing suitable conservation and restoration plan".* During the past few decades, the water and sediment quality of the mighty river the Ganges have been degraded considerably due to increased industrialization on the banks of the river Ganges, Industrial and agricultural effluents, Discharge from domestic wastes construction of dams, barrages, and increased anthropogenic activities to severe fold population blast. So, to take the appropriate action for the development of suitable conservation and restoration plan by observing the regular changes which take place in the water and sediment quality of the river.

Plan of work and study area

An exploratory survey was carried out during the year 2016-20 to assess the water and sediment quality of the river Ganga from Harshil to Fraserganj.

Table- GPS Coordinates of different stations of River Ganga

Sl No	Name	Hindi((हिंदी)) Name	Longitude	Latitude	state (राज्य)
1	Harsil	हरसिल	78.7377	31.03831	Uttrakhand (उत्तराखण्ड)
2	Tehri	तेहरि	78.4782	30.3753	Uttrakhand (उत्तराखण्ड)
3	Haridwar	हरिद्वार	78.16516	29.93404	Uttrakhand (उत्तराखण्ड)
4	Bijnor	बीजनोर	78.08725	29.35895	Uttrakhand (उत्तराखण्ड)
5	Narora	नरोरा	78.38138	28.19678	Uttrakhand (उत्तराखण्ड)
6	Farrukhabad	फर्रुख़ाबाद	79.71246	27.46263	Uttar Pradesh (उत्तर प्रदेश)
7	Kanpur	कानपुर	80.33187	26.44992	Uttar Pradesh (उत्तर प्रदेश)
8	Pryagraj	प्रयागराज	81.84631	25.4358	Uttar Pradesh (उत्तर प्रदेश)
9	Varanasi	वाराणसी	82.97391	25.31765	Uttar Pradesh (उत्तर प्रदेश)
10	Buxar	बक्सर	83.97775	25.56471	Bihar (बिहार)
11	Patna	पटना	85.13756	25.59409	Bihar (बिहार)
12	Bhagalpur	भागलपुर	86.98243	25.3478	Bihar (बिहार)
13	Farakka	फरक्का	87.90896	24.80067	West Bengal (पश्चिम बंगाल)
14	Jangipur	जंगीपुर	88.10301	24.45265	West Bengal (पश्चिम बंगाल)
15	Berhampore	बरहामपुर	88.26793	24.09883	West Bengal (पश्चिम बंगाल)
16	Balagarh	बलागढ़	88.46461	23.11886	West Bengal (पश्चिम बंगाल)
17	Tribeni	त्रिबेनि	88.4025	22.98671	West Bengal (पश्चिम बंगाल)
18	Godakhali	गोदाखाली	88.14256	22.39321	West Bengal (पश्चिम बंगाल)
19	Diamond Harbour	डायमंडहार्बर	88.20229	22.19873	West Bengal (पश्चिम बंगाल)
20	Fraserganj	फ्रेसरगंज	88.25829	21.58249	West Bengal (पश्चिम बंगाल)


Methodology
for
Analysis

WATER VARIABLES

PHYSICAL PARAMETERS

- Water Temperature
- Depth Flow
- Transperancy
- Turbidity

CHEMICAL PARAMETERS

- pH
- Total Alkalinity
- Magnesium Hardness
- Total Hardness
- Total Solid
- Dissolved Oxygen
- Calcium Hardness
- Total Dissolved Solid

NUTRIENT PARAMETERS

- Total Phosphorus
- Nitrate nitrogen
- Total Nitrogen
- Silicate

POLLUTION PARAMETERS

- Biochemical Oxygen Demand
- Specific Conductivity
- Free CO_2

PRODUCTIVITY

- Gross Primary Productivity
- Net Primary Productivity
- Community Respiration

SOIL PARAMETER

PHYSICAL PARAMETERS
Soil Texture: - (Hydrometer method)

CHEMICAL PARAMETERS: -
Soil pH

SOIL CONDUCTIVITY: -

SOIL ORGANIC CARBON: -

VARIABLE PHOSPHORUS (P): -

SOIL AVAILABLE N: -

FREE CALCIUM CARBONATE: -

WATER

Water sample collection

Water samples were collected at early morning in triplicates for laboratory analysis. For Total Solid, Total Dissolve Solid, Total Suspended Solid, and Total Hardness sterile water bottles were used and samples were immediately preserved at 4°C. For NO_2-N, NO_3-N, and NH_4-N 2ml/litre of concentrated H_2SO_4 was used as a preservative. For the chlorophyll analysis, in situ filtration was done with the help of Magnesium sulfate, and the residue was immediately transferred to the icebox for laboratory analysis. For Available -P and Total-P the samples were taken in containers that were pre-washed with phosphate-free detergents and were immediately kept at 4°C for laboratory analysis.

In situ Analysis

In situ analysis of water, samples were done with the help of advanced multi-parameter probes of YSI multiparameter probe and Aquaread probe (model AP-7000) In which parameters such as Temperature, Dissolved Oxygen, TDS, pH, Salinity, NH_3, NH_4, ORP, Turbidity, Dissolved oxygen saturation, Chlorophyll, Values were analyzed.

In situ Analysis of Chemical Parameters

Parameters such as Free CO_2, biochemical oxygen demand, Alkalinity, Total Hardness, Calcium Hardness, magnesium Hardness, and Chlorinity were analyzed.

Free Co_2: -

Free carbon dioxide was calculated by the titrimetric method with the help of a Phenolphthalein indicator, having an endpoint pH 8.3. During analysis, 50 ml of the sample was taken and titrated with the help of N/44 NaOH solution using the Phenolphthalein indicator. And was calculated by using the formula: -

$$\text{Free } CO_2 \text{ (ppm)} = \frac{\text{ml of N / 44 NaOH required x1000}}{\text{ml of the sample taken}}$$

Biochemical Oxygen Demand (BOD): -

Biochemical oxygen demand was calculated using 300 ml B.O.D glass bottles. During the analysis, the initial dissolved oxygen was measured by using the Wrinkler method and then the final D.O value was calculated after 5 Days of sample incubation at 20 ° C. Then the difference was calculated.

Calculation: BOD (mg/l) = Initial DO - Final DO after 5 days

(mg/l) (mg/l)

Alkalinity (Hydroxide +Carbonate+ Bicarbonate): -

Alkalinity was calculated by the titrimetric method using Phenolphthalein and Bromocresol Green-Methyl red indicators. For hydroxide and carbonate alkalinity100 ml of sample was taken and a Phenolphthalein indicator was used in case pink colour appeared the sample was titrated with the help of N/50 sulphuric acid till the colour less point is observed. For Bicarbonate alkalinity BCG mixed

indicator was used, if the sample turned Blue-green using the indicator then the sample was titrated with the help of N/50 sulphuric acid till the red colouration endpoint is observed.

Calculation:

$$\text{Phenolphthalein alkalinity (ppm)} = \frac{\text{ml of 0.02N H2SO4 used in PHTH indicator x 1000}}{\text{ml of sample}}$$

$$\text{Total alkalinity (ppm)} = \frac{\text{ml of 0.02N H2SO4 used in PHTH and BCG mixed indicator x 1000}}{\text{ml of sample}}$$

Total Hardness (TH): -

Total Hardness was calculated by the titrimetric method using the Eriochrome Black-T indicator and the sample was titrated with the help of ethylene diamine tetra acetic acid (EDTA) disodium salt (0.01M). For the analysis, Ammonia buffer was used to bring the pH of the sample to 10 ± 0.1. During the analysis, 50 ml of water sample was taken, and 1 ml of Ammonium buffer was added to it. And the sample was titrated until the endpoint is observed (Magenta to Blue).

Calculation:

$$\text{Total Hardness as } CaCO_3 \text{ mg/ l} = \frac{\text{ml of EDTA titrant x 1000}}{\text{ml sample was taken for titration}}$$

Calcium Hardness: -

The titrimetric method was used for the calculation of Calcium Content using a murexide (ammonium purpurate) indicator and the sample was titrated with the help of 0.01 M EDTA solution. For the analysis 25 ml water sample was taken in which 1 ml NAOH and a pinch of murexide was added and titrated with the help of 0.01 EDTA until the endpoint is observed i.e., pink to magenta.

Calculation:

$$Calcium\ (mg/l) = \frac{Titration\ reading\ x\ 400.8}{sample\ volume\ (ml)}$$

Magnesium Hardness: -

Magnesium hardness was calculated using the data collected for Total Hardness and Calcium Hardness with the formula.

Magnesium (mg/l) = [Total hardness (mg/l) - Calcium (as mg/l CaCO3)] x 0.243

Chlorinity: -

Chloride was calculated by the "**Argentometric method**" using the Potassium chromate indicator and the sample was titrated with the help of silver nitrate solution (0.0141N). For the analysis, 50 ml of sample was taken and 2-4 drops of Potassium chromate were added and titrated with the help of 0.0141 N Silver nitrate solution until the endpoint is observed (yellow to brick red).

Calculation:

$$\text{Chloride (mg/L)} = \frac{(\text{ml of titrant used for sample} - \text{ml of titrant for blank}) \times 0.0141 \times 35.46 \times 1000}{\text{ml of sample}}$$

Laboratory Analysis of water samples: - Lab analysis move to top of the total and available p

Nutrient parameters: - Nutrient parameters such as Nitrate Nitrogen, Total Nitrogen, Total-P available p and silicate

Nitrate Nitrogen (NO3-N): -

Nitrate Nitrogen was calculated by using the "Phenol disulphonic acid method". In which phenol disulphonic acid, 10% Aluminium sulfate, and 12 N NaOH were used. For the analysis, 20 ml of water sample was evaporated in a water bath, and on evaporated sample 2 ml of phenol disulphonic acid was added drop by drop and rubbed with the help of a glass rod. The sample was left for 5 minutes to react. After 5 minutes 2ml of aluminum sulfate solution was added. Then 12 N NaOH solution was added slowly and stirred until it gets alkaline. In case yellow colour appears, which signifies the presence of NO_3-N, Aluminium hydroxide is removed by filtration and absorbance was measured at 410 nm in a UV spectrophotometer. Concentration was calculated with the help of a standard absorbance curve.

Total Nitrogen: -

Total nitrogen was calculated with the help of sodium hydroxide (NaOH), Devarda's Alloy, and Nessler solution. For the analysis, 200 ml of distilled water was taken in the Kjeldahl flux and warmed. In the warmed sample, 2 pellets of NaOH and little dust of Devarda's Alloy along with 50 ml of water, the sample was added to it. After the addition of the water sample, the distillation assembly was added and 30 ml was collected at the receiver, and the volume was made up to 50 ml with the help of distilled water. In the sample, 10 drops of Nessler solution were added to it, and absorbance was observed at 410 nm in a spectrophotometer. Concentration was calculated with the help of a standard calibration curve.

Available phosphorus: -

For the analysis, all the glassware was pre-washed with phosphate-free detergent. Following reagents were prepared: -

1. Potassium antimony tartrate solution. (0.2743g PAT+ 100ml distilled water)
2. 4% Ammonium molybdate.
3. 5 N Sulphuric acid.
4. Ascorbic acid solution. (0.528g Ascorbic acid + 30ml water)
5. Colour developing reagent (50ml (5N) H_2SO +5 ml PAT solution+ 15 ml 4% ammonium molybdate solution + 30 ml freshly prepared ascorbic acid solution)

Prior to analysis 25 ml of water, the sample was filtered using Whatman 1 filter paper, and 4 ml of a color-developing agent was added and after 10 min absorbance was observed at 880 nm using a spectrophotometer.

Total-phosphorous: -

For the analysis of Total-P, 50 ml of the water sample was reduced to 20-25 ml in a sand bath, 2 ml of perchloric acid was added. After the addition of acid, the sample was evaporated on a hot plate with a volume up to 5-10 ml. In the solution, a little amount of distilled water was added to the sample and 1 N NaOH was added to neutralize the solution with the help of a phenolphthalein indicator. The volume was made up to 50 ml with the help of distilled water. Then the sample was analyzed by using the Ascorbic acid method, i.e., as mentioned the Available phosphorous analysis method.

Available Silicate: -

For the analysis of Available silicate following reagents were prepared.: -

1. Oxalic acid solution (5 g oxalic acid+ 50 ml of distilled water).
2. 6 N Hydrochloric acid.
3. 10% Ammonium molybdate

In 25 ml of filtered water, 1 ml of 6 N HCl solution and 1 ml of 100% ammonium molybdate were mixed and left to react for 5 minutes. After 5 minutes, 0.5 ml of oxalic acid solution was added. After 2 minutes, absorbance of the sample was observed at 410 nm.

SEDIMENT

Sample collection: - sediment samples were collected with the help of Van Veen grab, and was air-dried.

1. Physical parameters

Soil Texture: - (Hydrometer method)

100 g of air-dried soil was taken in a 500 ml conical flask in which 0.5 N sodium oxalate and 200 ml distilled water were added to it and shacked for 1 hour in a mechanical shaker. The sample was transferred to 1000 ml of the cylinder and the volume was made up to 1000 ml with the help of distilled water. The hydrometer is dipped in the cylinder after 5 minutes and the percentage of clay + silt was determined similarly to clay% was noted after 2 hours. Sand is obtained by deducting the percentage of clay + salt from 100. Likewise, the percentage of silt is obtained from clay + silt %.

2. Chemical Parameters: -

Soil pH

20 g of sample was mixed in 50 ml of distilled water and stirred for 30 minutes with a glass and reading was taken with the help of a pH electrode.

Soil Conductivity: -

20 g of sample was mixed in 50 ml of distilled water and stirred for 30 minutes with a glass rod. And reading was taken with the help of a conductivity electrode.

Soil Organic Carbon: - (Walkley-Black method)

For the analysis, 1 g of sample was taken in 500 ml of a conical flask in which 10 ml of 1 N $K_2Cr_2O_7$ solution was added. Then 20 ml of conc. H_2SO_4 was added to it and was kept inside the cupboard for 1 hr. Then 200 ml of distilled water was added. After that 10 ml of conc. Orthophosphoric acid (H_3PO_4) and 1 ml diphenylamine indicator was added to it. Then the sample was titrated with the help of a ferroin indicator using N/4 Mohr's solution until the endpoint is observed.

Calculation: -

$$\text{Organic carbon (\%)} = \frac{\text{Volume of dichromate (ml)} \times \text{Strength of dichromate} \times \text{(Blank- sample reading)} \times 0.3}{\text{Blank reading (ml)} \times \text{Sample weight (g)}}$$

Variable phosphorus (P): -

In 1g of dried soil sample, 200 ml of 0.002N H_2SO_4 (pH-3), was added and the mixture was shaken for 30 minutes in a mechanical shaker, left for 10 minutes and filtered with Whatman 42 filter paper. Then 50 ml of the sample was collected and 4 ml of the colour developing reagent was added. After 10 minutes, absorbance was measured at 880 nm using a UV spectrophotometer.

Calculation:

Available-P mg/100g=quantity of P obtained from X-axis (mg/l) against a sample reading x volume of extracting reagent (l) x 100/ weight of sediment (g)

Soil available N: -

For analysis, a 10 g soil sample was taken in a 500 ml Kjeldahl flask in which 100 ml of 0.32% $KMnO_4$ solution, 100 ml of 2.5% NaOH, 2 ml of liquid paraffin, and some glass beads were added. Then the mixture was distilled and collected the distillate in a conical flask containing 20 ml of 0.02N H_2SO_4 and added few drops of methyl red indicator. Collected about 75-80 ml of distillate. The excess of 0.02N H_2SO_4 was titrated with 0.02N NaOH to a colourless endpoint for the methyl red indicator.

Calculation: Available nitrogen (mg/100 g soil) = [20- (No. of ml of 0.02 N NaOH)] x 2.8

Free Calcium carbonate: -

5 g soil sample was taken in a 250 ml bottle. 100 ml 1 N HCl was added and shaken for one hour. Allow to settle the suspension and pipette out 20 ml of the clear liquid in a conical flask. Titration was done with 1N NaOH using Bromothymol blue indicator until it just turns blue (yellow to blue). A blank was carried out in the same way without taking soil.

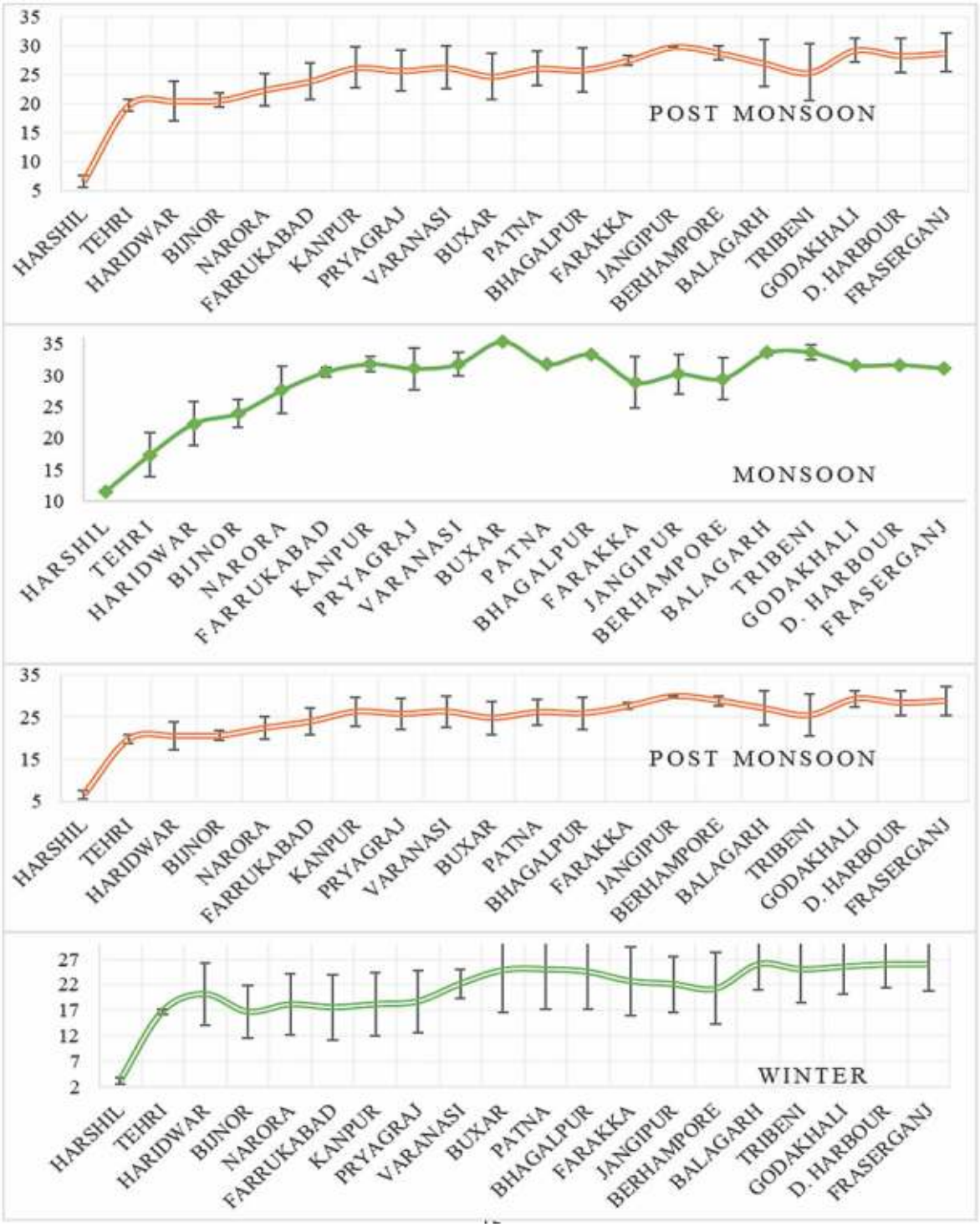
Calculation:

% $CaCO_3$ = (Titre for blank - Titre for soil solution) x 5

PHYSICAL PARAMETERS

Water temperature (°c)

Water temperature is the essential physical property used for the measurement of hotness or coldness of the water; it is a significant water quality parameter used for the comprehensive evaluation of water quality condition of the aquatic habitat. As temperature can affect several physical, chemical and biological components of the aquatic ecosystem. The change in temperature can affect diffusion of gases which can directly or indirectly affects many of the water quality parameters such as dissolved oxygen, pH, salinity, conductivity, oxidation reduction potential (ORP) etc. The change in temperature can also affect the ecological niche of many of the aquatic organisms, especially the poikilothermal animals like fish. The change in temperature can affects the metabolic rate of majority of aquatic plants and animals. Study shows that alteration in temperature can amplify body metabolism of the aquatic organisms and even death in extreme cases.


35
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POST MONSOON
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
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BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
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MONSOON
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
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BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
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POST MONSOON
HARSHIL
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BIJNOR
NARORA
FARRUKABAD
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PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
27
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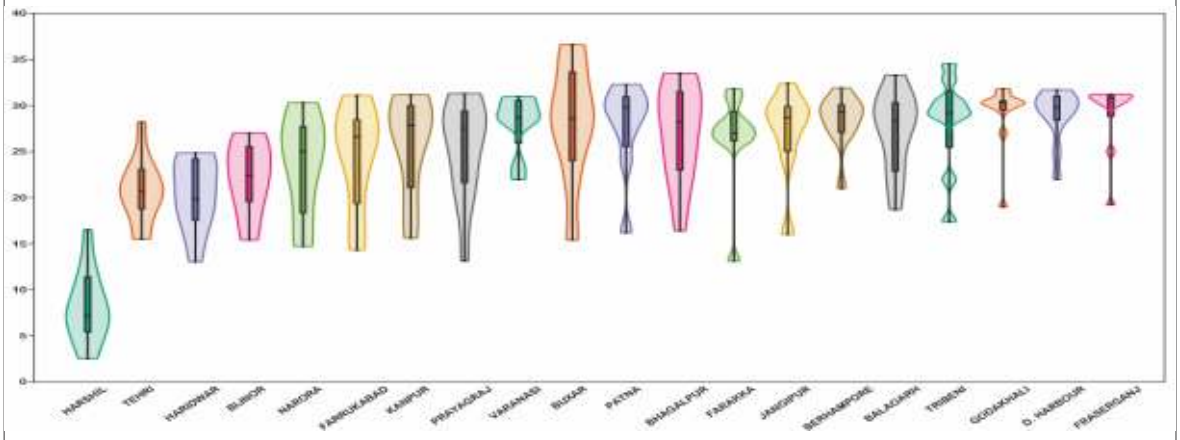
17
12
7
2
WINTER
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

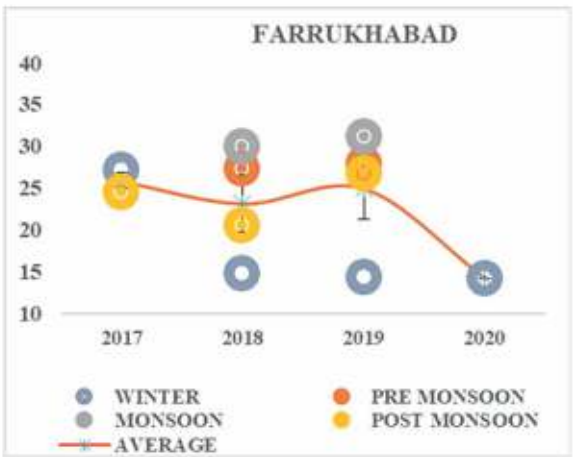
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN WATER TEMPERATURE (°c) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)



Changing Pattern of Temperature		
Stretches	**Period**	**Temp(°C)**
Haridwar	1984-85	11.25-19.75
	1995-96	12.5-26
	2016-20	21.88
Kanpur	1960	16-30.5
	1995-96	16-30
	2016-20	25.65
Pryagraj	1960	17.5-31.5
	1995-96	17-32
	2016-20	25.35
Varanasi	1960	18.5-31.5
	1995-96	20-31.5
	2016-20	26.39
Buxar	1960	18-31
	1995-96	19-33
	2016-20	28.22
Patna	1960	18.5-31
	1995-96	19.5-31
	2016-20	27.75
Bhagalpur	1960	18.5-31.5
	1995-96	18.5-31
	2016-20	27.42
Farakka	1960	18.5-31.5
	1995-96	18.5-31
	2016-20	26.43
Diamond Harbour	1953-55	18-33
	1995-96	20.5-30
	2016-20	29.163

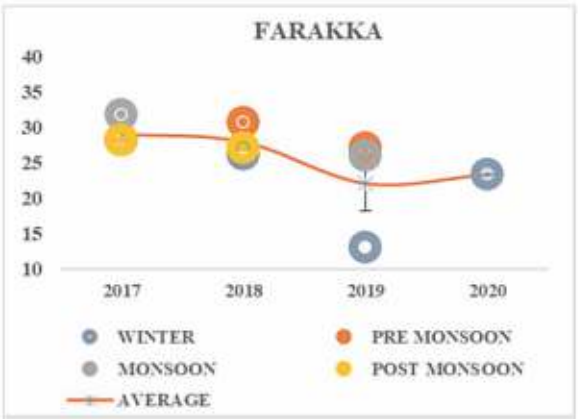
The average water temperature in the entire stretch during 2016-20 varied from 7.22 ± 2.94 °C to 29.16 ± 2.99 °C. During the entire sampling the minimum temperature was observed at Harshil i.e., 2.53°C, while the highest temperature of 36.6 °C at Buxar-Baliya stretch of the Bihar and Uttar Pradesh. During winter season the average temperature across entire stretch was 21.65 ± 0.96 °C. The enhanced maximum temperature of 34.50 °C was observed at Tribeni of West Bengal, which may be possibly due to thermal discharge from the BTPS thermal power plant which significantly influences the water temperature of the river. During the pre-monsoon season the average temperature was found 27.07 ± 0.8 °C. The average temperature during the monsoon was found 27.72 ± 1.17 °C. During the post monsoon the average temperature was found 24.71 ± 0.8 °C.

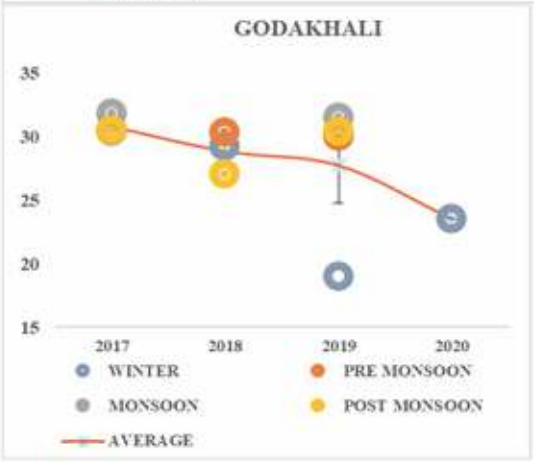
TIMESCALE CHANGES OF WATER TEMPERATURE (°c) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)



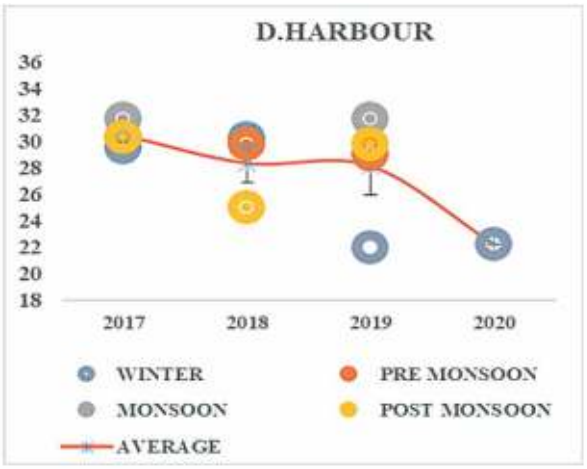
TIMESCALE CHANGES OF WATER TEMPERATURE (°c) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

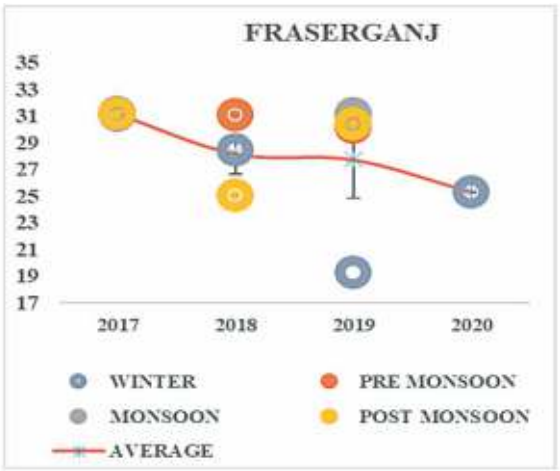
TIME-SCALE CHANGES OF WATER TEMPERATURE (°c) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)





TIMESCALE CHANGES OF WATER TEMPERATURE (°c) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



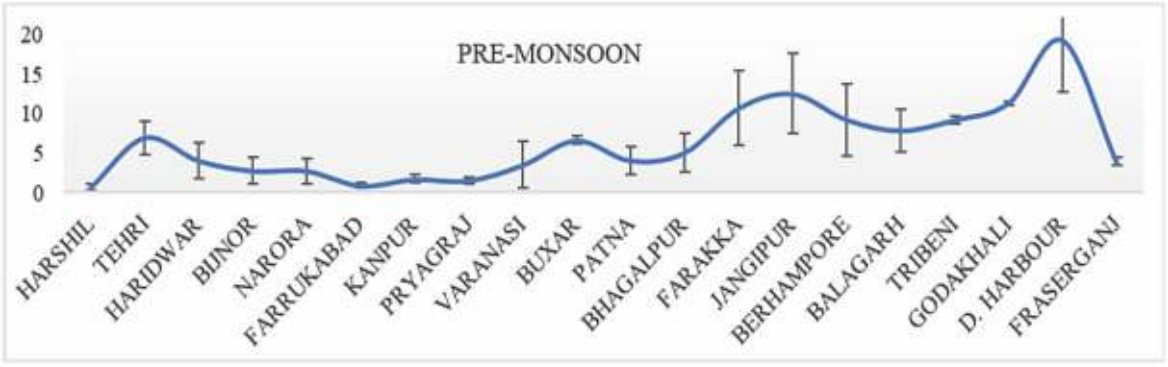


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch of the river no significant alteration in the temperature has been observed irrespective of years.
- In the middle stretch of the river modest variations have been observed from 2017 to 2020. The relative decrease in the temperature has been observed at the majority of the sampling sites i.e., at Kanpur, Buxar, Patna, and Bhagalpur. Although at a few of the sampling sites i.e., at Prayagraj, and Varanasi rise in temperature has been observed.
- In the lower stretch of the river, a relative decrease trend in temperature has been observed at the majority of the sampling sites except at Balagarh and Tribeni.
- Similar to the lower stretch of the river the temperature in estuarine stretch also varied and differed from 2017 to 2020.

Water depth (m)

Water depth plays pivotal role in the determination of water level of the aquatic system and is significant contributor in the assessment of aquatic environment for the better management of the aquatic ecosystem. The depth of the water depends on multiple natural as well man-made activities. The major factor which affects the water depth is rainfall and water from tributaries and distributaries of the river system. Along with rainfall and water inflow the dams and barrages also affect the water depth in the Ganga River system. The reduction in water depth may lead to reduction or shift of ecological niche of many of the aquatic flora and fauna. The distribution of Dolphin is also greatly affected by water depth, as the reduction in water depth may lead to reduction in their number.


PRE-MONSOON
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HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
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FARAKKA
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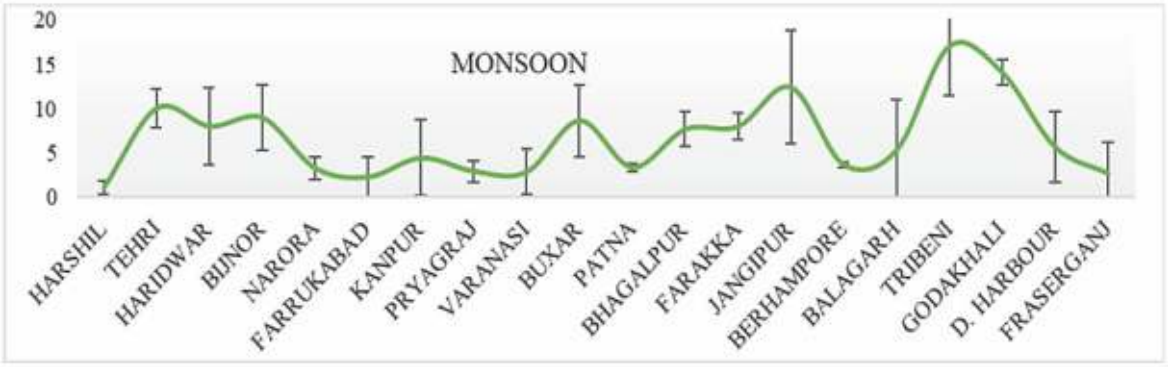
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
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HARIDWAR
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VARANASI
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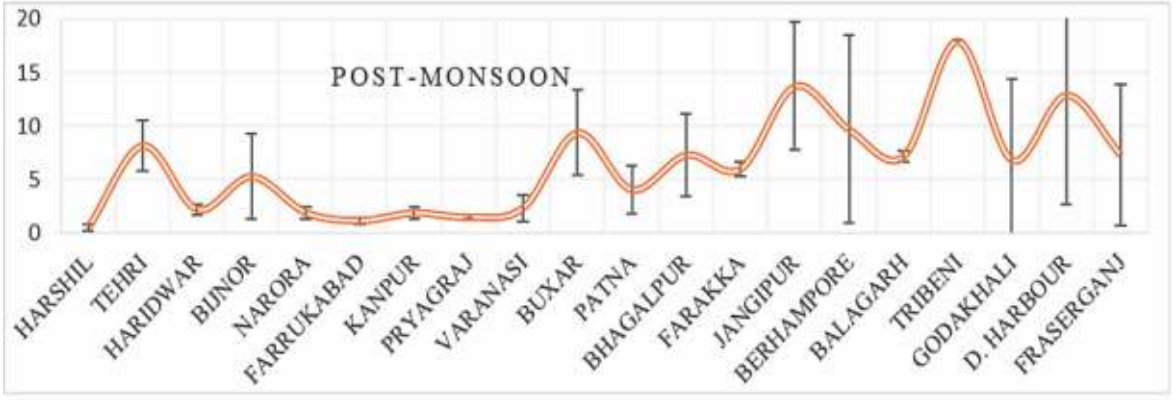
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
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HARSHIL
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BERHAMPORE
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TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
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FARRUKABAD
KANPUR
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VARANASI
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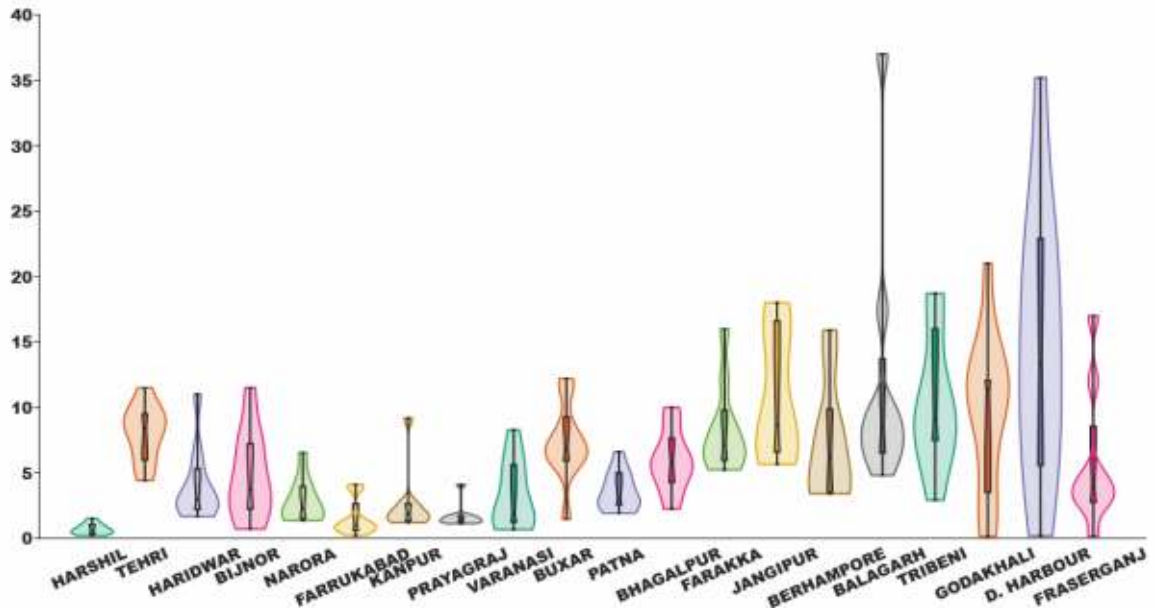
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

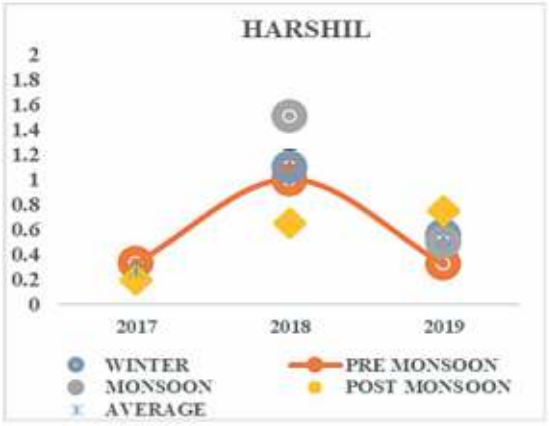
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN DEPTH (m) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

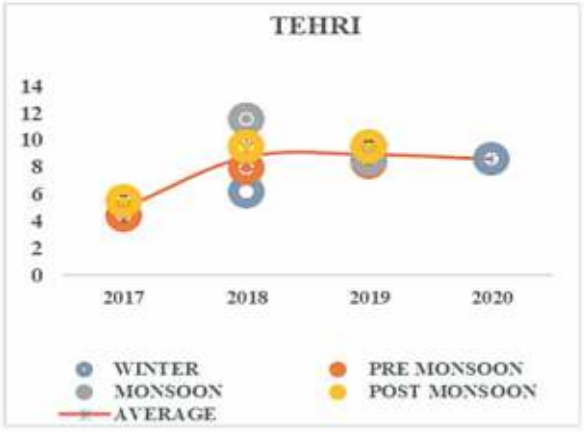


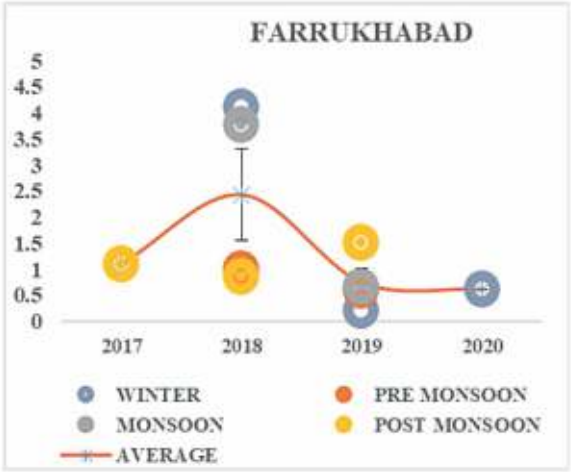
BRIEF DESCRIPTION

The observed average depth in the entire river was 6.26 ± 0.41 m. The highest average depth of 12.70 ± 2.44 m was observed at Diamond Harbor of West Bengal, which is a tidal zone of the river. The lowest average depth of 0.69±0.13 m was observed at Harshil from where the river arises. During pre-monsoon season the average depth of the river was 6.46 ± 0.71m. The average depth of the river during monsoon was 6.97 ± 1.06 m. The average depth during winter season was 6.34 ± 0.90 m. While the average depth of the river during post monsoon season was 5.42 ± 0.71 m. During the entire 5 years the lowest depth of 0.13 m was observed at Harshil, and the highest depth was observed 35.20 m at Diamond Harbour during high tide.

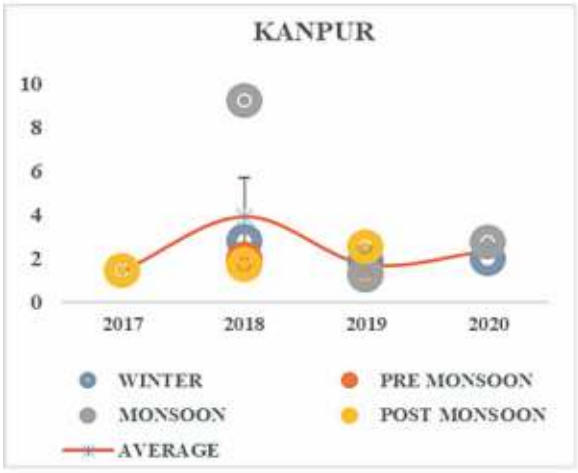
TIMESCALE CHANGES OF DEPTH (m) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

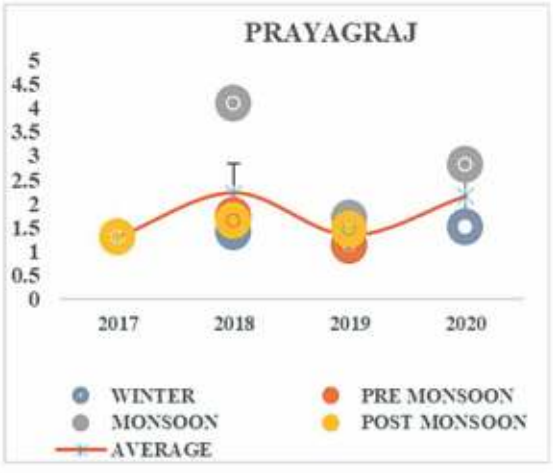


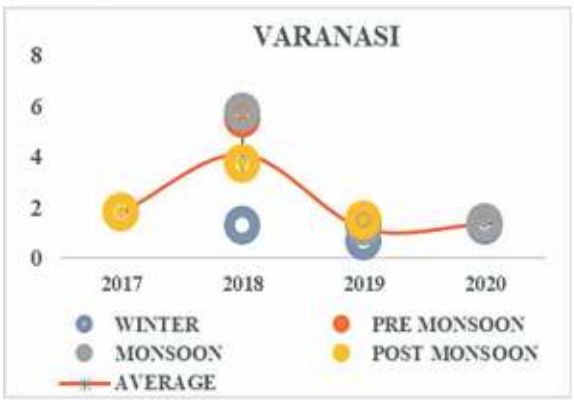


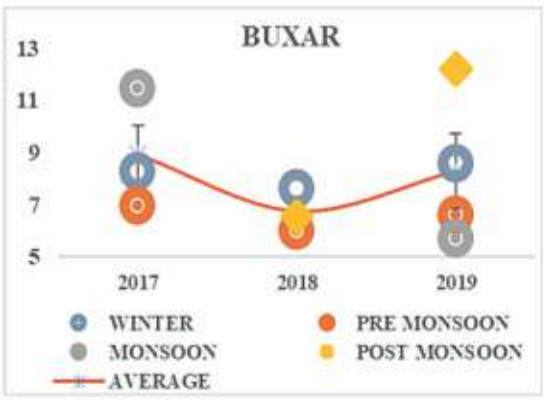


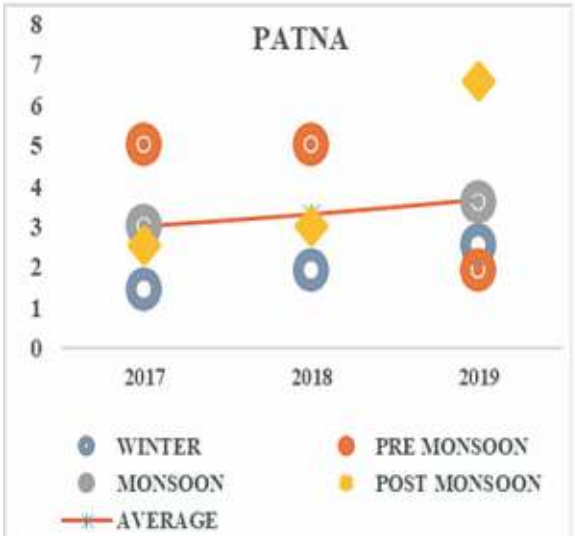
TIMESCALE CHANGES OF DEPTH (m) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

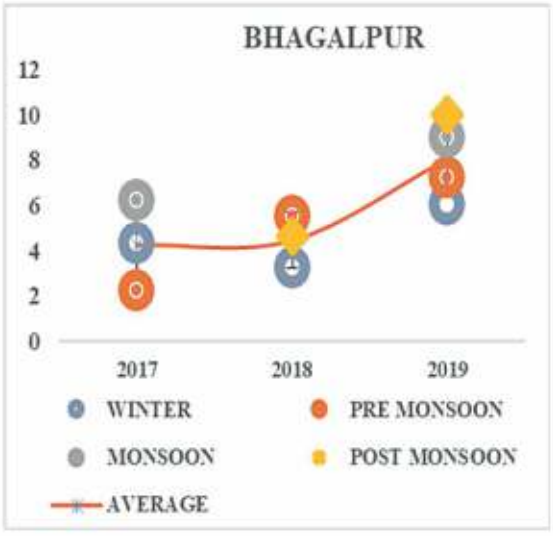




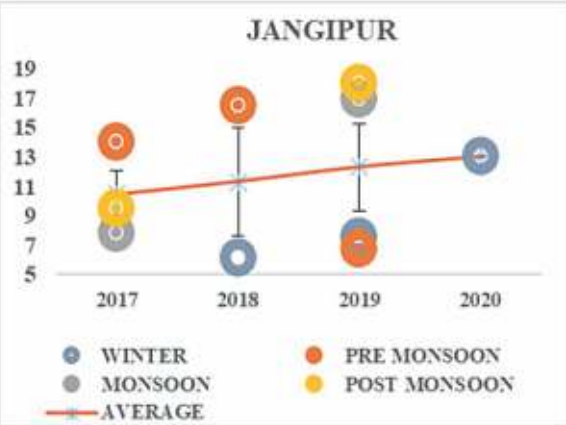


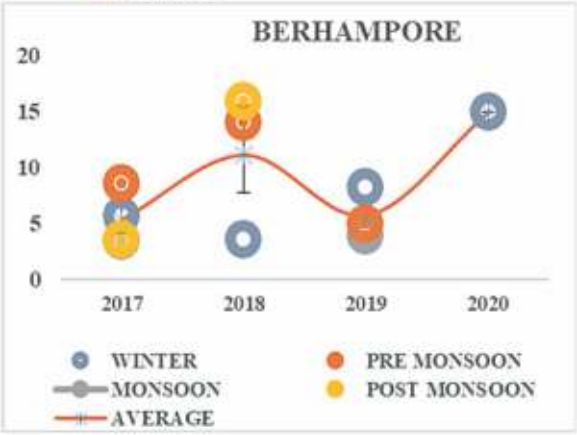


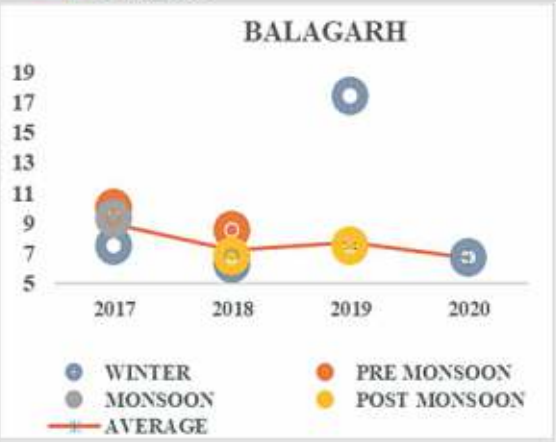


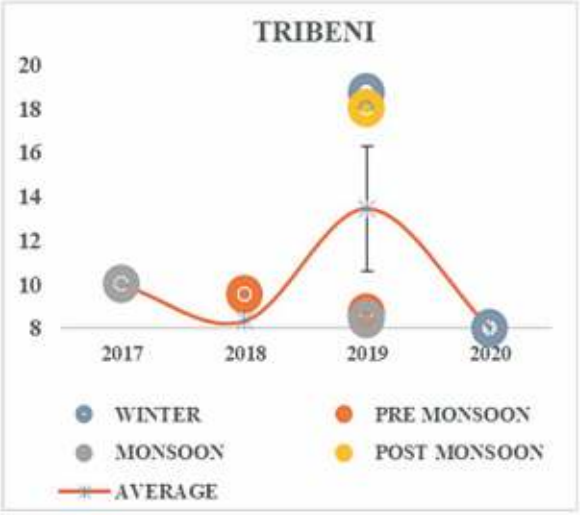


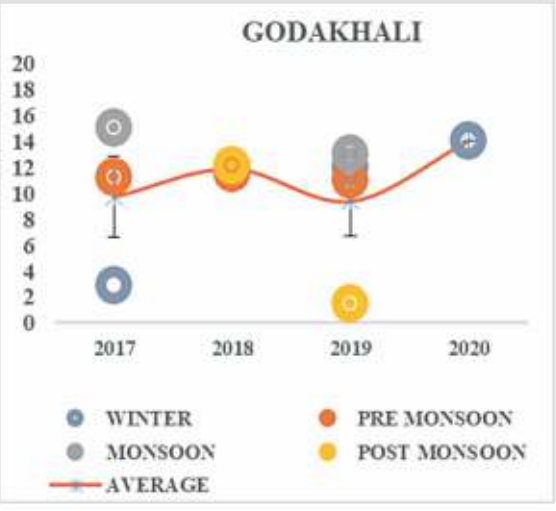
TIME-SCALE CHANGES OF DEPTH (m) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)



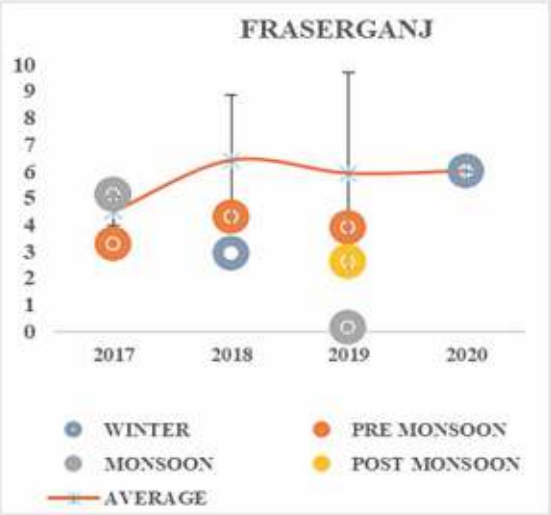








TIMESCALE CHANGES OF DEPTH (m) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

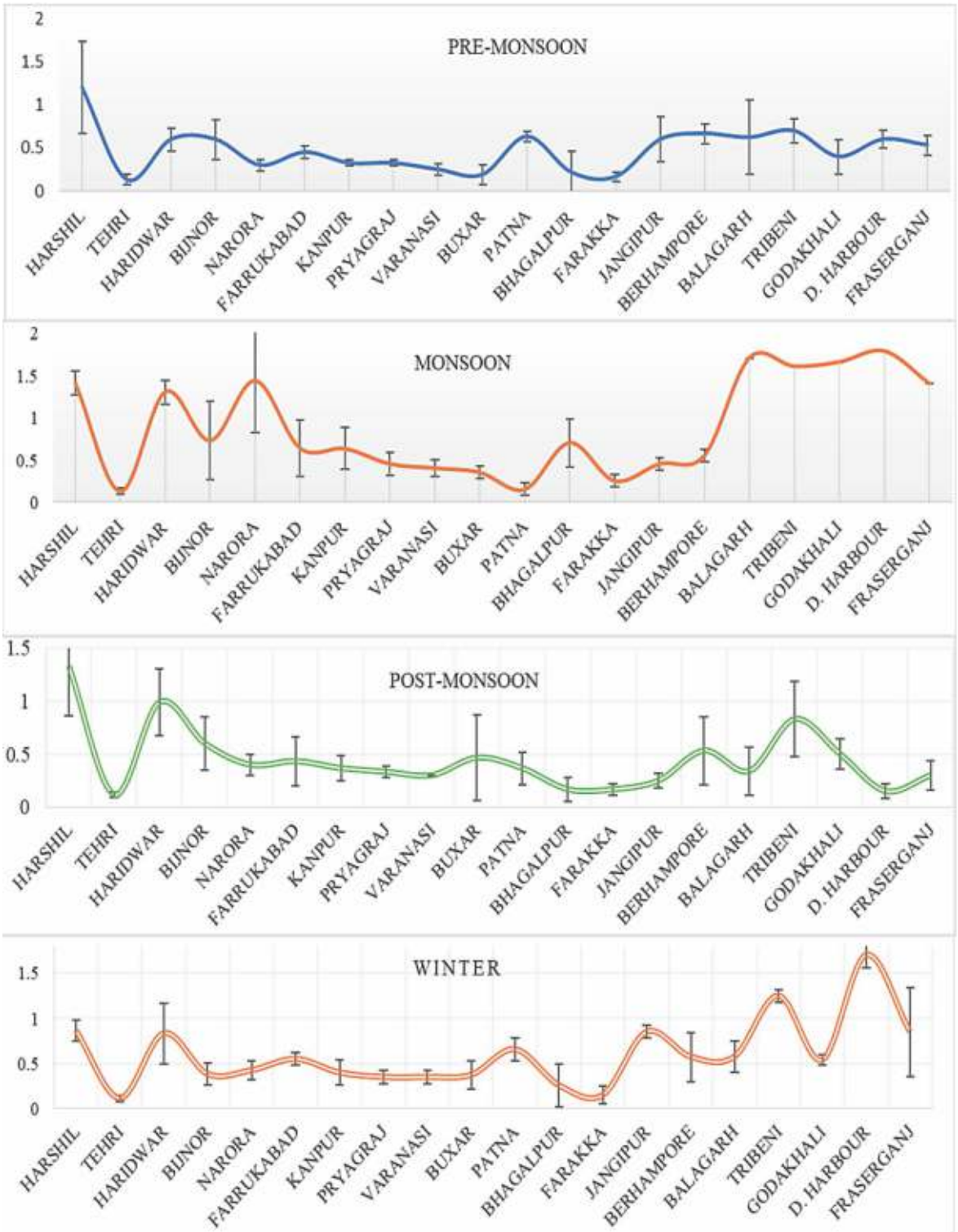


SALIENT TIMESCALE OBSERVATIONS

- Among the sampling stations of the upper stretch relative decrease in depth was recorded at Haridwar and Farrukhabad while an increase has been observed at Harshil, Tehri, Bijnor, and Narora.
- In the middle stretch the increase in the depth has been recorded at Kanpur, Prayagraj, Patna, and Bhagalpur. While decreases in depth has been observed at Varanasi and Buxar.
- In the lower stretch there is a decrease in depth recorded at all the sampling stations in 2017 as compared to 2020 except at Balagarh and Tribeni.
- In the estuarine stretch there is a decrease in depth has been recorded in 2020 as compared to 2017.
- Tidal amplitude in estuarine zone has to be taken into cognizance while monitoring the parameter.

Water flow (m/sec)

Water flow has great impact on the riverine ecology as the enhanced riverine flow may lead to reduction in the riverine pollution and vice versa. The reduction in the pollution is due to dilution of water in the river system. There are multiple factors responsible for the alteration in the riverine flow but major of them are dam and barrages, which creates hindrance in the ecosystem. The alteration in the river flow adversely affects the aquatic floral and faunal distribution. In the fish also flow make significant impact on their maturity, by affecting their hormonal and body physiology, which directly affects fish seed production and catch.


PRE-MONSOON
MONSOON
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HARIDWAR
BIJNOR
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FARRUKABAD
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PRYAGRAJ
VARANASI
BUXAR
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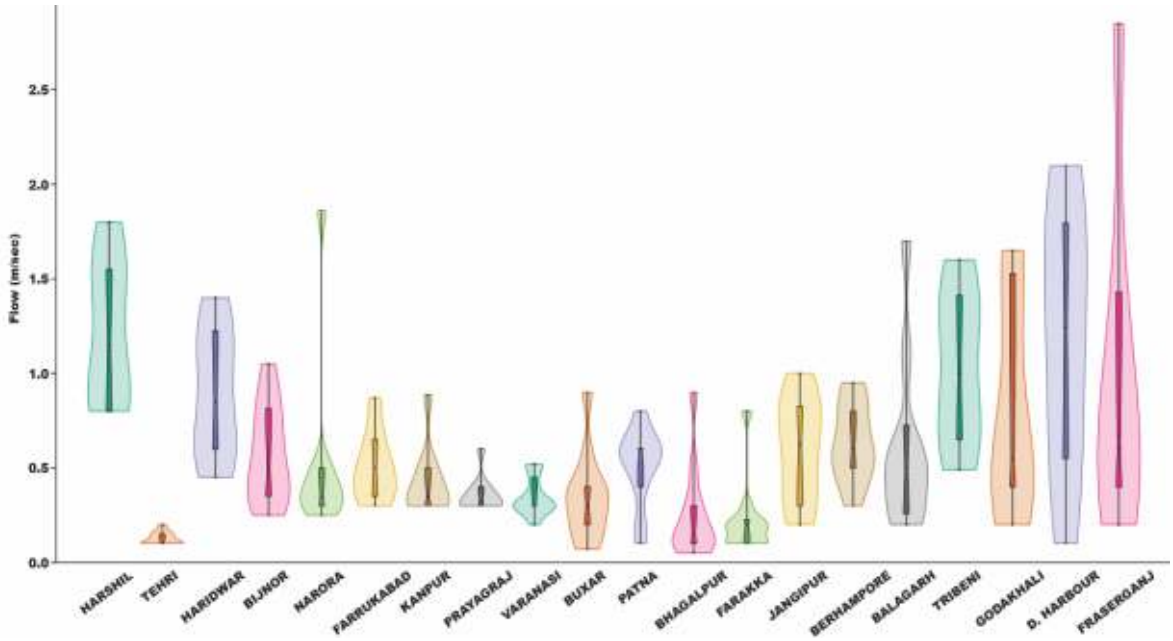
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

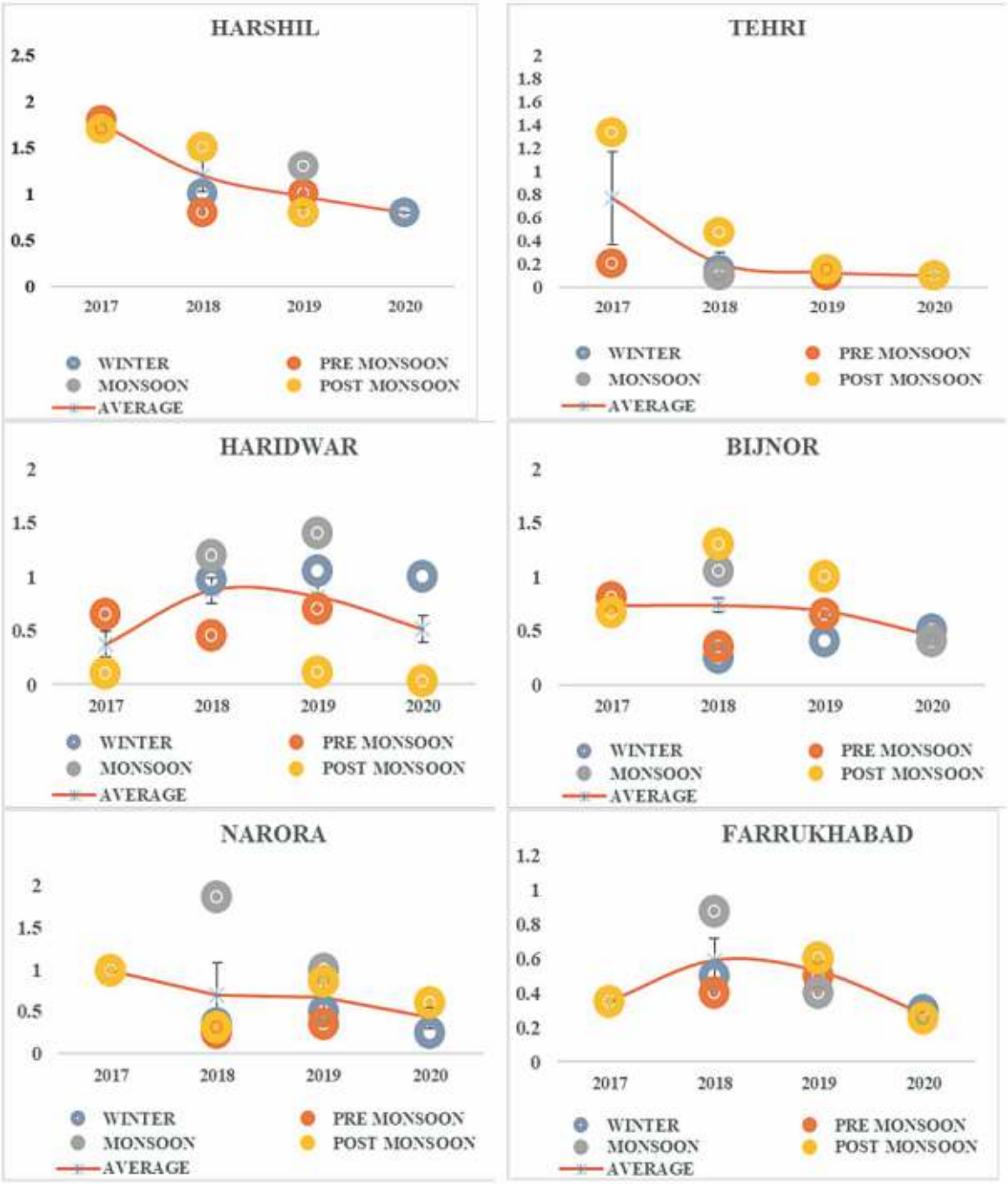
VIOLIN BOX PLOT ILLUSTRATING IN FLOW (m/sec) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)



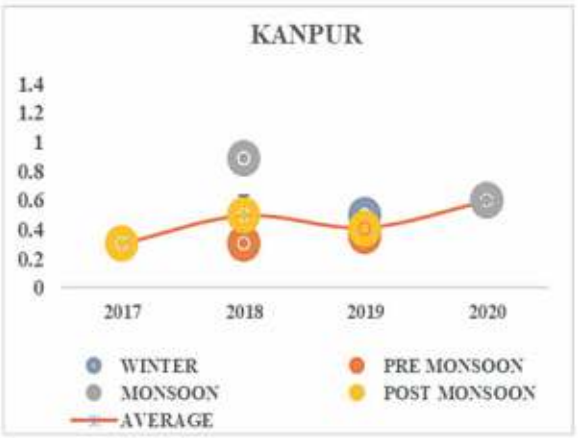
BRIEF DESCRIPTION

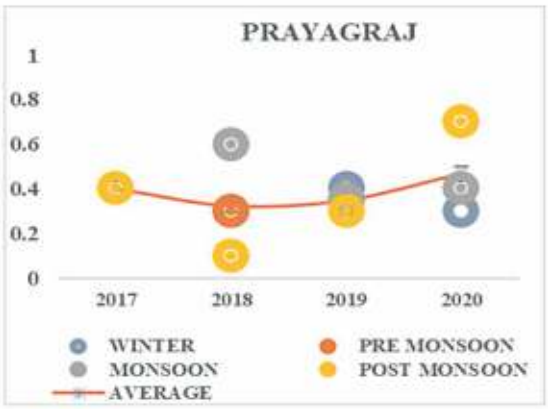
The flow in the entire stretch ranges from 0.05 m/sec to 3.8 m/sec. Average flow in the entire river was 0.6 ± 0.03 m/sec. The highest mean flow of 1.09 ± 2.02 m/sec was observed in the estuarine stretch of the river near the sea mouth. However, in the entire river, the highest flow was observed 1.22 ± 0.12 m/sec at Harshil sampling station. Reduced riverine flow was observed at Tehri sampling site which is due to the impact of Tehri Dam. Among all the studied stretches the least flow of 0.37 ± 0.03 m/ sec was observed in the middle stretch of the river. The mean flow in the lower stretch of the river was 0.70 ± 0.08 m/sec. Among the different seasons, the highest flow of 0.86 ± 0.12 m/sec was observed during monsoon season. The least flow was observed 0.48 ± 0.05 m/sec during post monsoon season.

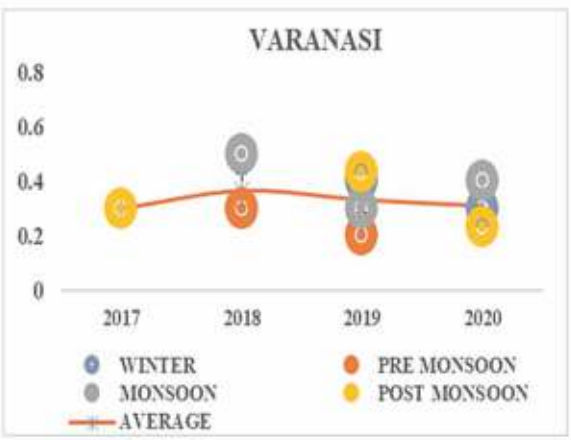
TIMESCALE CHANGES OF FLOW (m/sec) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

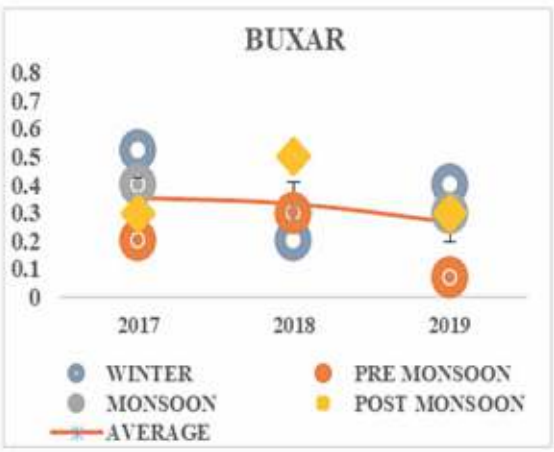


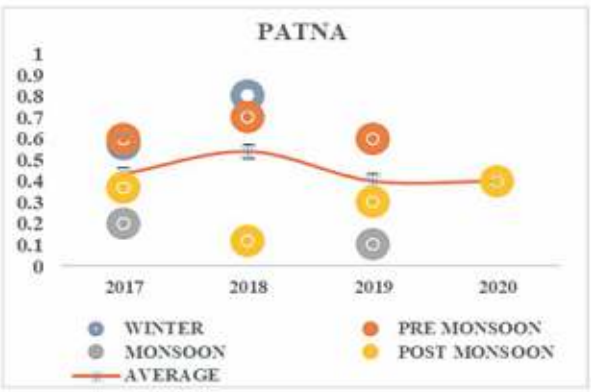
TIMESCALE CHANGES OF FLOW (m/sec) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

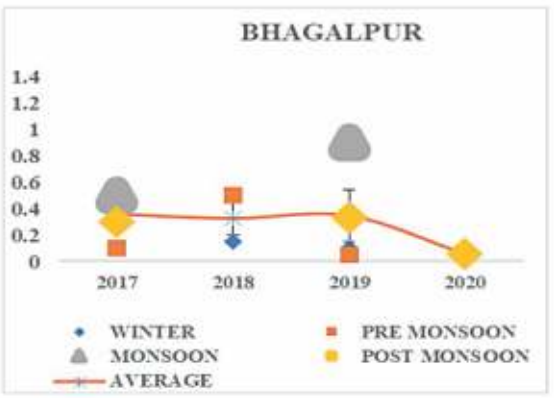




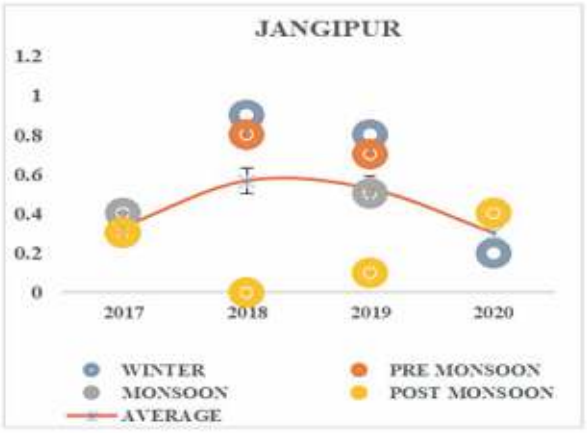


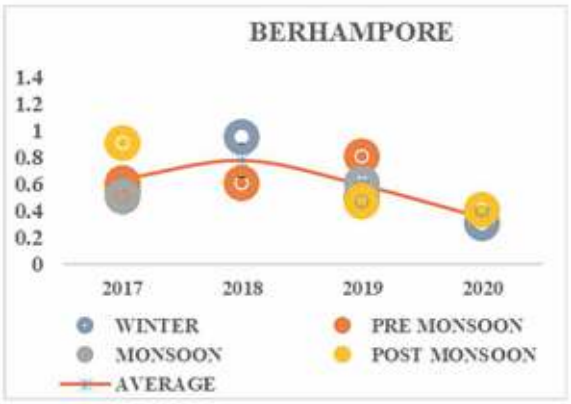


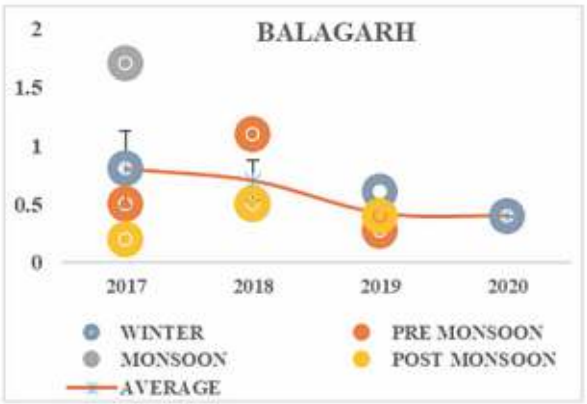


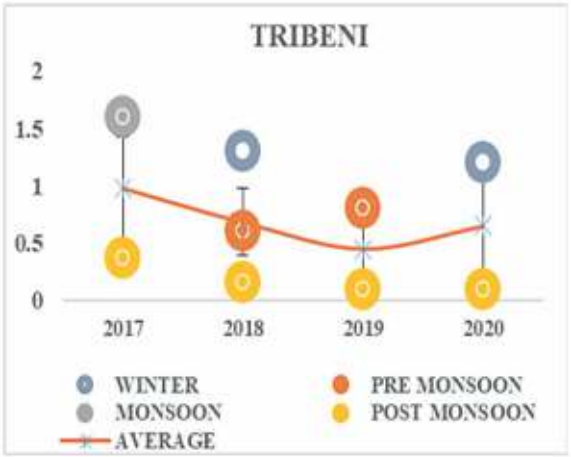


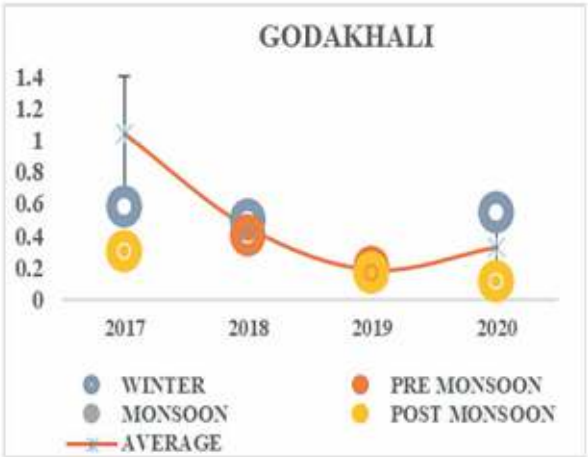
TIME-SCALE CHANGES OF FLOW (m/sec) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)



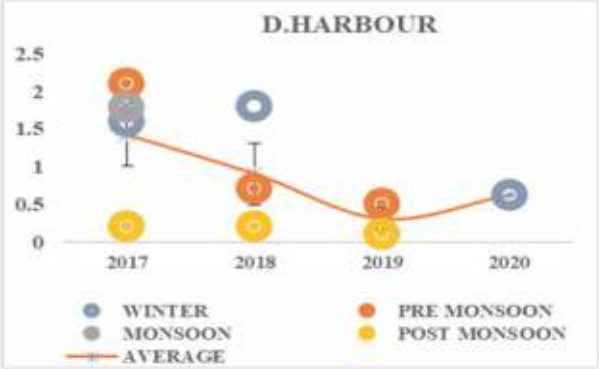








TIMESCALE CHANGES OF FLOW (m/sec) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

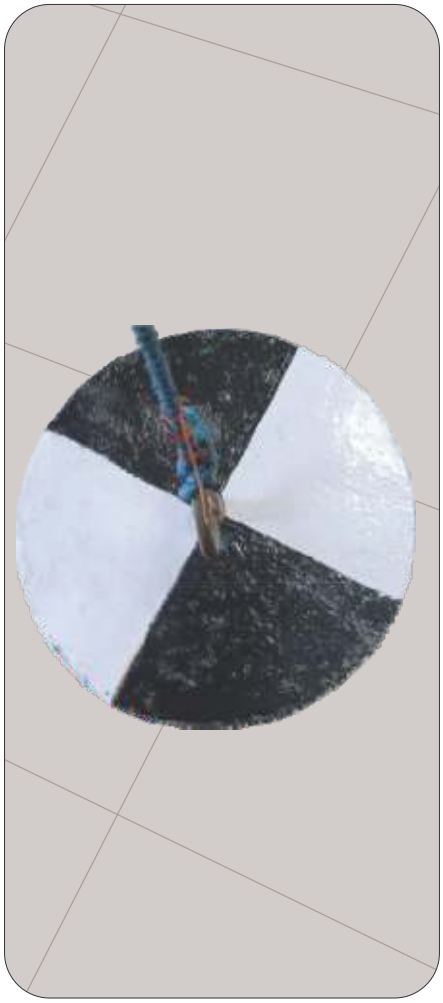


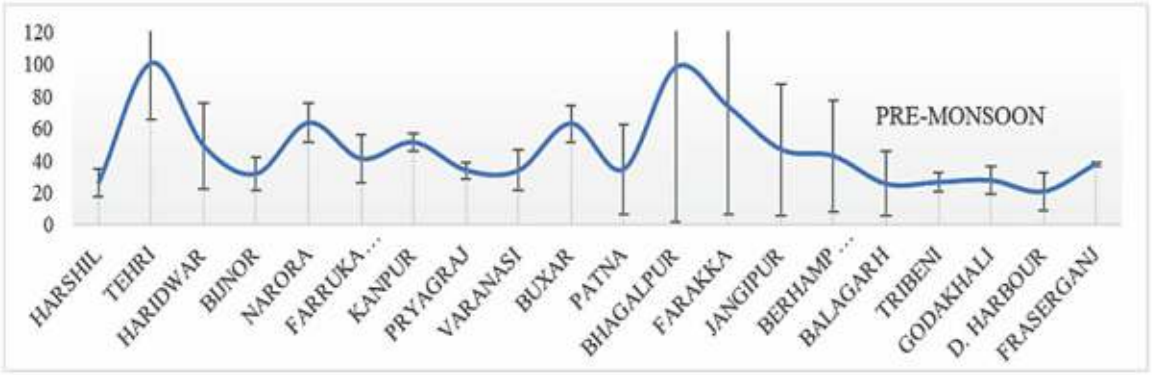
SALIENT TIMESCALE OBSERVATIONS

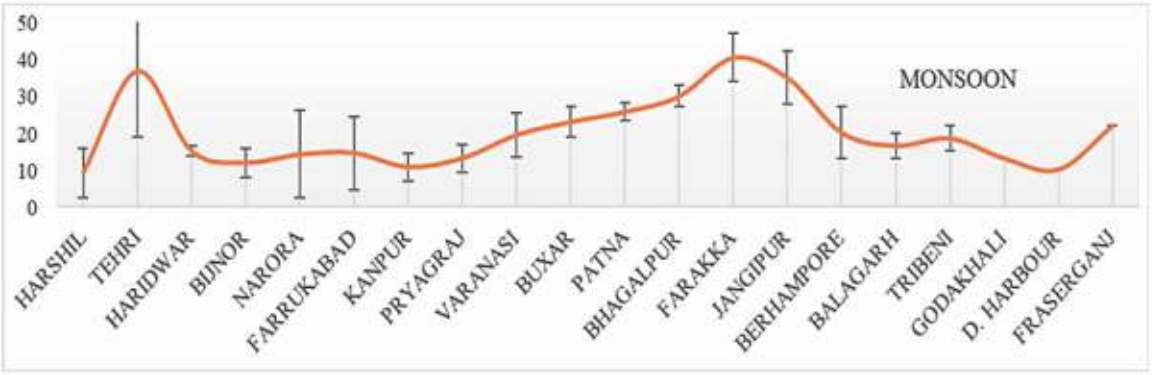
- In the majority of sampling sites in the upper stretch the reduction in the riverine flow has been observed.
- In the middle stretch the increase in flow has been recorded at Kanpur, Prayagraj, and Patna while decrease in flow has been observed at Varanasi, Buxar and Bhagalpur from 2017 to 2020.
- Among the sampling stations of lower stretch, increased flow has been recorded in 2020 as compared to 2017.
- Whereas, in the estuarine stretch, the flow rate has been reduced in 2020 as compared to 2017.

Transparency (cm)

Water transparency is the measurement of clarity of water. The measurement of transparency is done with the help of secchi disk. The transparency and turbidity show inverse relation. There are multiple factors such as river flow, runoff from surrounding, tributaries and distributaries, scattering of light, algal concentration etc. affects the transparency in the river system. The transparency affects the aquatic habitat of the aquatic organism as lower transparency due to planktonic bloom shows the unhealthy aquatic environment.




PRE-MONSOON
120
100
80
60
40
20
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKA…
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMP…
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
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40
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10
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TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
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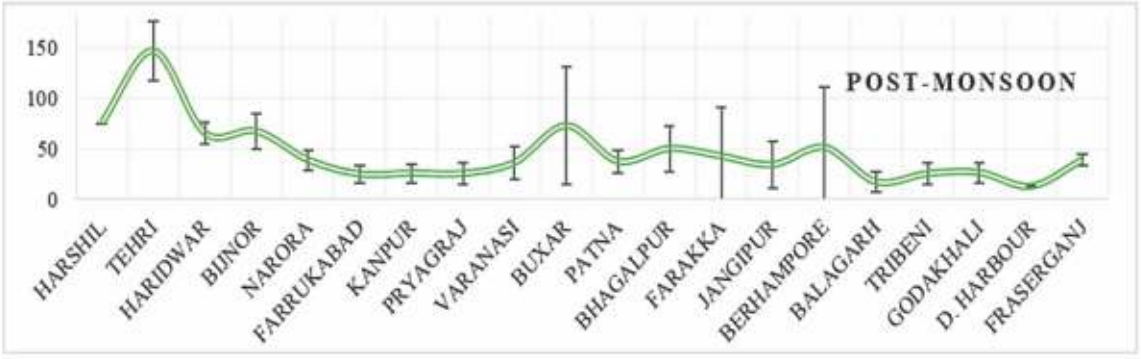
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
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100
50
0
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HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
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BHAGALPUR
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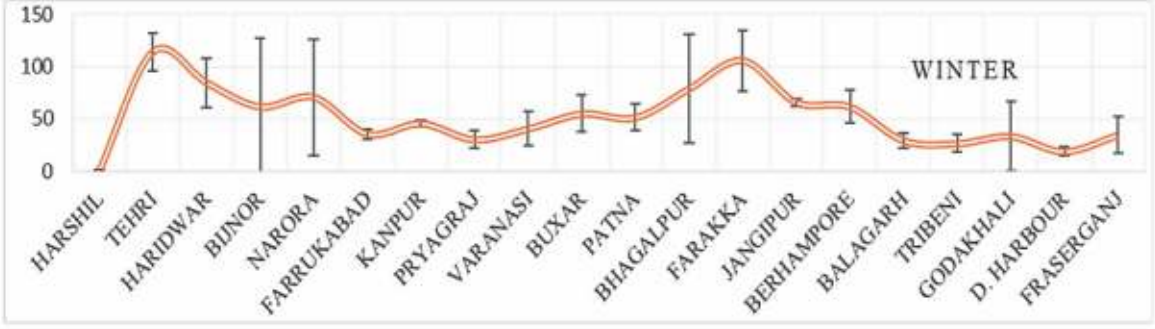
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
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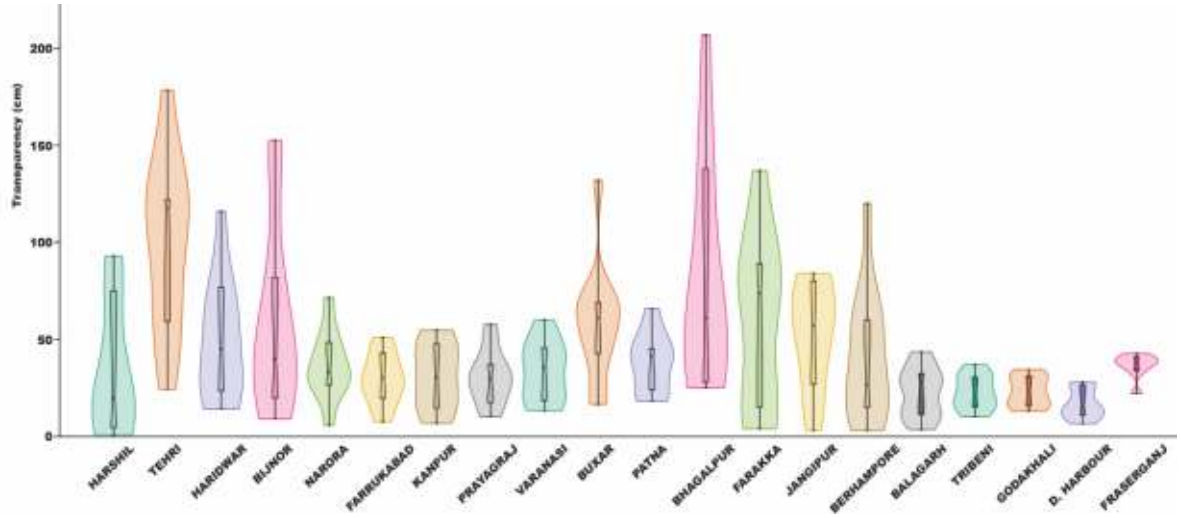
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

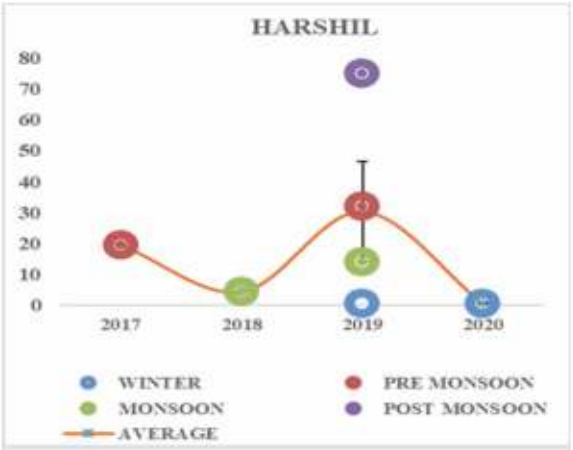
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN TRANSPARENCY (cm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

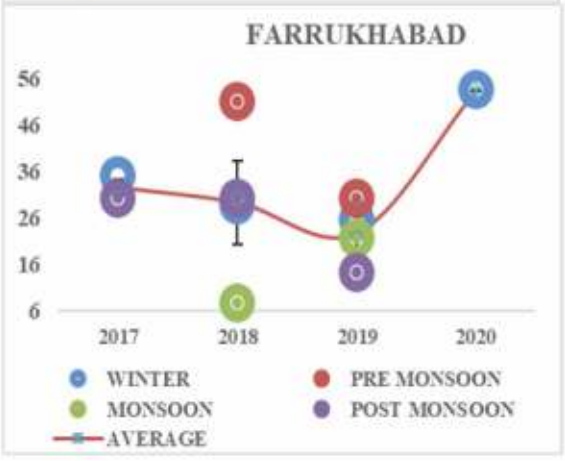


BRIEF DESCRIPTION

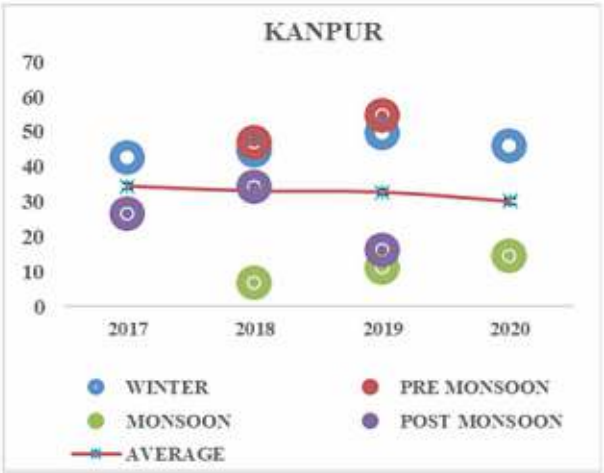
The observed average transparency in the entire river was 43.94 ±2.49 cm. The highest mean transparency value of 101.80 ± cm was observed at Tehri in the upper stretch of the river, in the middle stretch highest mean transparency was observed at Buxar having transparency value of 58.50 ± 9.32 cm, and in the lower stretch observed highest observed average transparency was 67.24 ± 16.54 cm at Farakka. The lowest transparency value in the entire stretch was observed 18.05 ± 2.78 cm at Diamond Harbour. Among different seasons the highest mean transparency was observed 52.64 ± 4.94 cm during winter. The lowest mean transparency was observed 24.35 ± 3.21 cm during monsoon, which may be due to the impact of enhanced riverine flow. Among the different stretches of the river the highest value was observed in the upper stretch of the river 53.40 ± 5.45 cm. The lowest transparency of 26.01 ± 2.80 cm was observed in the estuarine stretch of the river due to the tidal impact. The middle and lower stretches have transparency values of 44.51 ± 4.10 and 39.41 ± 4.25 cm respectively.

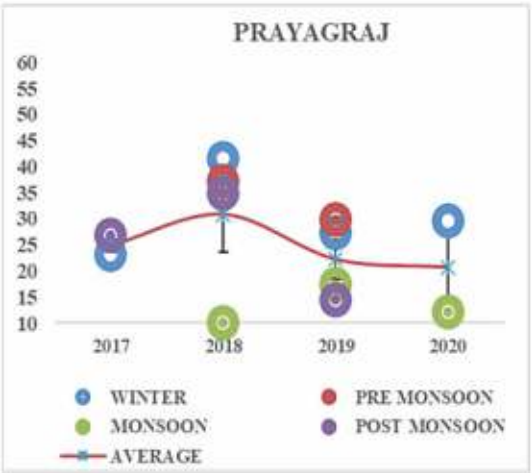
TIMESCALE CHANGES OF TRANSPARENCY (cm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

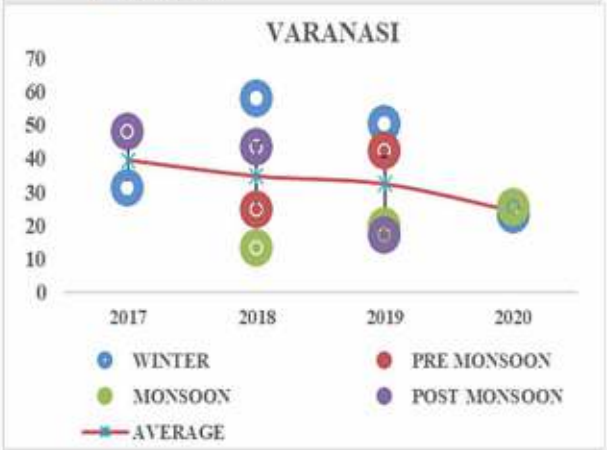


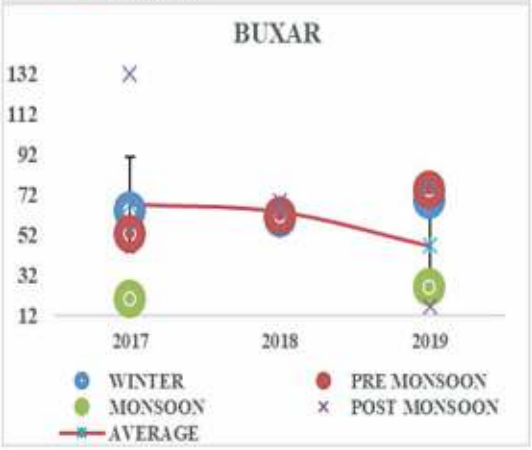


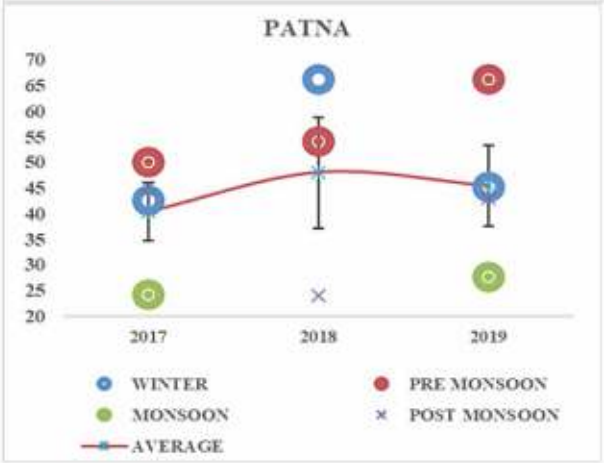
TIMESCALE CHANGES OF TRANSPARENCY (cm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

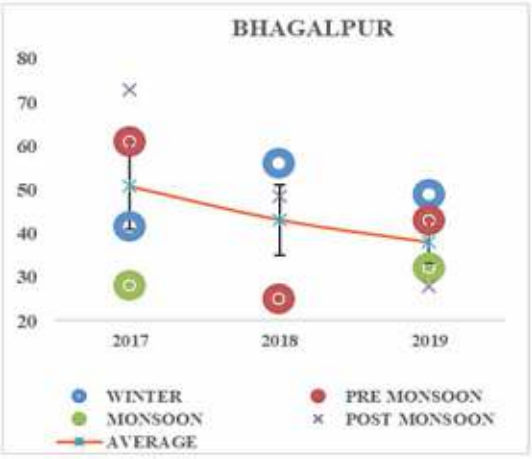




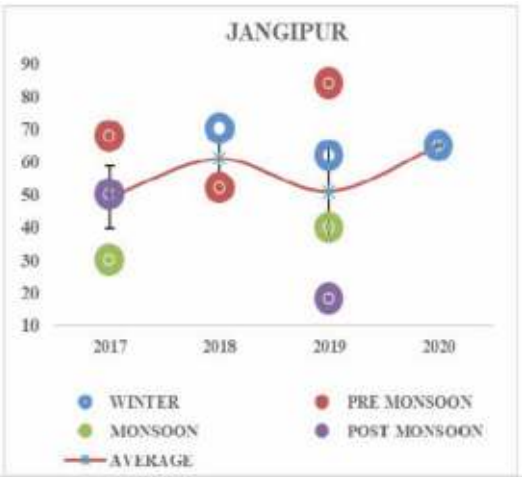


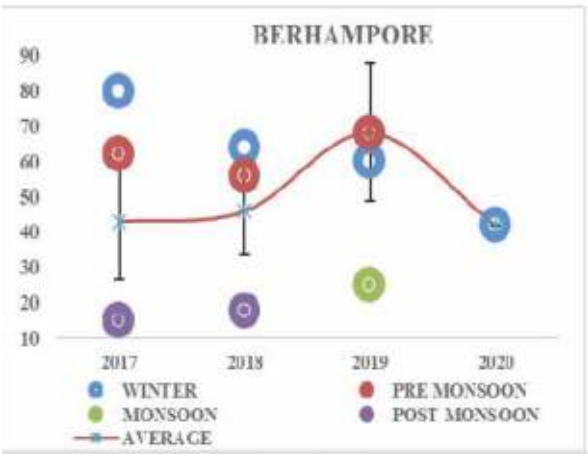


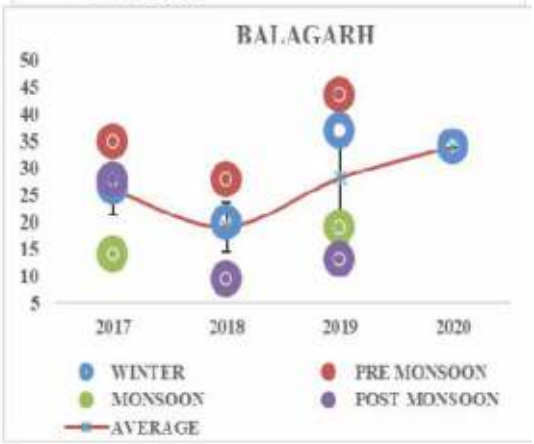


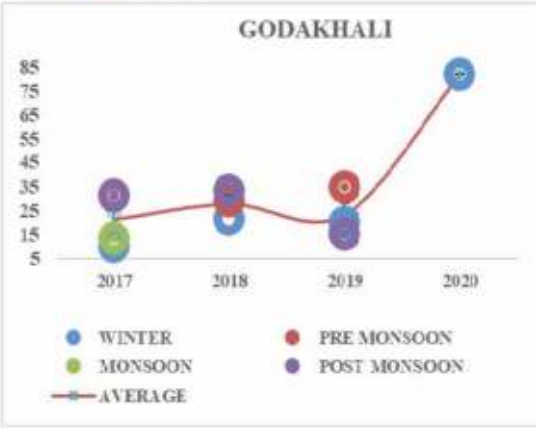


TIME-SCALE CHANGES OF TRANSPARENCY (cm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

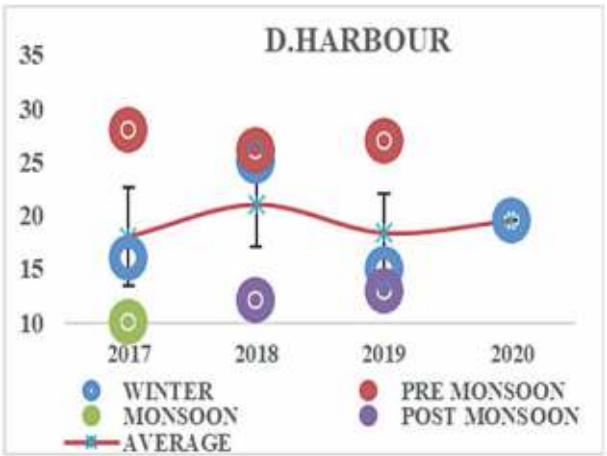


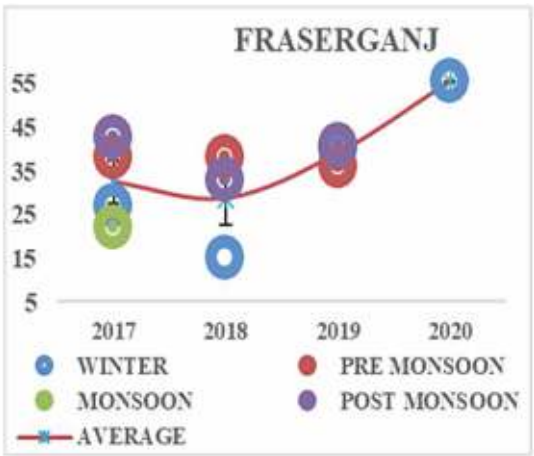






TIMESCALE CHANGES OF TRANSPARENCY (cm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



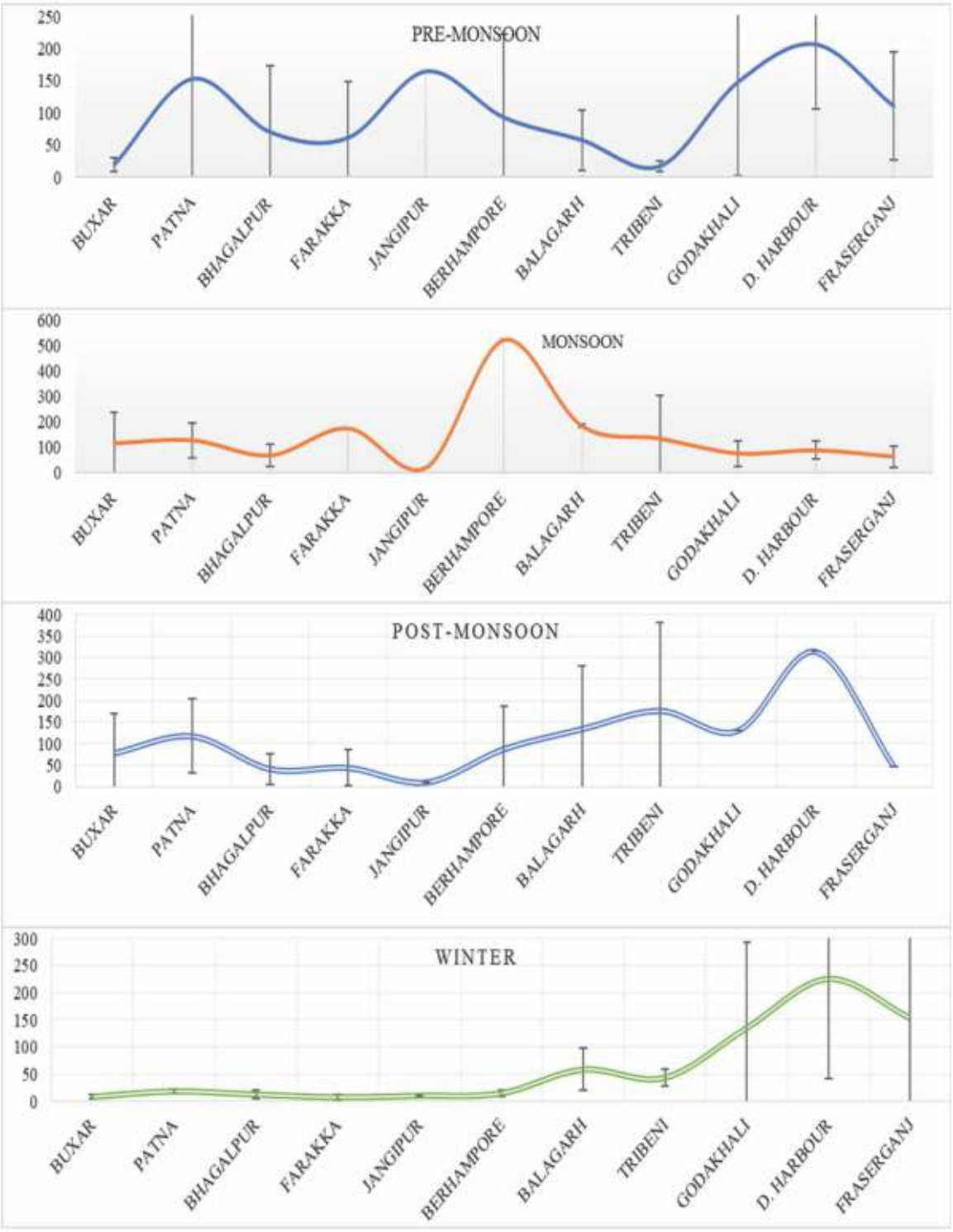


SALIENT TIMESCALE OBSERVATIONS

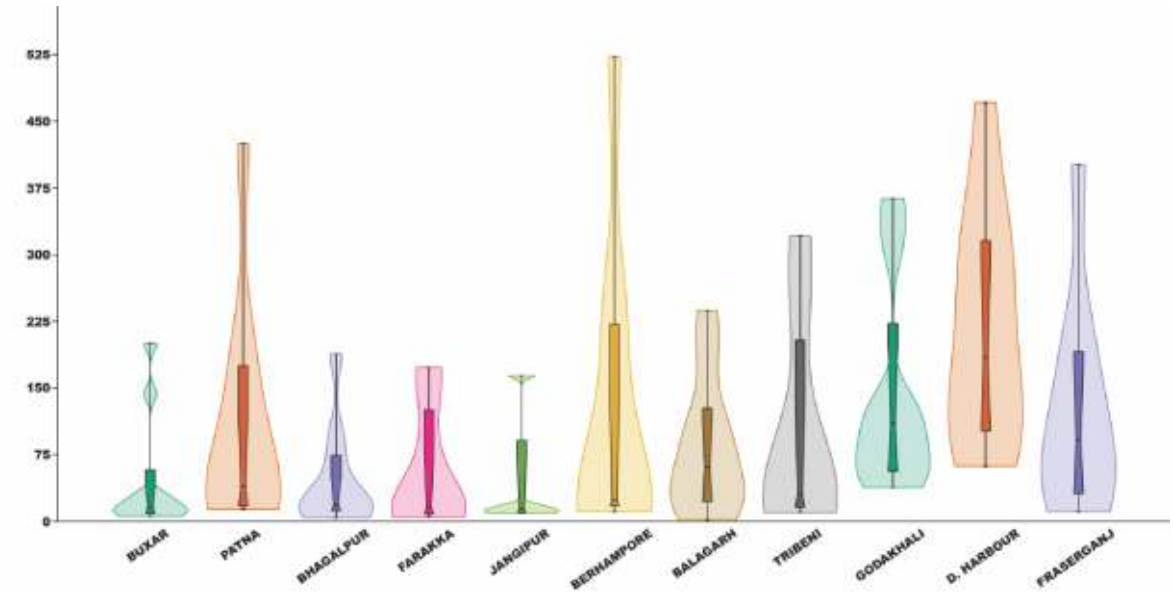
- In the upper stretch, the value of transparency has increased at Harshil, Haridwar, and Bijnor while reduction in thetransparency values have been observed at Tehri, Narora, and Farrukhabad in 2020 as compared to 2017.
- In the middle stretch at all the sampling stations, the transparency values have decreased during 2020 with respect to 2017.
- At all the sampling sites in the lower stretch, the transparency value has increased during 2020 with respect to 2017.
- In the estuarine stretch, at all the stations transparency has increased from 2017 to 2020.

Turbidity (NTU)

Turbidity is the relative measurement of cloudiness or fogginess in the water. The turbidity of the water is due to dissolved elements such as planktons, sediment particles, contaminants, erosion, organism movement etc. The alteration in the turbidity can affect drinking water standard as well as aquatic organisms such as fish, plankton and benthos. The increased turbidity in the water can adversely affect the feeding of many aquatic organisms such as planktivorous fish.


PRE-MONSOON
250
200
150
100
50
0
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
MONSOON
600
500
400
300
200
100
0
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
POST-MONSOON
400
350
300
250
200
150
100
50
0
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ
WINTER
300
250
200
150
100
50
0
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

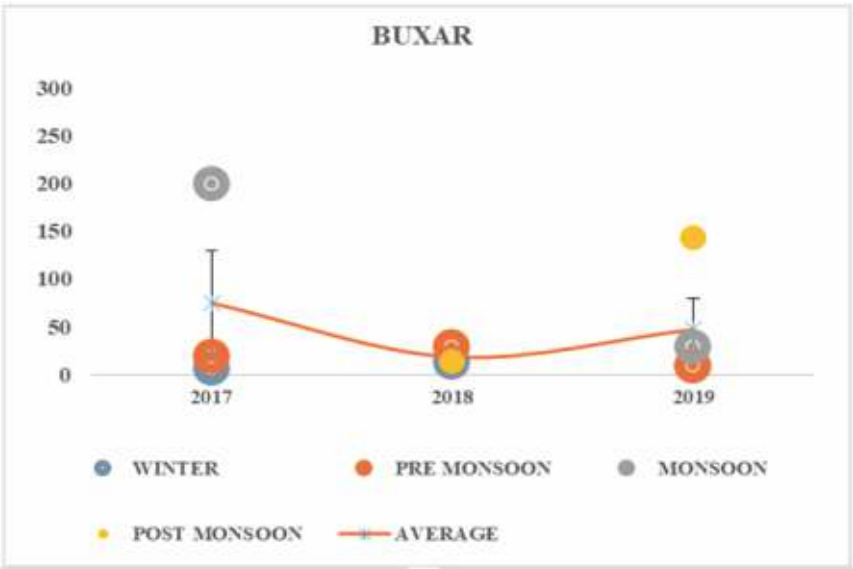
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN TURBIDITY (NTU) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

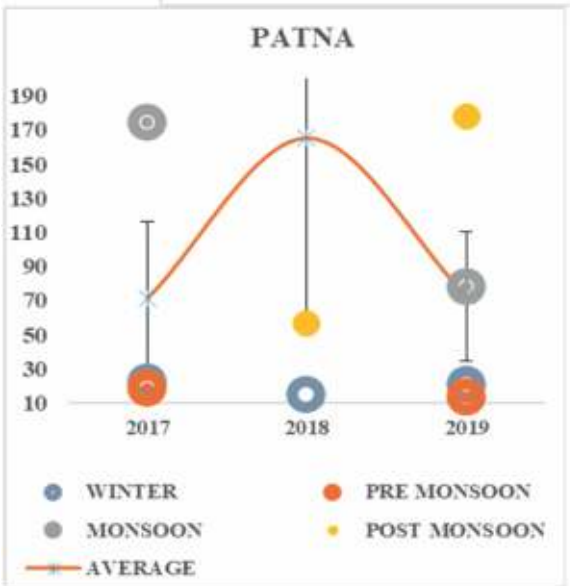


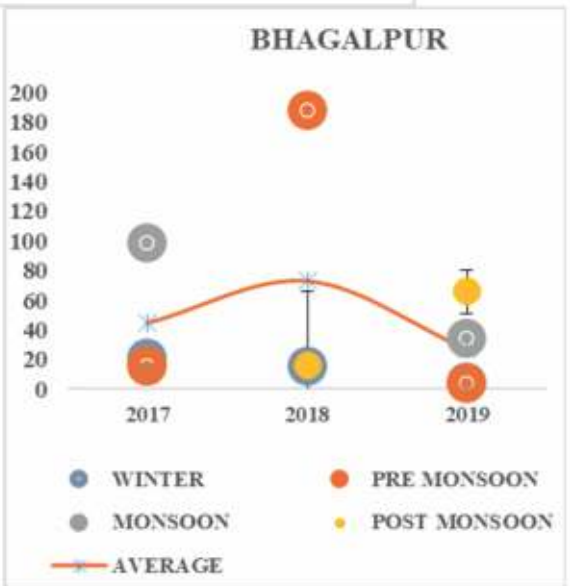
BRIEF DESCRIPTION

The mean value of turbidity in the middle and lower stretch ranged from 48.40 ± 21.07 NTU to 206.96 ± 40.2 NTU. Average turbidity in the entire river was 98.79 ± 11.78 NTU. Among the middle stretch, the highest mean turbidity was observed 99.95 ± 41.31 NTU at Patna, while the lowest value of 45.44 ± 18.4 NTU was observed at Bhagalpur. In the lower stretch of the river the highest turbidity was observed at Godakhali. In the estuarine stretch the highest turbidity of 206.95 ± 40.26 NTU was observed at Diamond Harbour. Among the different seasons the highest mean turbidity was observed 117 ± 28.05 NTU in monsoon. During the post monsoon season the mean turbidity was observed 99.50 ± 22.54 NTU. The least turbidity was observed 87.10 ± 24.53 NTU in winter months.

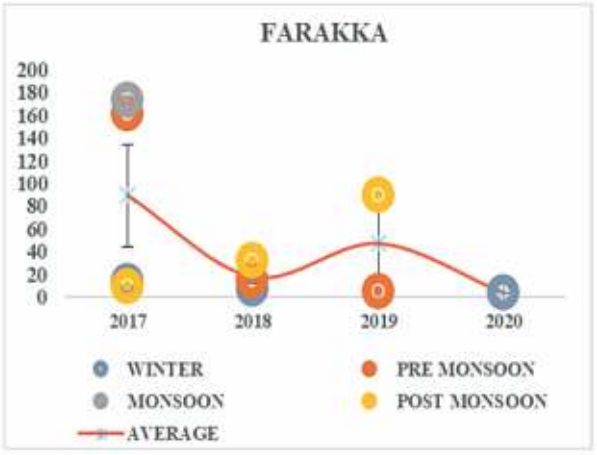
TIMESCALE CHANGES OF TURBIDITY (NTU) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

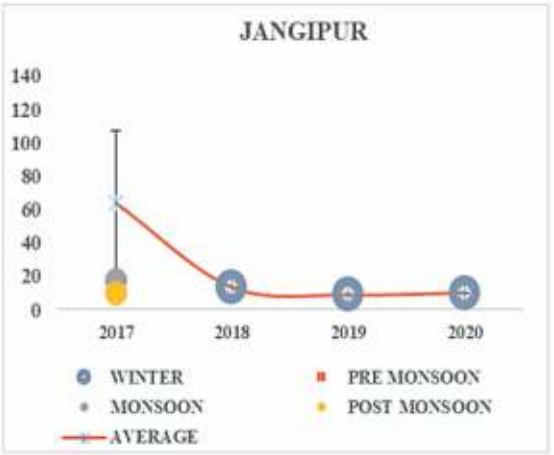


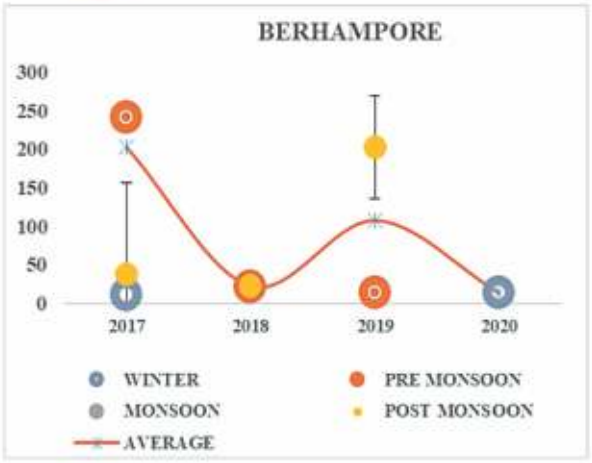


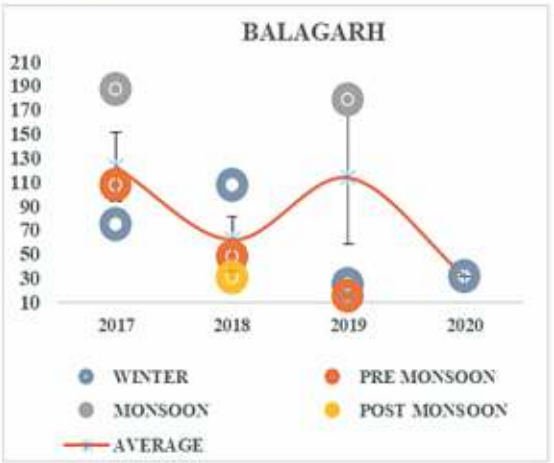


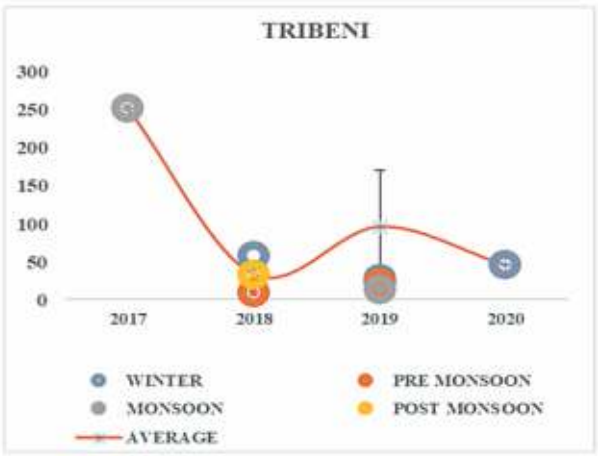
TIME-SCALE CHANGES OF TURBIDITY (NTU) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)



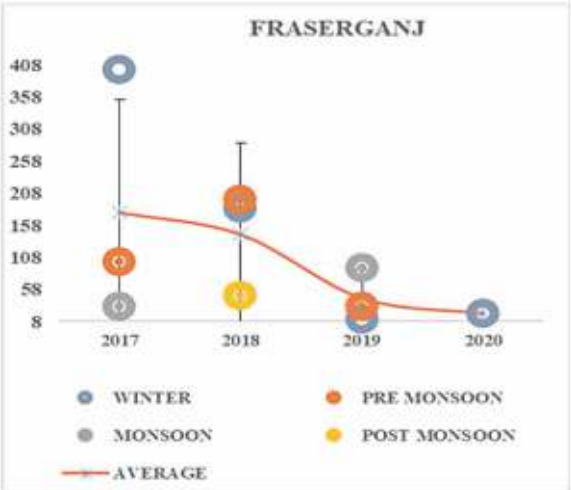








TIMESCALE CHANGES OF TURBIDITY (NTU)IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



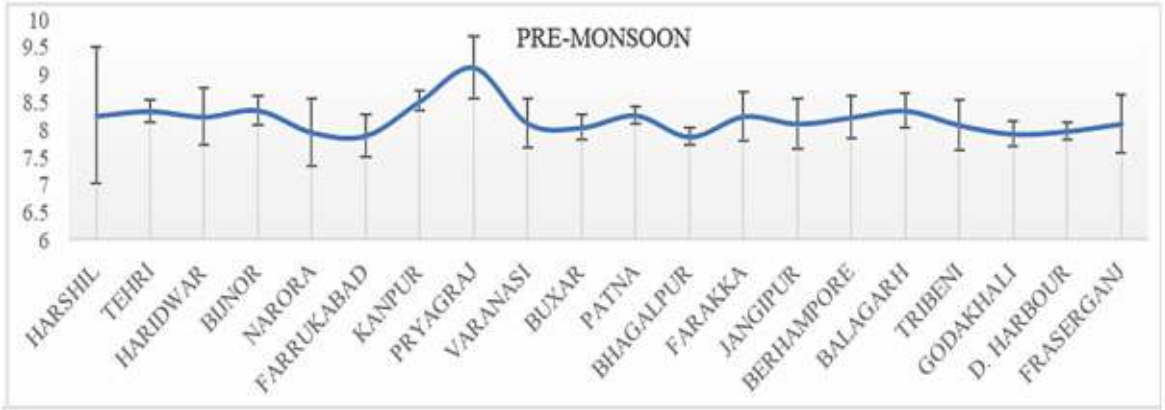
SALIENT TIMESCALE OBSERVATIONS

- Among the stations of middle stretch fluctuations of turbidity have been observed during the entire sampling periods.
- In the lower stretch turbidity decreases from 2017 to 2020.
- Similar to lower stretch, in the estuarine stretch also the value of turbidity decreased from 2017 to 2020.

CHEMICAL PARAMETERS

pH

pH is the measurement for the amount of acidity as well as basicity of the water. It is the measurement of H^+ ion in the water. The significance of the pH is well known for the aquatic animals like fish and aquatic insects. The planktonic diversity also gets affected with the change in pH. The higher pH can denature the cellular membrane of the fish due to by converting the ammonium (NH_4^+) ion to ammonia (NH_3).


PRE-MONSOON
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9
8.5
8
7.5
7
6.5
6
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
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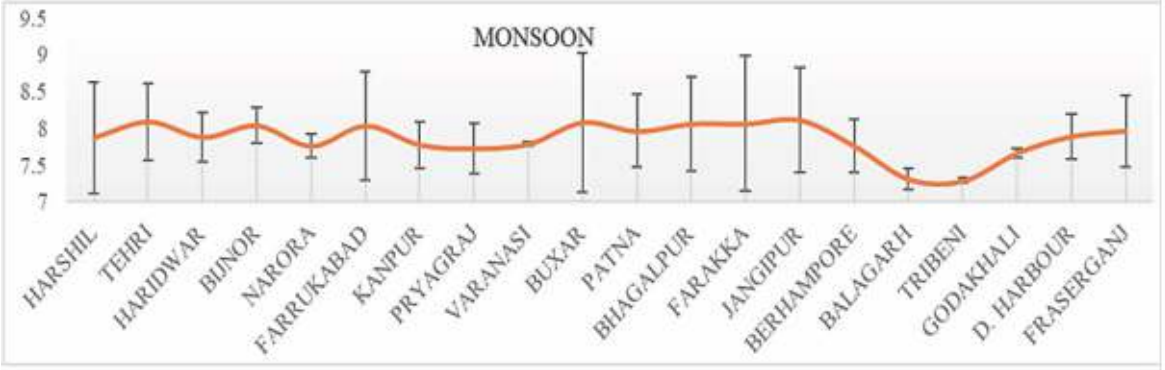
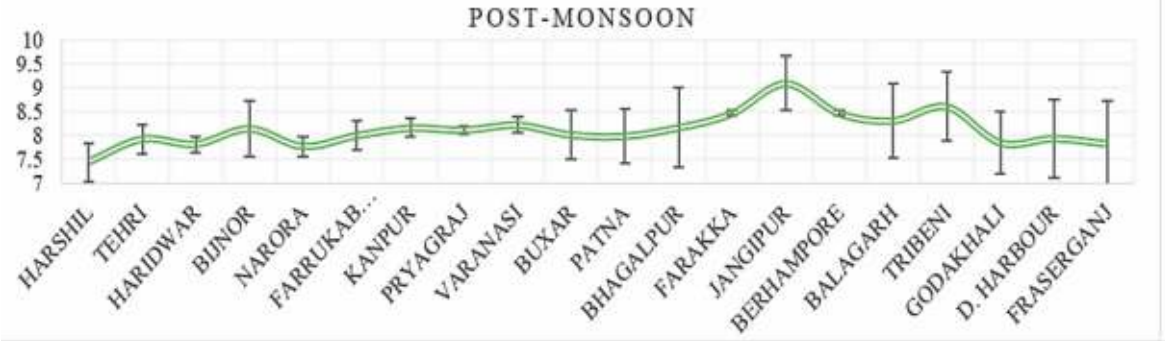
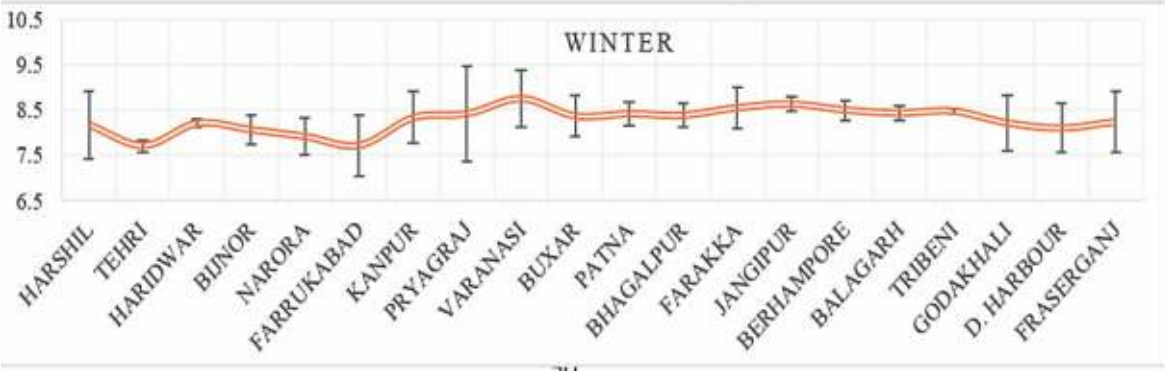
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
9.5
9
8.5
8
7.5
7
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
10
9.5
9
8.5
8
7.5
7
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKAB...
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
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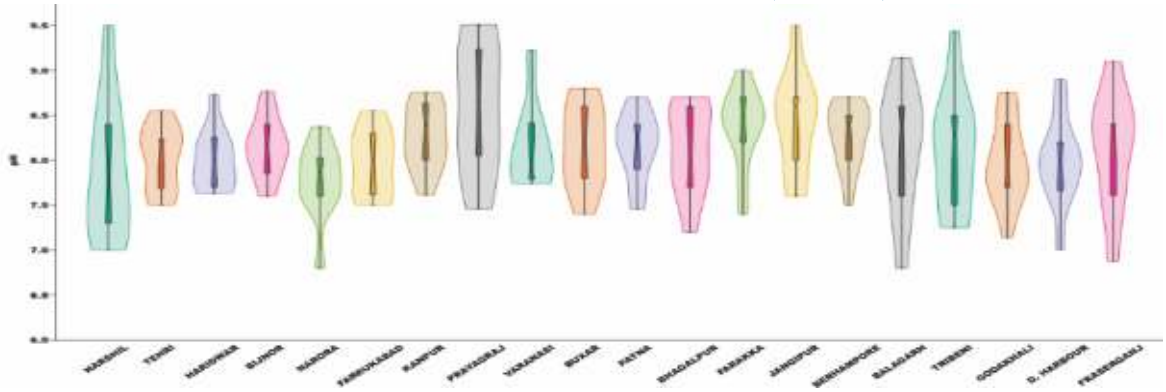
8.5
7.5
6.5
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING VARIATION IN pH IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)



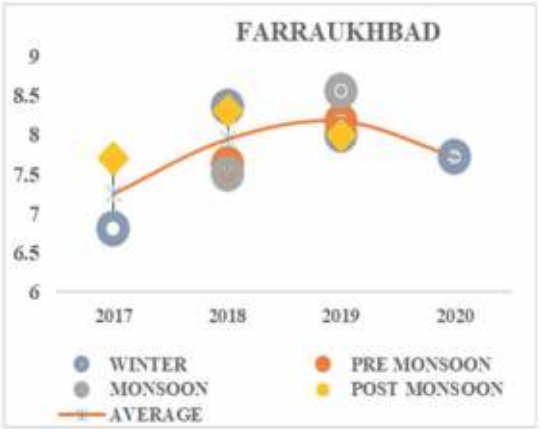
CHANGING pH PATTERN OVER THE YEARS

Stretches	Period	pH
Kanpur	1960	7.9
	1987-88	7.2
	2001-06	8.2
	2016-20	8.25
Prayagraj	1960	8.1
	1987-88	8
	2001-06	8.2
	2016-20	8.48
Varanasi	1960	8
	1987-88	7.4
	2001-06	8.1
	2016-20	7.72
Patna	1960	7.9
	1987-88	8
	2001-06	8.1
	2016-20	8.16
Bhagalpur	1960	8.2
	1987-88	8.1
	2001-06	8.2
	2016-20	8.11
Farraka	1960	NA
	1987-88	NA
	2001-06	8.1
	2016-20	8.36
Diamond Harbour	1953-55	8.2
	2016-20	7.98

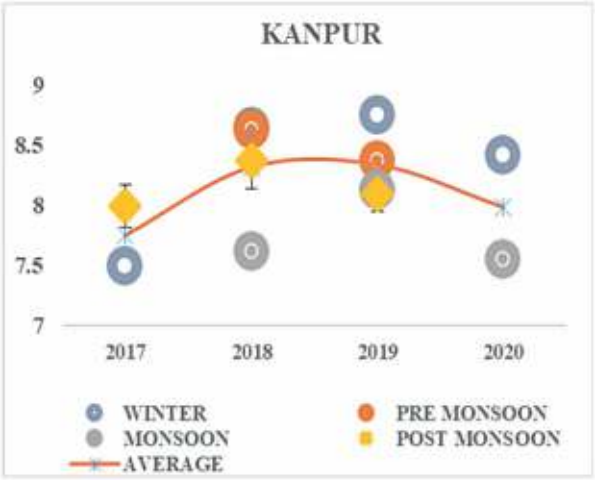
BRIEF DESCRIPTION

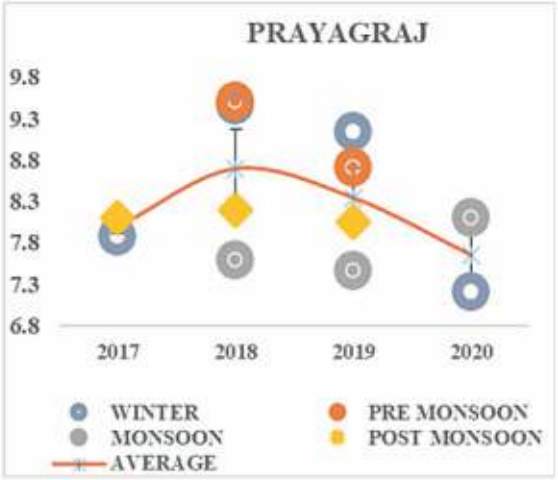
The observed mean pH value in the river is 8.13 ± 0.03, which ranged from 7.87 ± 0.25 to 8.43 ± 0.17 at all the sampling stations. The lowest mean pH value of 7.87 ± 0.25 was recorded at Harshil. Among the different stretches the highest mean pH value was recorded 8.23 ± 0.05 in the middle stretch of the river, while the lowest mean pH value was observed 7.98 ± 0.05 in the upper stretch of the river. The lower stretch and estuarine stretch have mean pH values of 8.21 ± 0.12 and 8.02 ± 0.12 respectively. Among the different seasons, the highest pH value of 8.32 ± 0.07 was recorded during the winter season, while the lowest pH value was recorded 7.83 ± 0.07 in monsoon. During pre-monsoon, the mean pH value was 8.17 ± 0.06, and post-monsoon has a mean pH value of 8.09 ± 0.71.

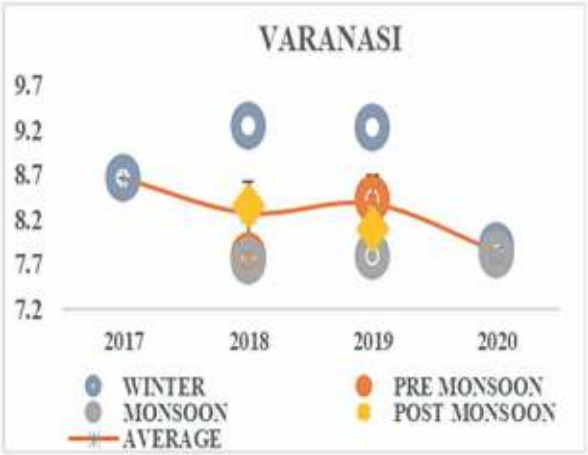
TIMESCALE CHANGES OF pH IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

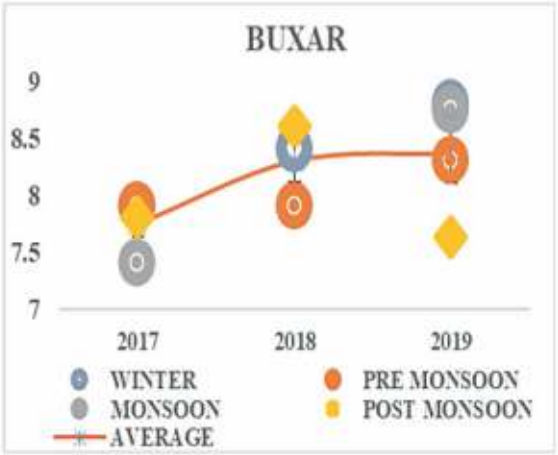


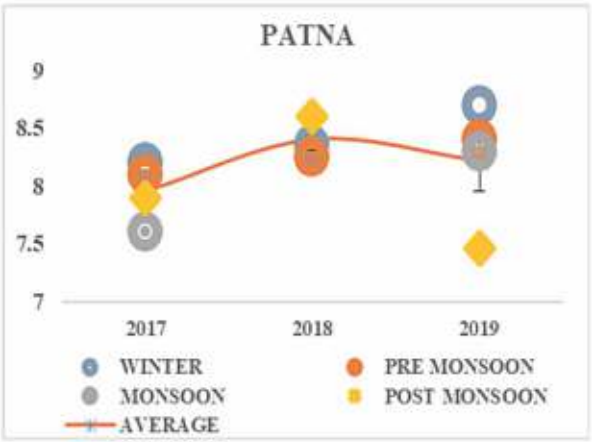
TIMESCALE CHANGES OF pH IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

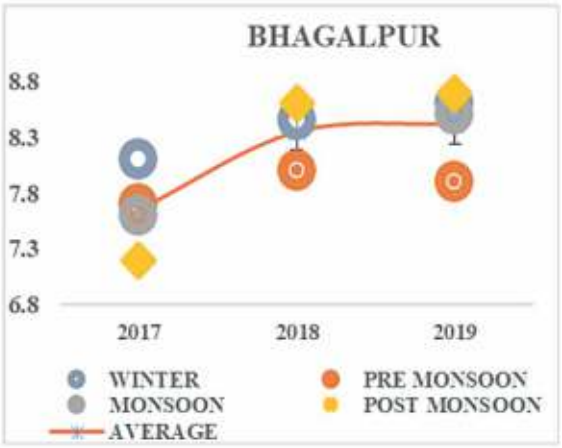




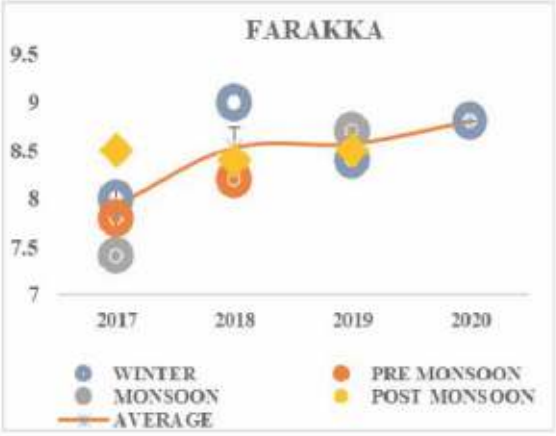


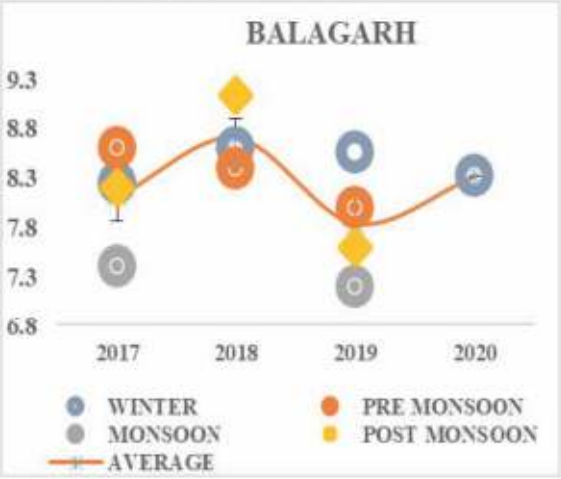


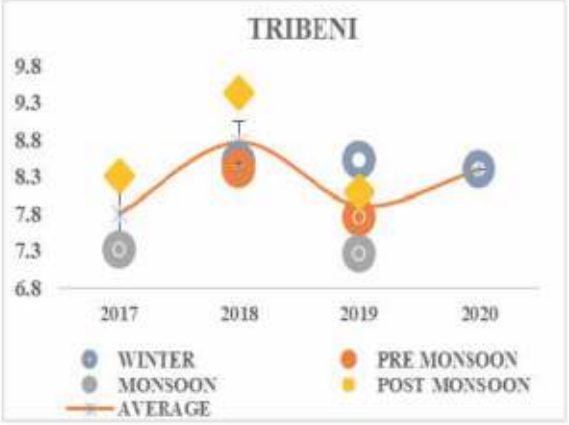


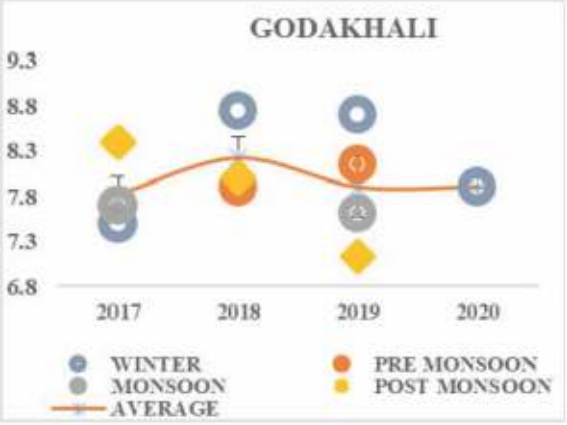


TIME-SCALE CHANGES OF pH IN THE LOWER STRETCH OF RIVER GANGA (2016-20)









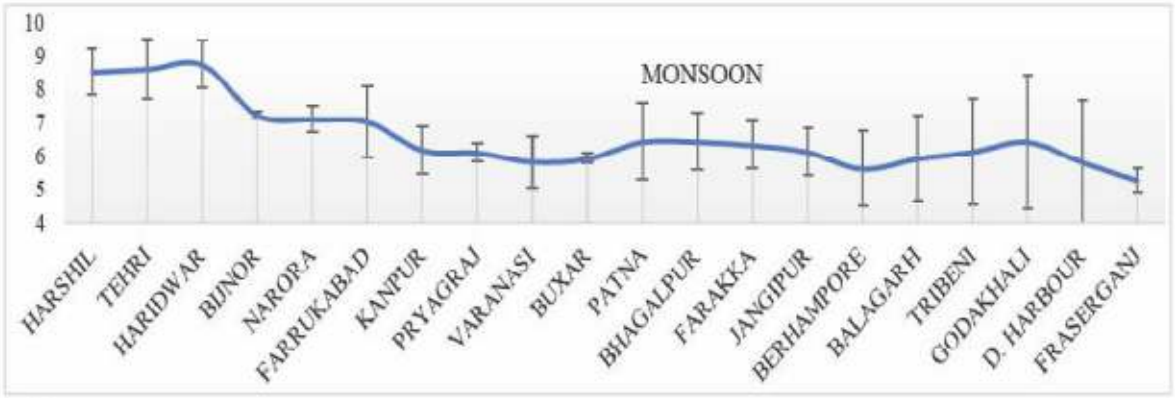
TIMESCALE CHANGES OF pH IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

SALIENT TIMESCALE OBSERVATIONS

- Among the stations of upper stretch increase in pH values have been recorded at Harshil, Haridwar, Bijnor and Farrukhabad. However, the decreased pH values have been recorded at Tehri, and Narora in 2020 as compared to 2017.
- In the middle stretch a rise in pH value have been observed at Kanpur, Buxar, Patna and Bhagalpur. While lowering of water pH have been observed at Prayagraj and Varanasi from 2017 to 2020.
- In the lower stretch of the river a rise in pH values have been observed in 2020 as compared to 2017.
- In the estuarine stretch a lowering in pH have been recorded in 2020 as compared to 2017.

Dissolved oxygen (ppm)

The dissolved oxygen is the measurement of oxygen gas dissolved in the water. The oxygen requirement of the fish and several other aquatic organisms. The major sources for availability of dissolved oxygen in the water are atmospheric diffusion, effect of wind and wave, photosynthesis by aquatic organisms etc. The availability of the oxygen in the water also depends on the sunlight, which promotes the process of photosynthesis.


MONSOON
10
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7
6
5
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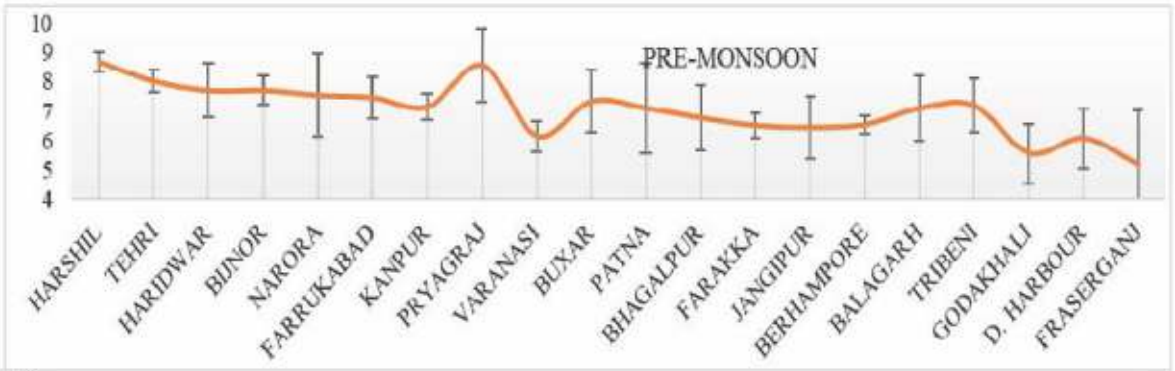
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


PRE-MONSOON
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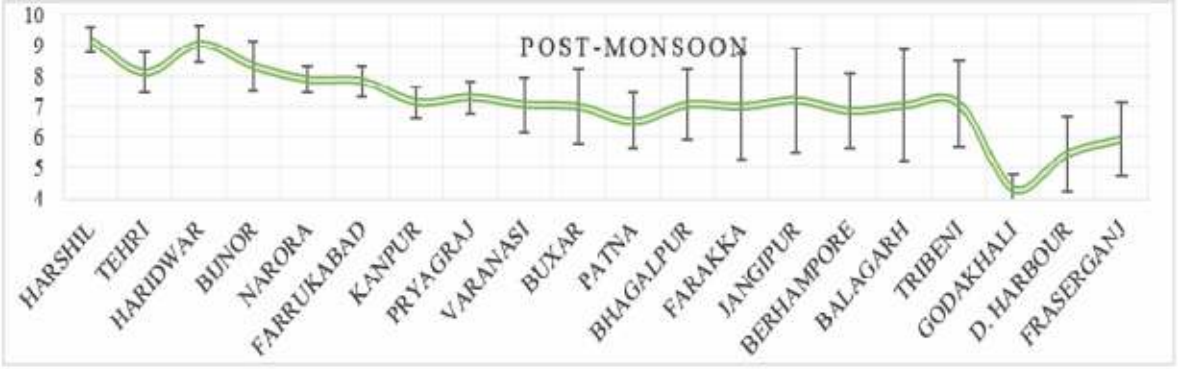
4
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
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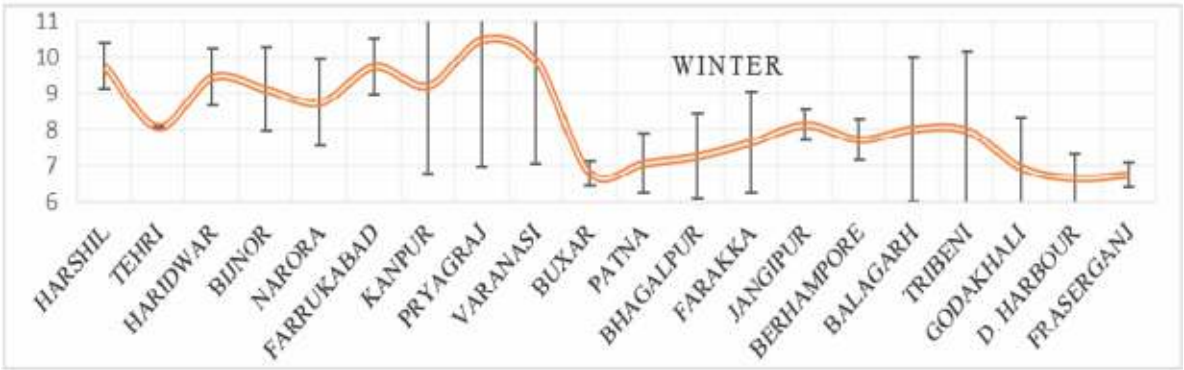
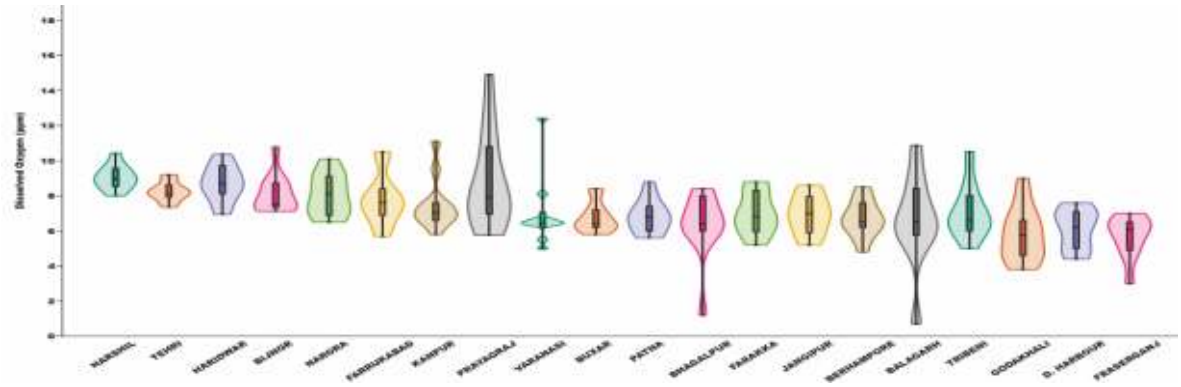
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
11
10
9
8
7
6
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING VARIATION IN DISSOLVED OXYGEN (ppm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

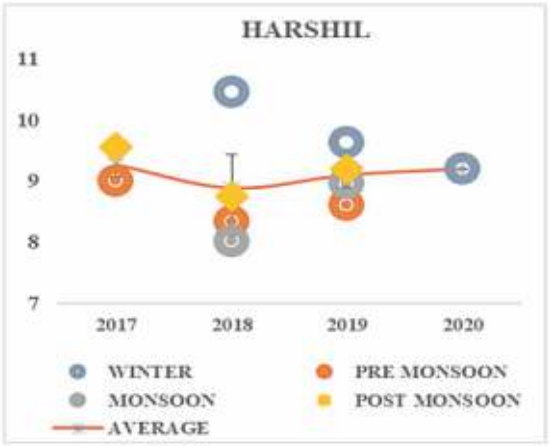


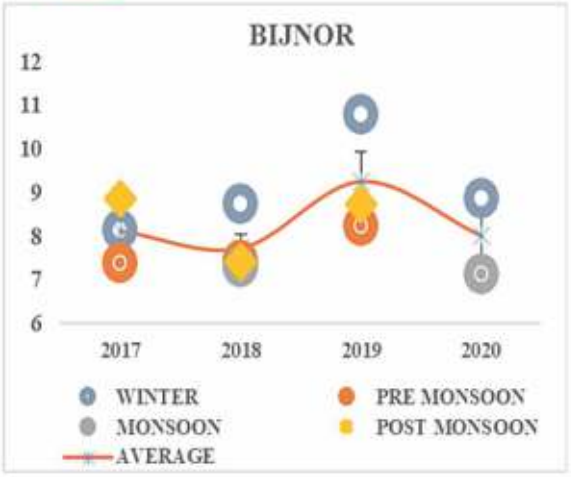
CHANGING PATTERN OF DISSOLVED OXYGEN OVER THE YEARS		
Stretches	Period	D.O (PPM)
	1960	7.9
	1987-88	7.2
	2001-06	8.2
	2016-20	7.51
Pryagraj	1960	8.4
	1987-88	8
	2001-06	7.8
	2016-20	8.49
Varanasi	1960	7
	1987-88	2.2
	2001-06	7.4
	2016-20	7.47
Patna	1960	7
	1987-88	7.8
	2001-06	7.8
	2016-20	6.83
Bhagalpur	1960	6.9
	1987-88	7.2
	2001-06	7.6
	2016-20	6.34
Farraka	1960	NA
	1987-88	NA
	2001-06	7.4
	2016-20	7
Diamond	1953-55	4.8-7.3
Harbour	2016-20	6.1

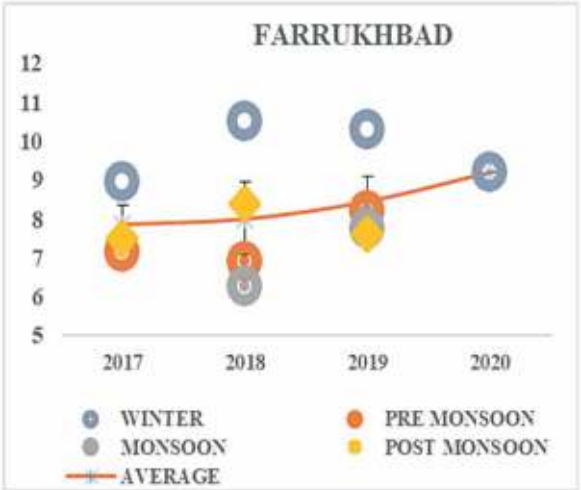
BRIEF DESCRIPTION

The mean DO in the entire stretch was observed 7.28 ± 0.11 ppm. The average DO in the entire stretch ranged from 5.69 ± 0.38 ppm at Fraserganj to 9.04 ± 0.22 ppm at Harshil. Although, all the sampling sites possess > 5 ppm of the DO level. In the different stretches of the river the upper stretch has the highest mean dissolved oxygen of 8.32 ± 0.13 ppm, while the minimum DO was observed 5.90 ± 0.25 ppm in the estuarine stretch of the river. The dissolved oxygen in the middle and lower stretches were 7.32 ± 0.21 and 6.78 ± 0.18 ppm. Among the different seasons also winter has the highest DO value of 8.40 ± 0.25 ppm, while the lowest DO was observed 6.56 ± 0.20 ppm during monsoon. The dissolved oxygen during pre-monsoon and post monsoon were 6.99 ± 0.15 ppm and 6.56 ± 0.19 ppm respectively.

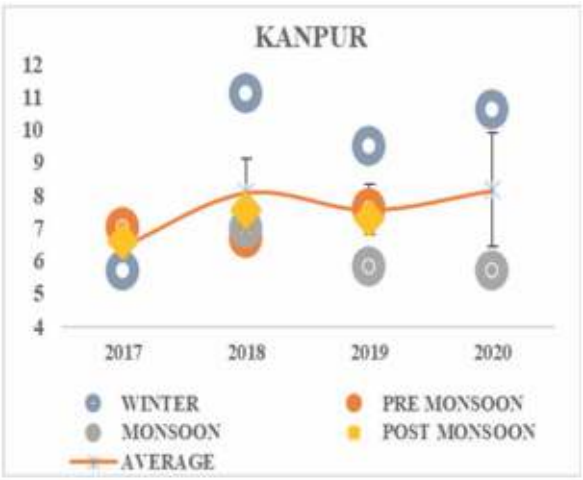
TIMESCALE CHANGES OF DISSOLVED OXYGEN (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

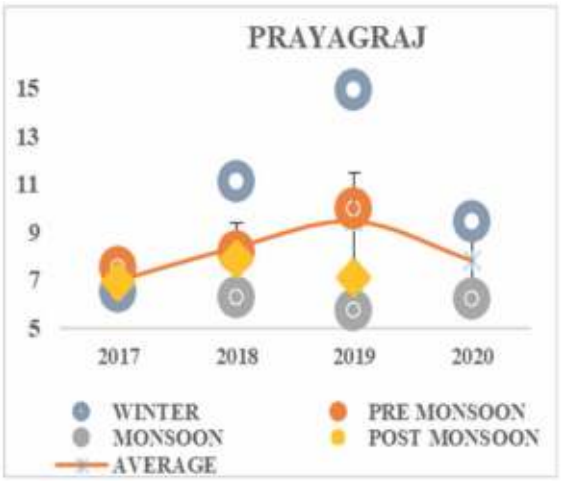


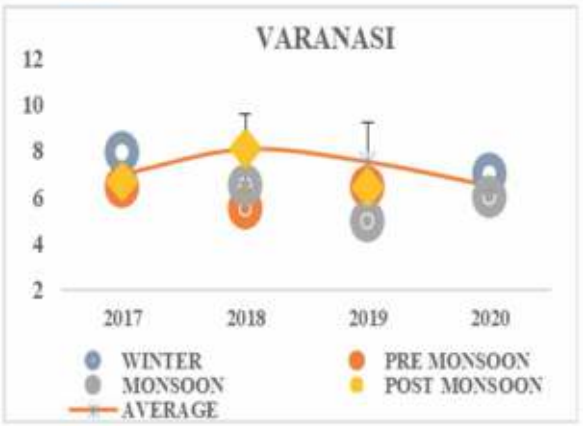


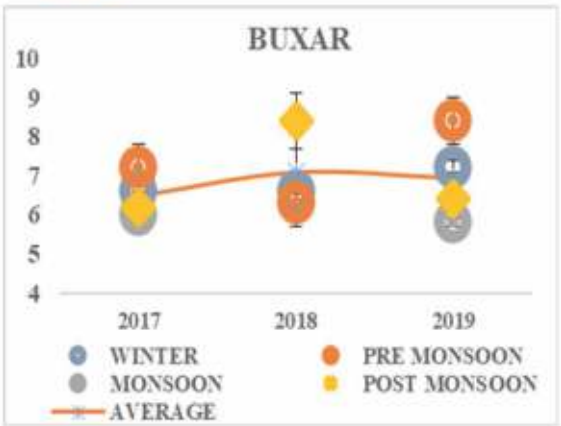


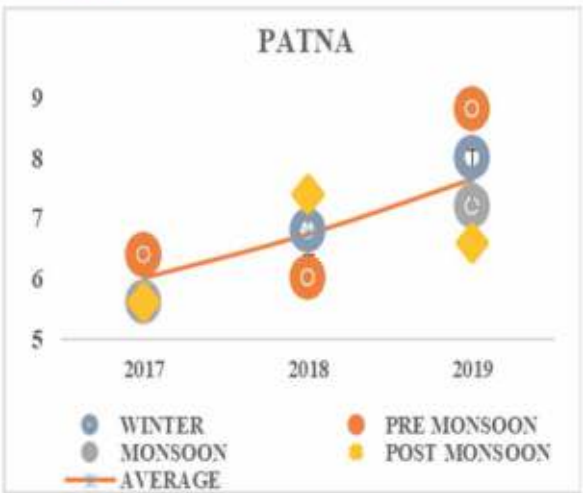
TIMESCALE CHANGES OF DISSOLVED OXYGEN (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

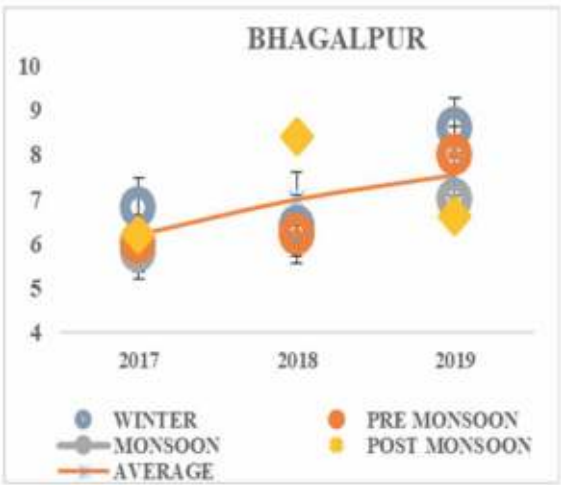




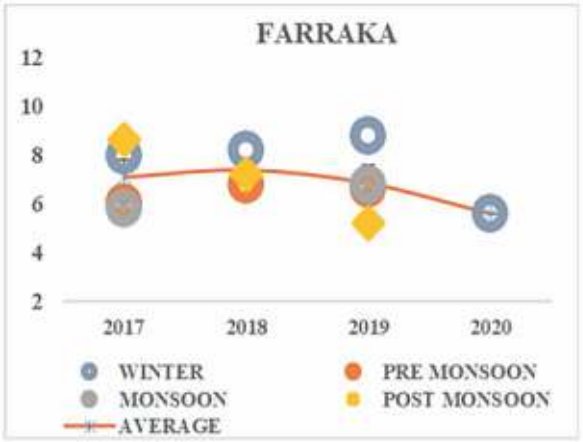


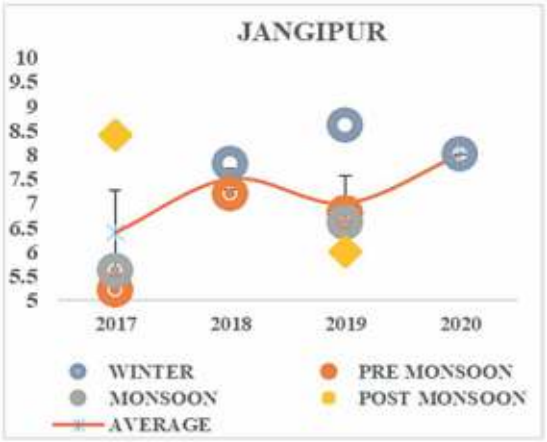


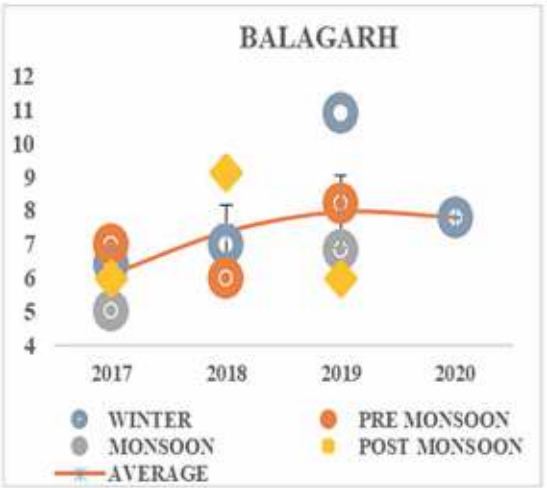


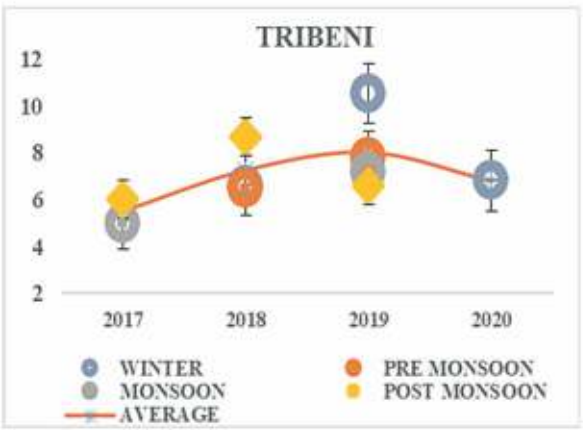


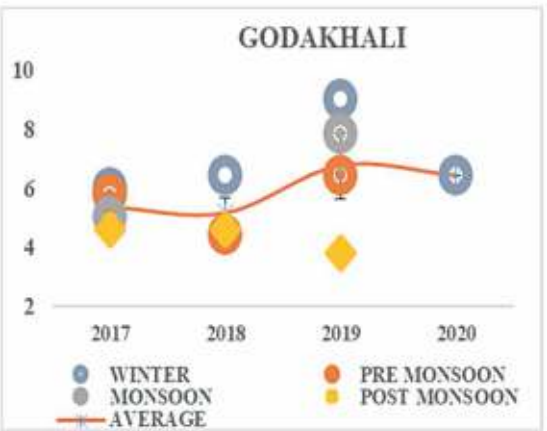
TIME-SCALE CHANGES OF DISSOLVED OXYGEN (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)



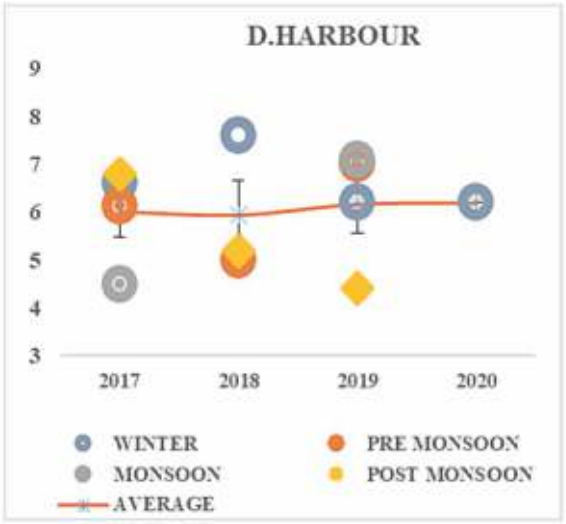


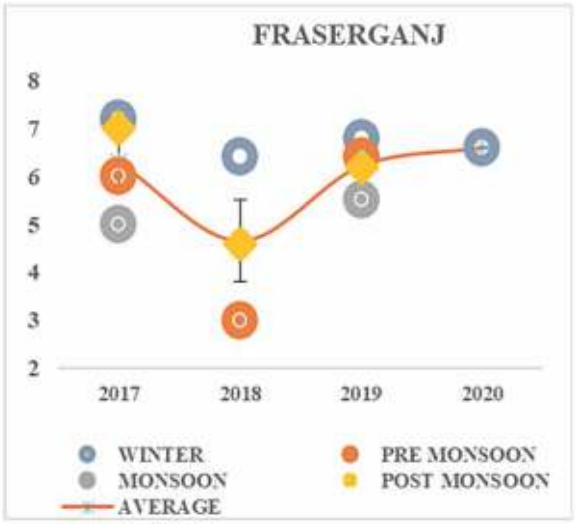






TIMESCALE CHANGES OF DISSOLVED OXYGEN (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



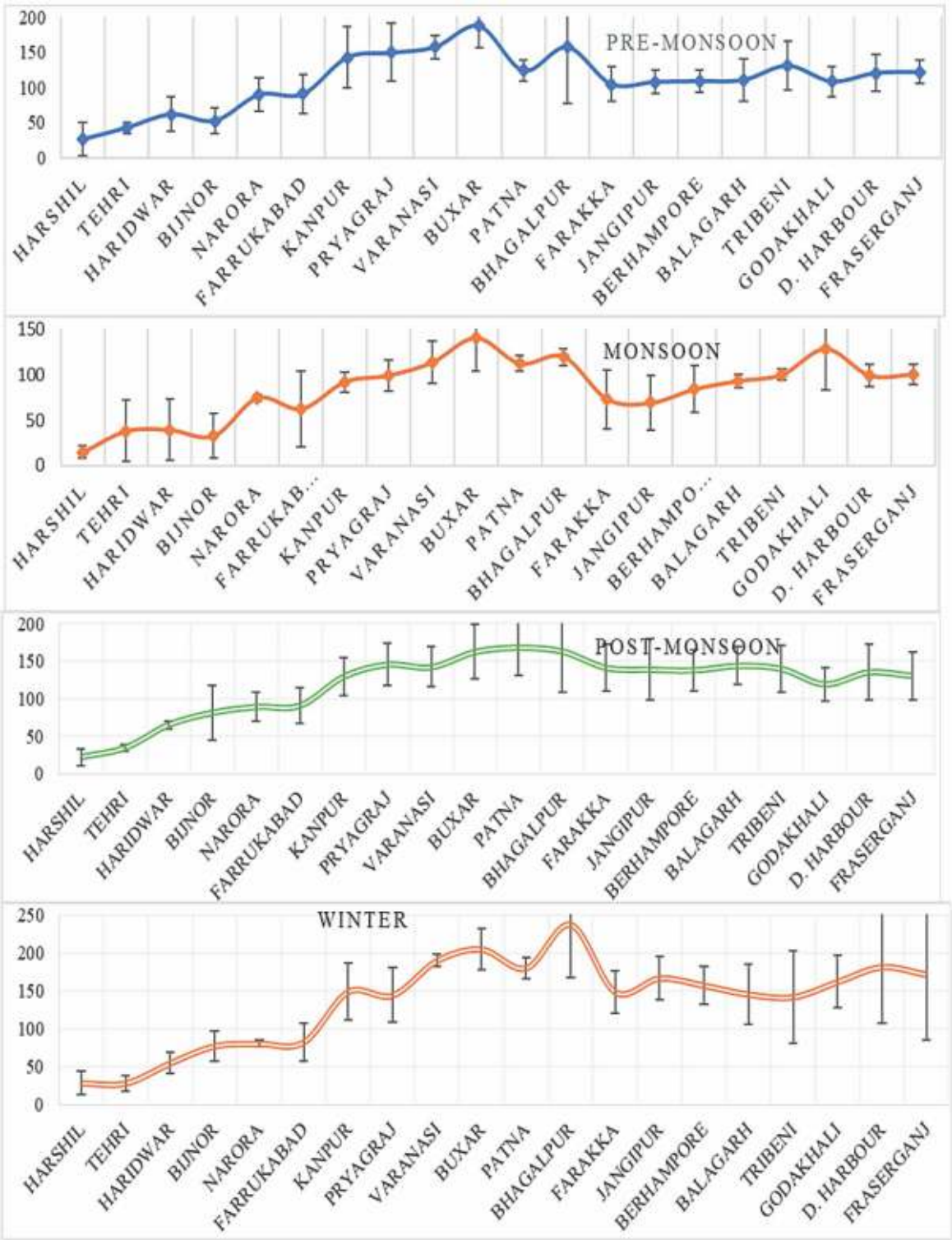


SALIENT TIMESCALE OBSERVATIONS

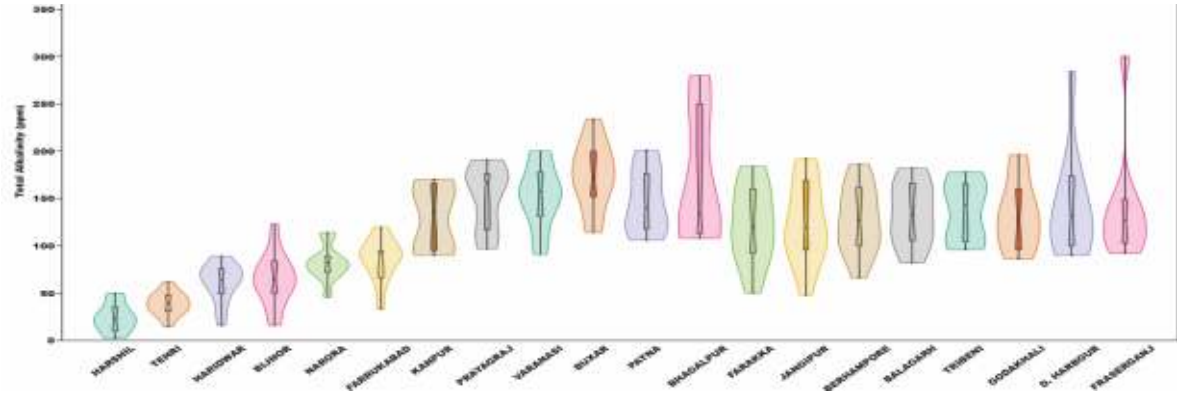
- In the upper stretch, an increase in the DO values have been recorded at Harshil, Narora, and Farrukhabad while a lowering of DO value has been observed at Harshil, Tehri, and Bijnor from 2017 to 2020.
- In the middle stretch an increase in DO values has been recorded at Kanpur, Prayagraj, Buxar, Patna, and Bhagalpur but a lowering of DO values have been observed at Varanasi from 2017 to 2020.
- Among the sampling stations of lower stretch, the DO value of Farraka has been recorded in rising pattern during 2020 as compared to 2017.
- In the estuarine stretch at all the stations, the DO values were observed in a rising trend in 2020 as compared to 2017.

Total alkalinity (ppm)

The total alkalinity of the water in the river system is the concentration of carbonates and bicarbonates released from the alkali and alkali earth metals. The total alkalinity in the water is expressed as the parts per million of calcium carbonate ($CaCO_3$). The change in the total alkalinity in the water may cause several changes to the aquatic organisms. As, lower alkalinity value may cause pH to plummet. The increment of the total alkalinity beyond the limit may cause increased body metabolism in the fish and other dependent organisms.


PRE-MONSOON
MONSOON
POST-MONSOON
WINTER
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING VARIATION IN TOTAL ALKALINITY (ppm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

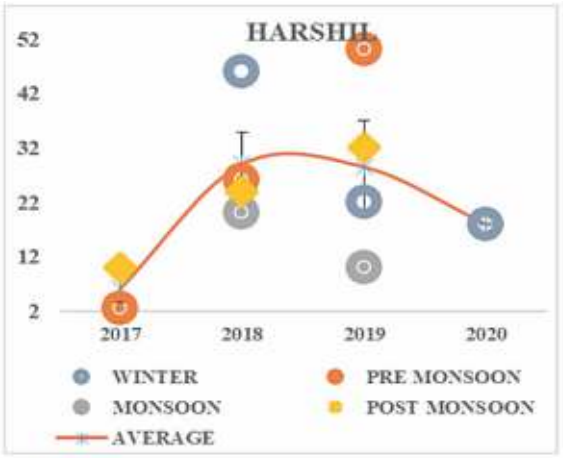


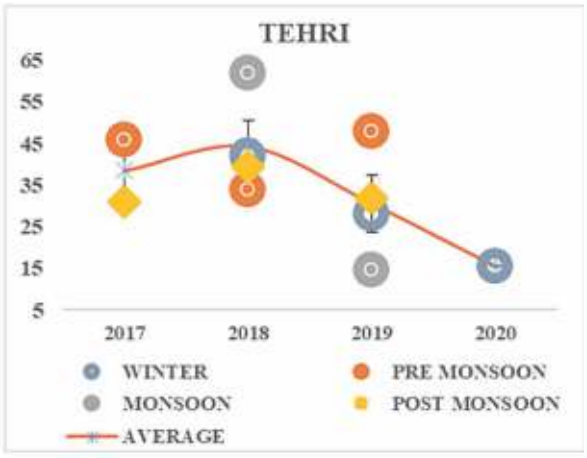
CHANGING PATTERN OF TOTAL ALKALINITY OVER THE YEARS		
Stretches	Period	Total Alkalinity (PPM)
Kanpur	1960	148.5
	1987-88	198
	2001-06	200
	2016-20	130
Pryagraj	1960	142
	1987-88	171
	2001-06	198
	2016-20	147.02
Varanasi	1960	127.5
	1987-88	178.6
	2001-06	192
	2016-20	155.59
Patna	1960	141.7
	1987-88	139.6
	2001-06	168
	2016-20	147.72
Bhagalpur	1960	131.4
	1987-88	142.2
	2001-06	146
	2016-20	171.90
Farakka	1960	NA
	1987-88	NA
	2001-06	7.4
	2016-20	122.40
Diamond Harbour	1953-55	NA
	2016-20	141.27

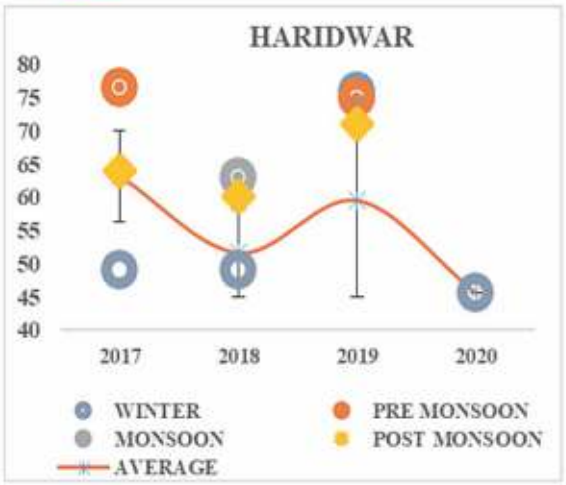
BRIEF DESCRIPTION

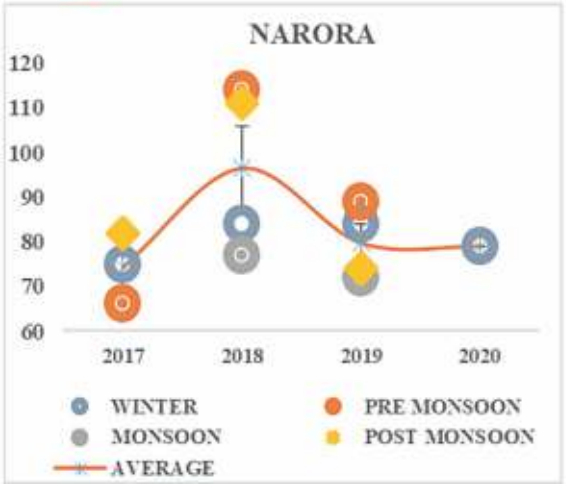
The mean alkalinity in the entire stretch was 117.28 ± 3.78 ppm. The mean value of total alkalinity varied at all the sampling sites from 24.24 ± 4.83 ppm to 174.18 ± 10.77 ppm. Among the different stretches of the river the highest total alkalinity was observed 154.40 ± 5.34 in the middle stretch of the river, while the lowest total alkalinity value was observed 60.01 ± 3.67 ppm in the upper stretch of the river. In the lower and estuarine stretches the mean total alkalinity was 129.85 ± 4.65 ppm and 140.76 ± 12.41 ppm. The higher total alkalinity value was observed 146.13 ± 8.75 ppm during winter season, while the lowest mean total alkalinity was observed 86.26 ± 6.16 ppm during monsoon. Pre-monsoon and post monsoon has mean total alkalinity was 109.47 ± 6.22 ppm and 118.73 ± 6.23 ppm respectively.

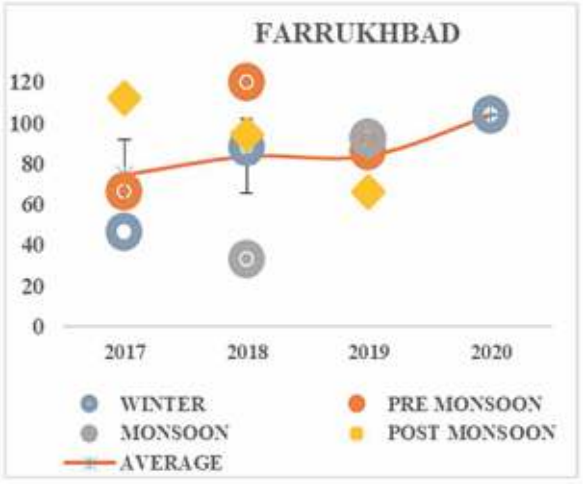
TIMESCALE CHANGES OF TOTAL ALKALINITY (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)



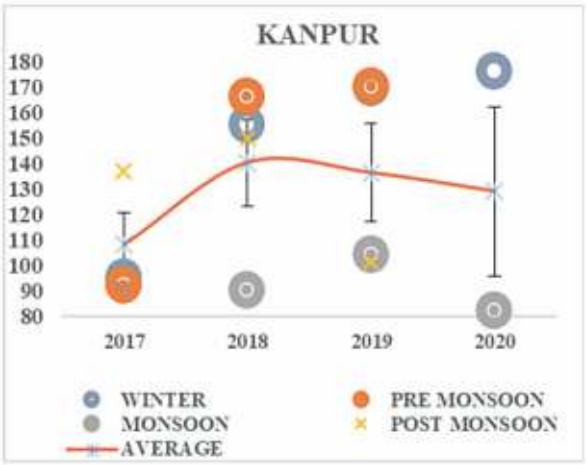


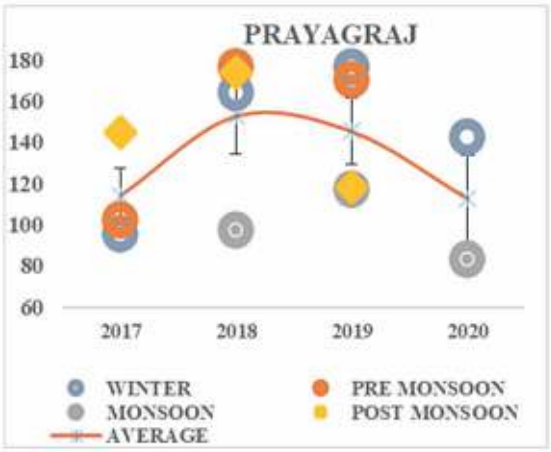


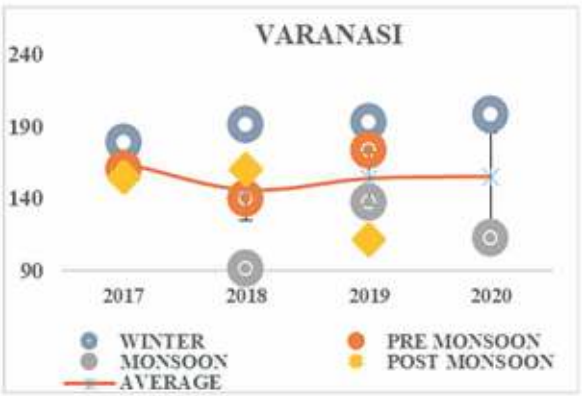


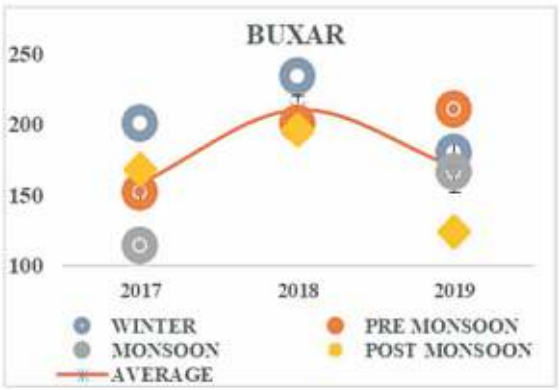


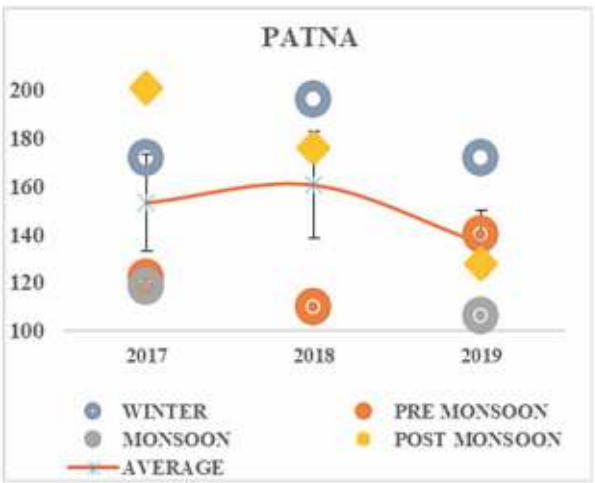
TIMESCALE CHANGES OF TOTAL ALKALINITY (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

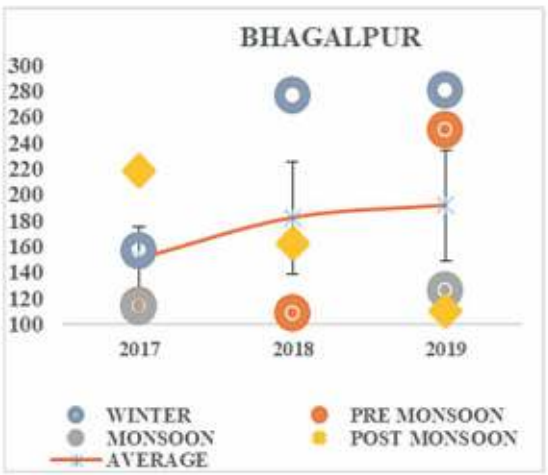




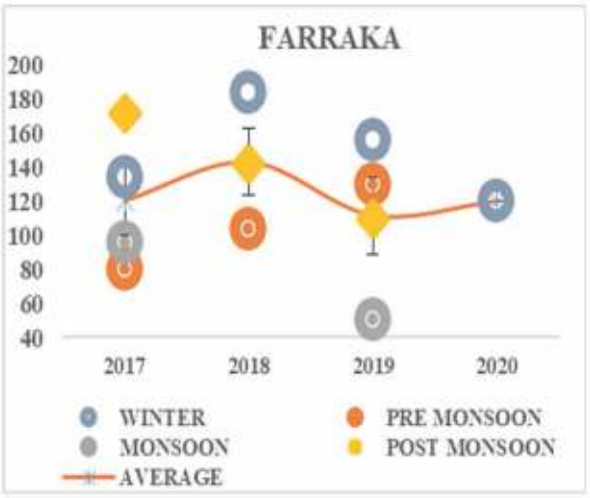


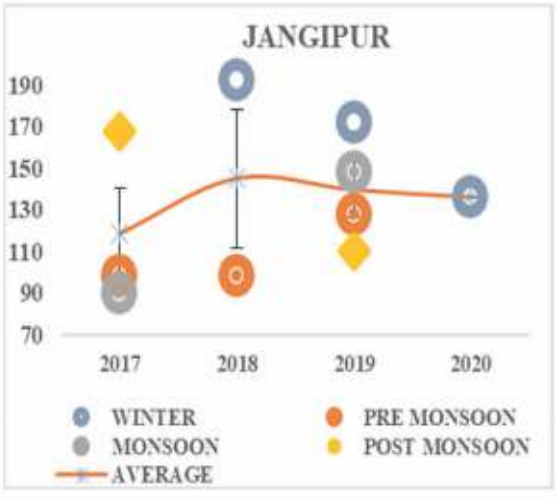


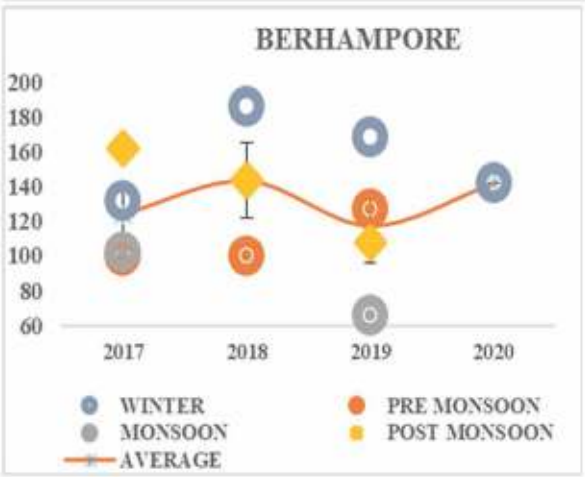


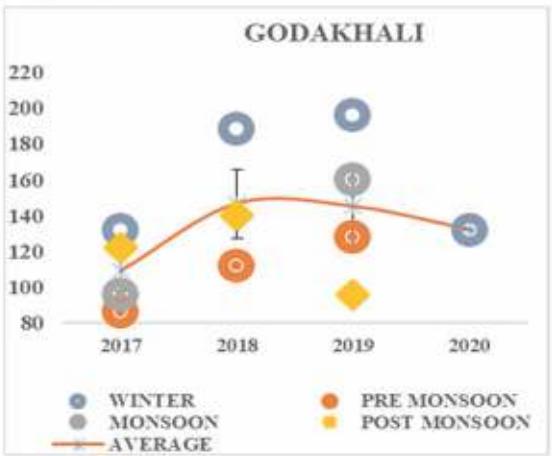


TIME-SCALE CHANGES OF TOTAL ALKALINITY (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

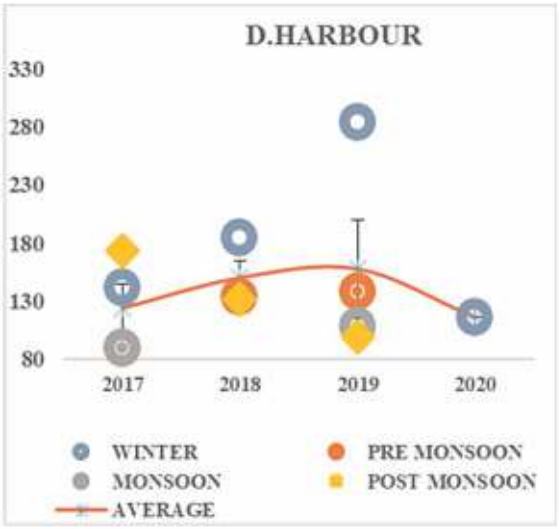


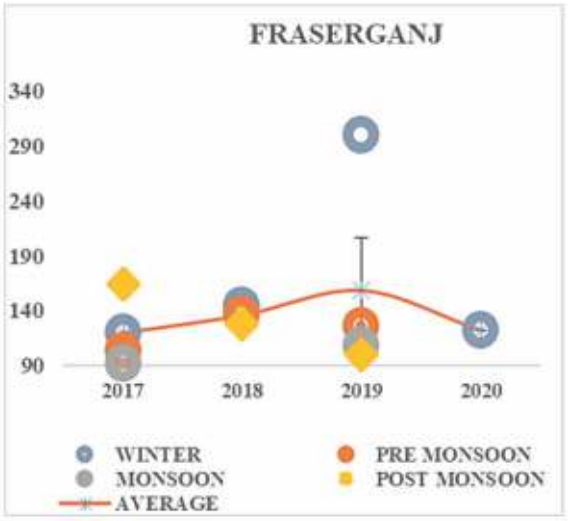






TIMESCALE CHANGES OF TOTAL ALKALINITY (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



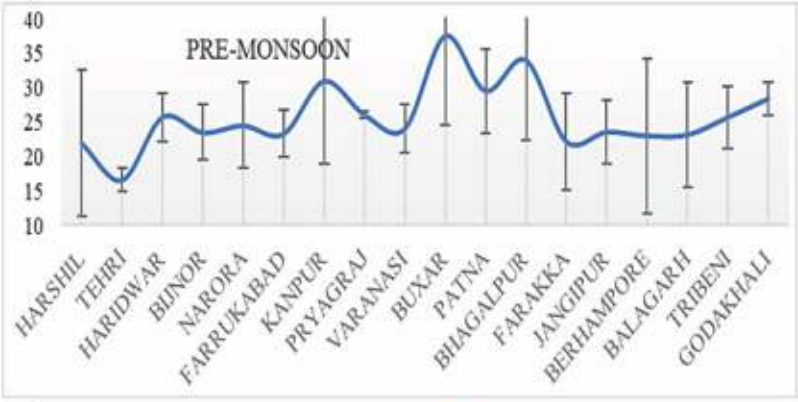


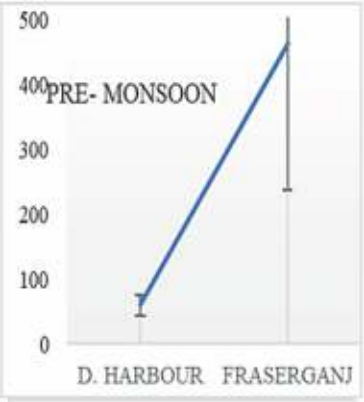
SALIENT TIMESCALE OBSERVATIONS

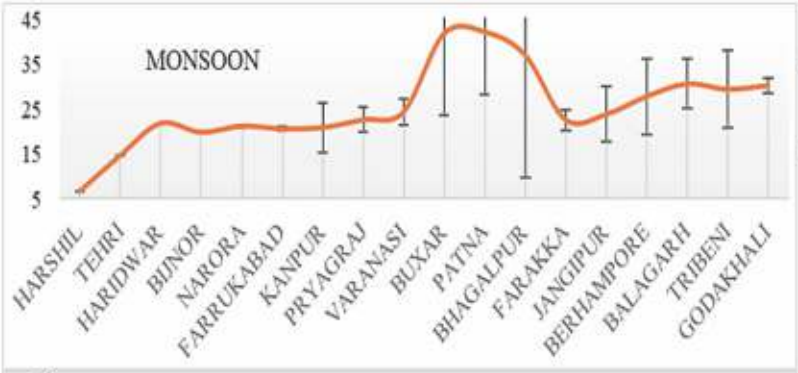
- In the upper stretch the rise in the total alkalinity has been recorded at Harshil, Narora, and Farrukhabad while decreases in the total alkalinity have been observed at Tehri, Haridwar, and Bijnor from 2017 to 2020.
- In the middle stretch rise in total alkalinity has been recorded at Kanpur, Prayagraj, Varanasi, Buxar, and Bhagalpur while a decrease has been observed at Patna from 2017 to 2020.
- Among the sampling stations of a lower stretch there is an increase in total alkalinity has been recorded at all stations except at Balagarh and Tribeni from 2017 to 2020.
- In the estuarine stretch increase in total alkalinity has been recorded at Fraserganj and a decrease in total alkalinity has been recorded at D. Harbour from 2017 to 2020.

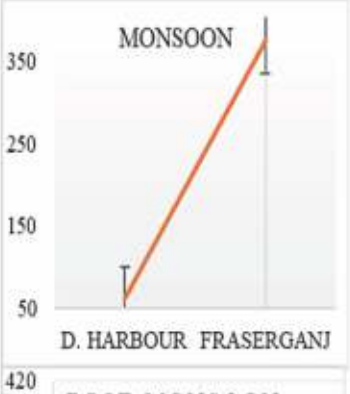
Calcium hardness (ppm)

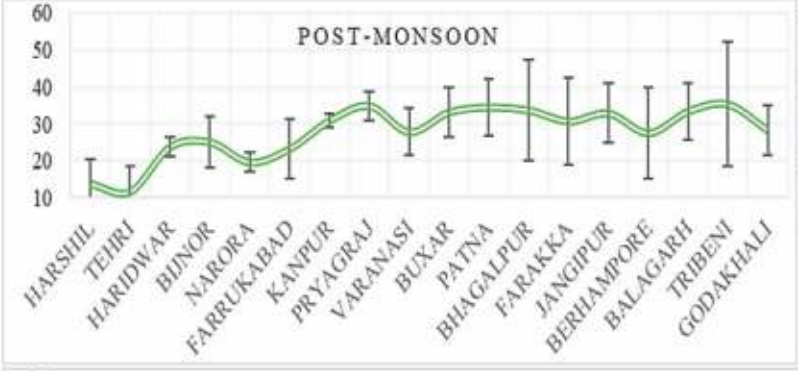
Calcium hardness is the important available calcium element ion. It is the important element of animal nutrition which helps in the formation and maintenance of bones. The calcium is the significant contributor of the total hardness. The alteration in the calcium hardness may also lead to deformity in the larval development of aquatic organisms like fish.

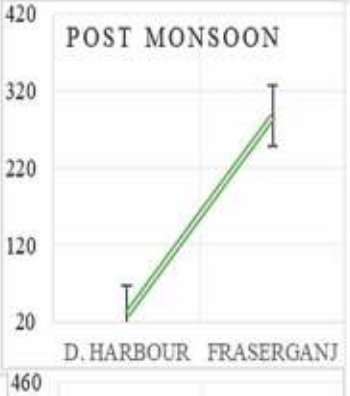

PRE-MONSOON
40
35
30
25
20
15
10
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI

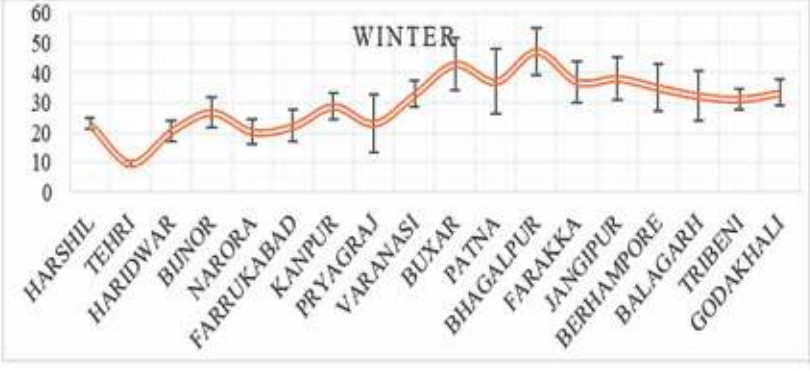

PRE- MONSOON
500
400
300
200
100
0
D. HARBOUR
FRASERGANJ


MONSOON
45
35
25
15
5
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


MONSOON
350
250
150
50
D. HARBOUR
FRASERGANJ

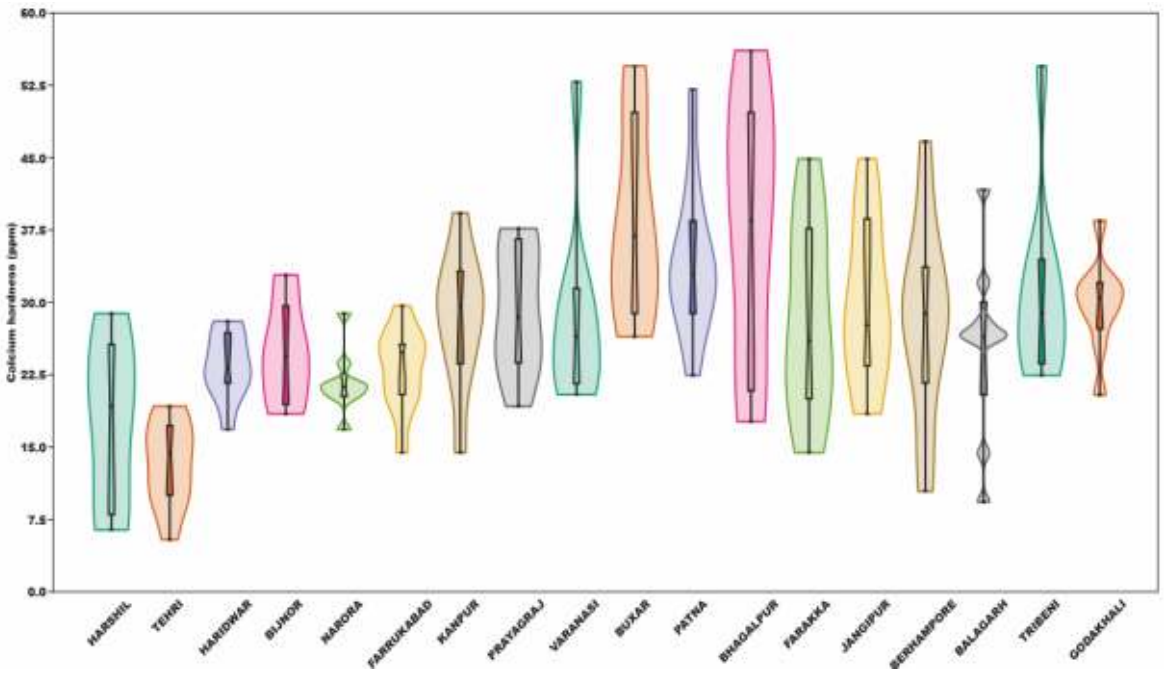

POST-MONSOON
60
50
40
30
20
10
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


POST MONSOON
420
320
220
120
20
D. HARBOUR
FRASERGANJ


WINTER
60
50
40
30
20
10
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


WINTER
460
360
260
160
60
D. HARBOUR
FRASERGANJ

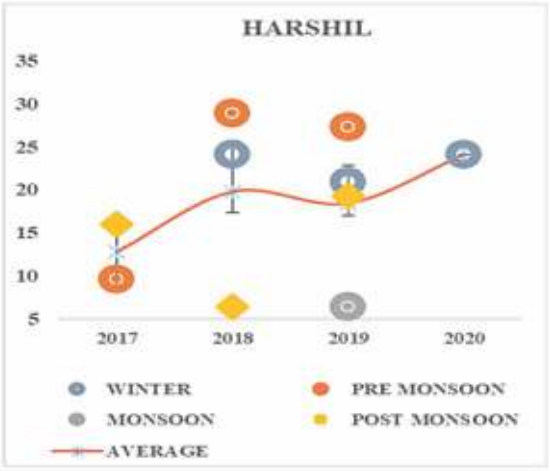
VIOLIN BOX PLOT ILLUSTRATING IN CALCIUM HARDNESS (ppm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

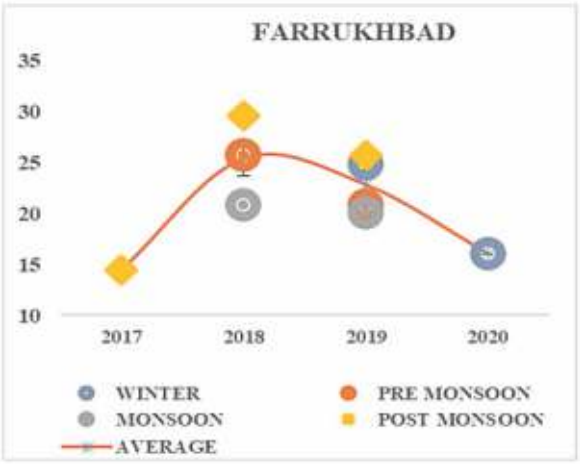


BRIEF DESCRIPTION

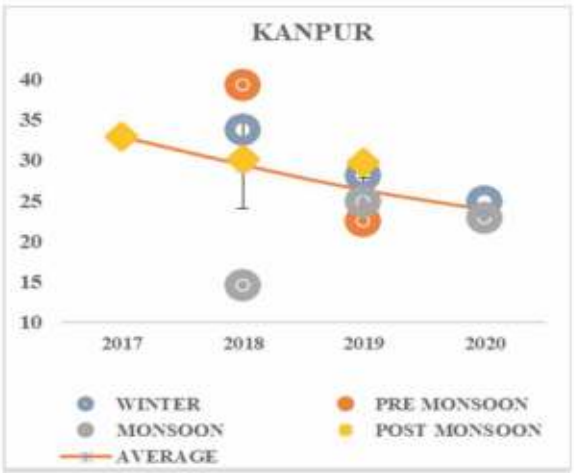
The mean calcium hardness in the entire stretch was recorded 48.22 ± 6.26 ppm. The average calcium hardness in the entire stretch ranged from 17.63 ± 2.86 ppm at Harshil to 375.83 ± 52.81 at Fraserganj. Among the different stretches the lowest calcium hardness was recorded (20.64 ± 0.87 ppm) in the upper stretch of the river, while the highest calcium hardness, was recorded (224.85 ± 46.47) ppm in the estuarine stretch of the river. The middle and lower stretches of the river have 33.12 ± 1.30 ppm and 32.20 ± 3.50 ppm of calcium hardness respectively. In the different seasons the winter has maximum mean calcium hardness of 54.74 ± 13.06 ppm, while the minimum mean calcium hardness was observed 40.99 ± 8.52 ppm during post monsoon. The pre-monsoon and monsoon have calcium hardness value of 51.76 ± 13.06 ppm and 46.80 ± 13.63 ppm, respectively.

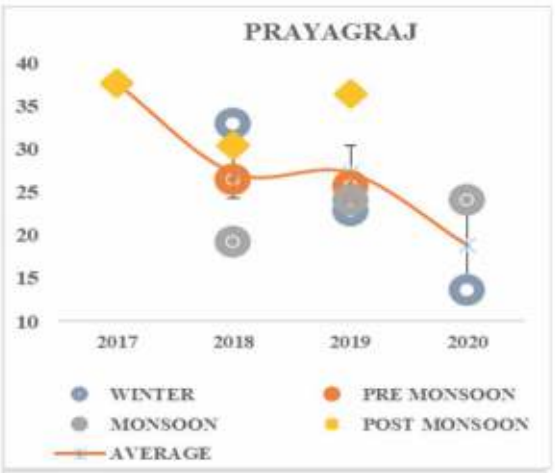
TIMESCALE CHANGES OF CALCIUM HARDNESS (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

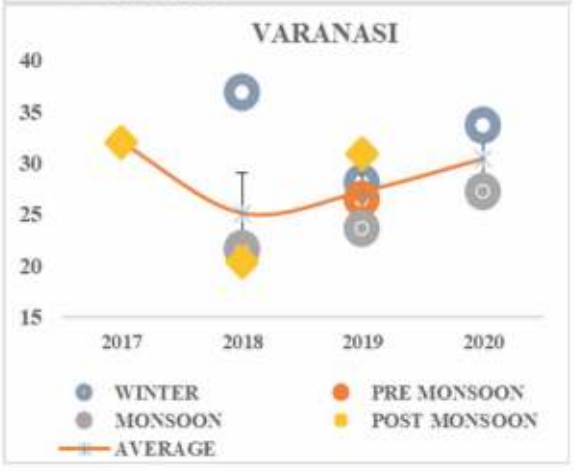


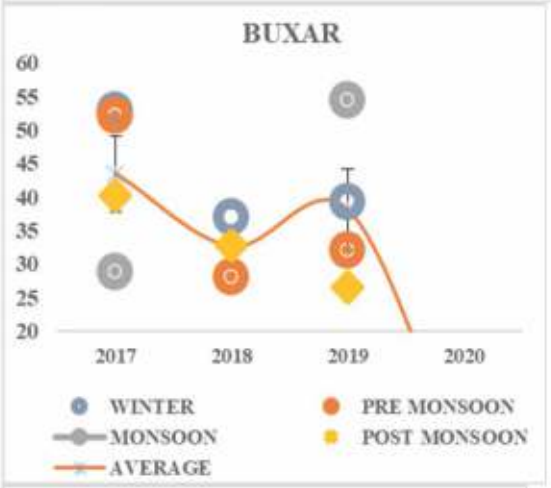


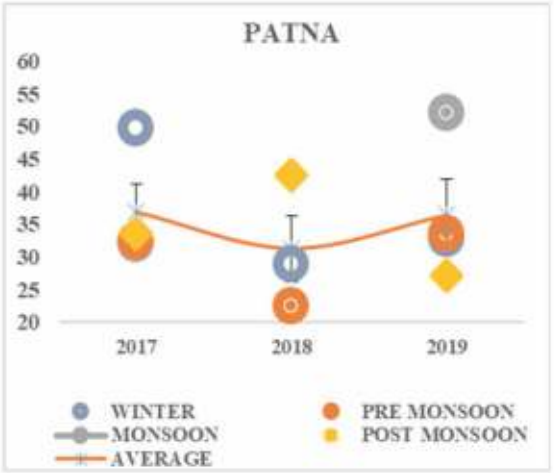
TIMESCALE CHANGES OF CALCIUM HARDNESS (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

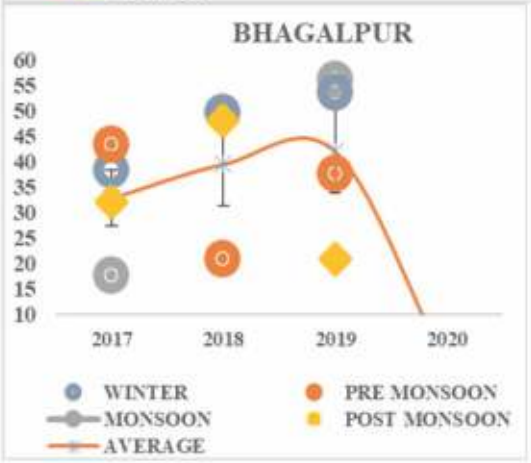




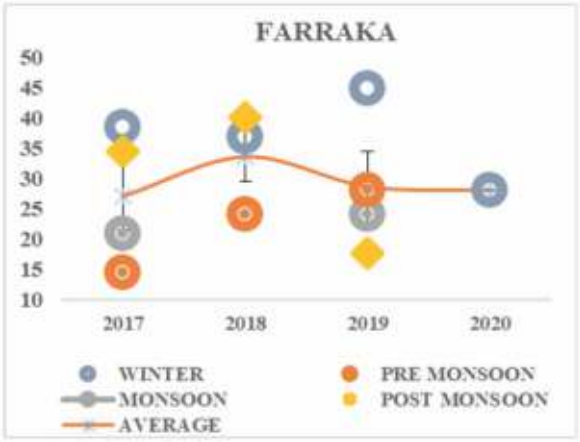


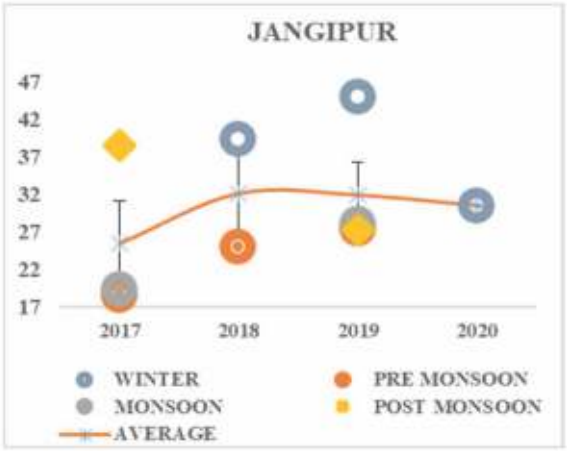


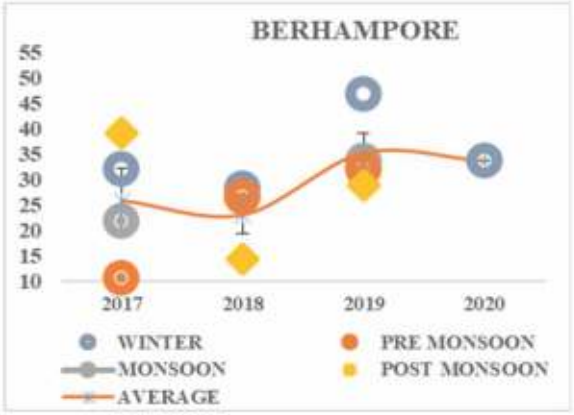


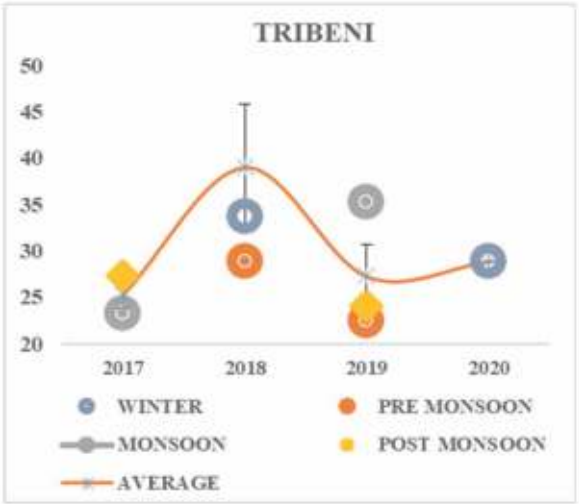


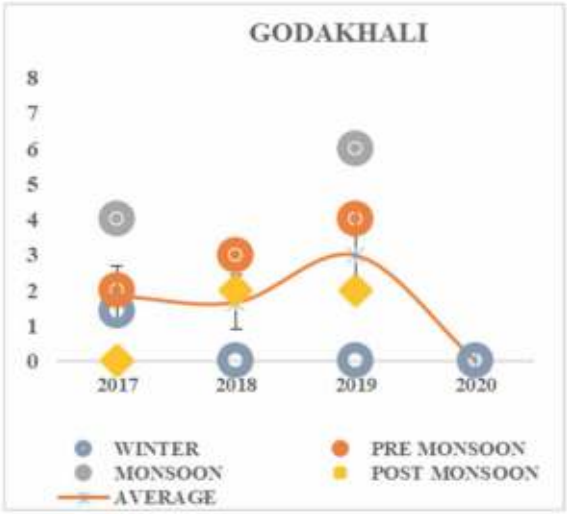
TIME-SCALE CHANGES OF CALCIUM HARDNESS (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)



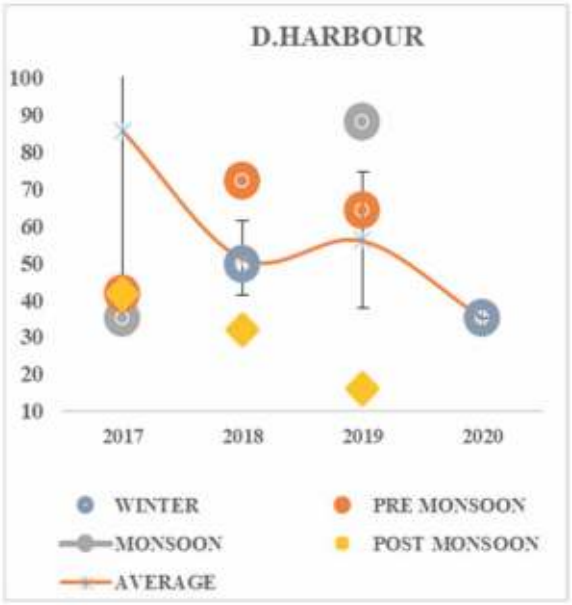


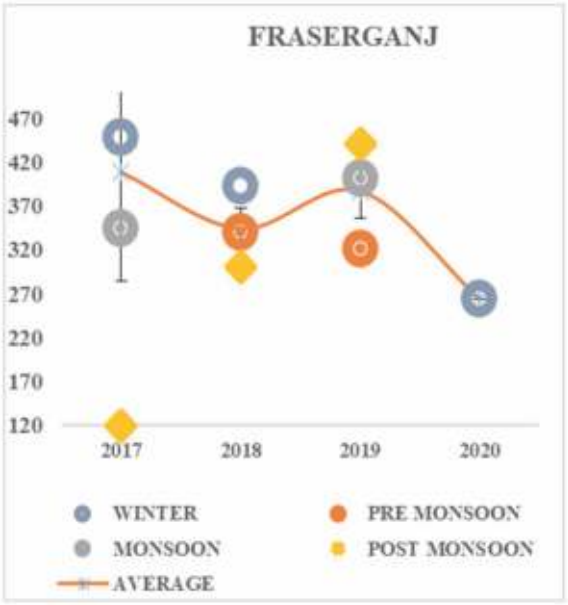






TIMESCALE CHANGES OF CALCIUM HARDNESS (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



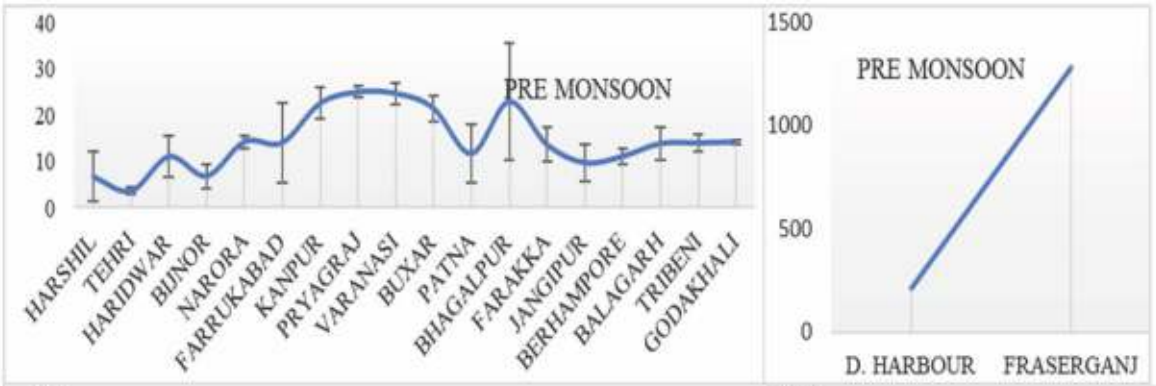


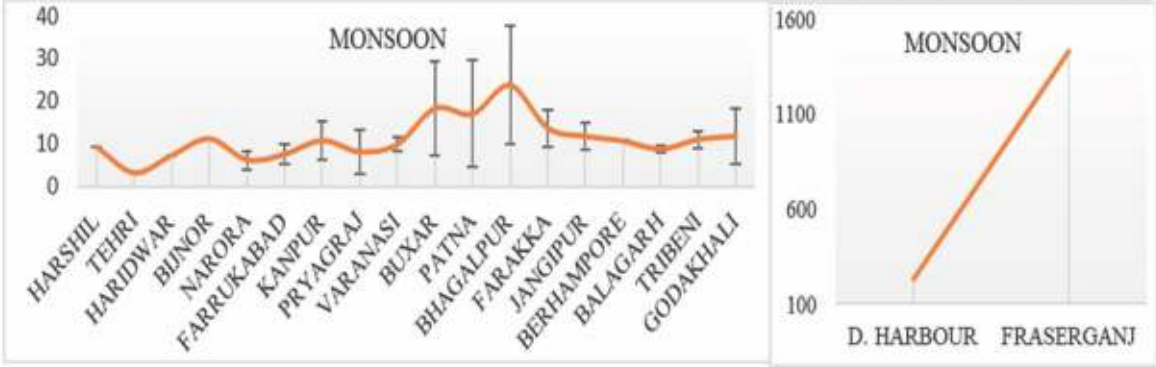
SALIENT TIMESCALE OBSERVATIONS

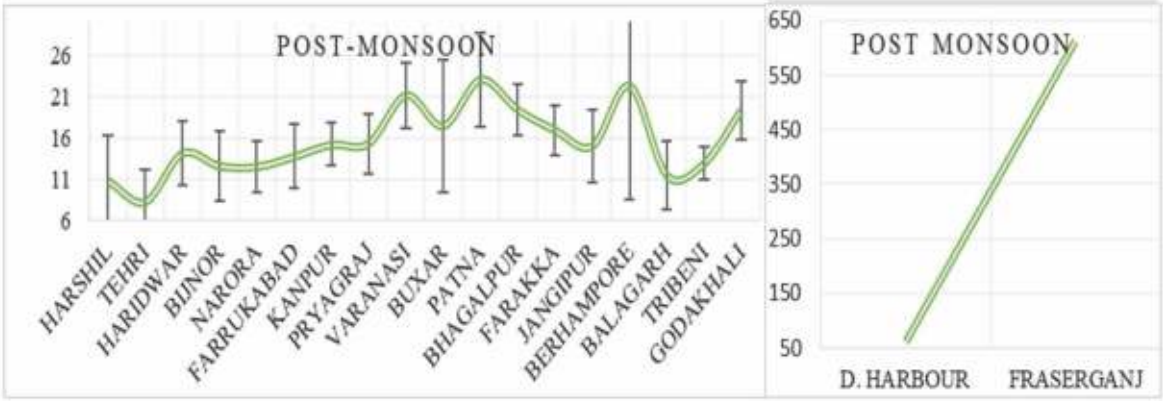
- In the upper stretch relative decrease in calcium hardness has been recorded at Harshil, and Farrukhabad while rise in the calcium hardness have been observed at Tehri, Narora Haridwar, and Bijnor from 2017 to 2020.
- In the middle stretch decrease in the calcium hardness has been observed at all the stations except at Prayagraj and Varanasi from 2017 to 2020.
- Among the sampling stations of lower stretches increase in calcium hardness has been recorded at all stations except at Godakhali from 2017 to 2020.
- In the estuarine stretch decrease in calcium hardness has been recorded at all stretches from 2017 to 2020.

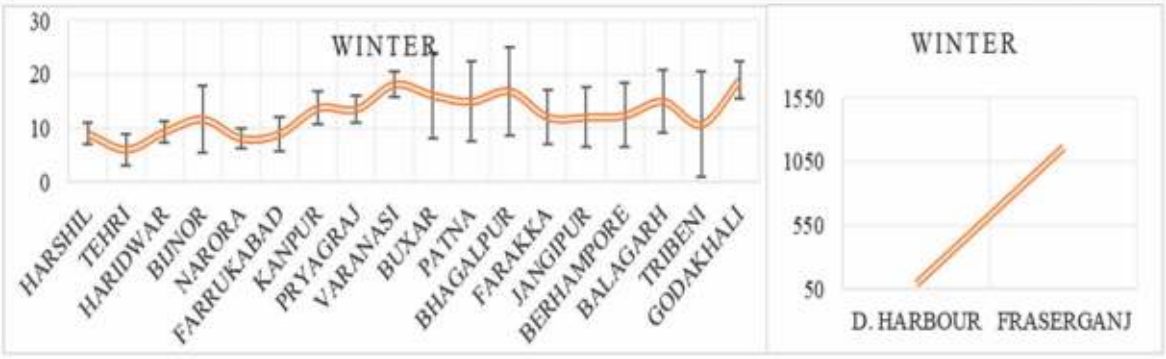
Magnesium hardness (ppm)

Magnesium hardness is the amount of magnesium ion present in the water. The magnesium in the aquatic ecosystem is very essential element. It is present in the chlorophyll pigment which promotes the process of photosynthesis of aquatic plants. In animals it is present in the blood cells. Magnesium hardness is represented as $CaCO_3$.

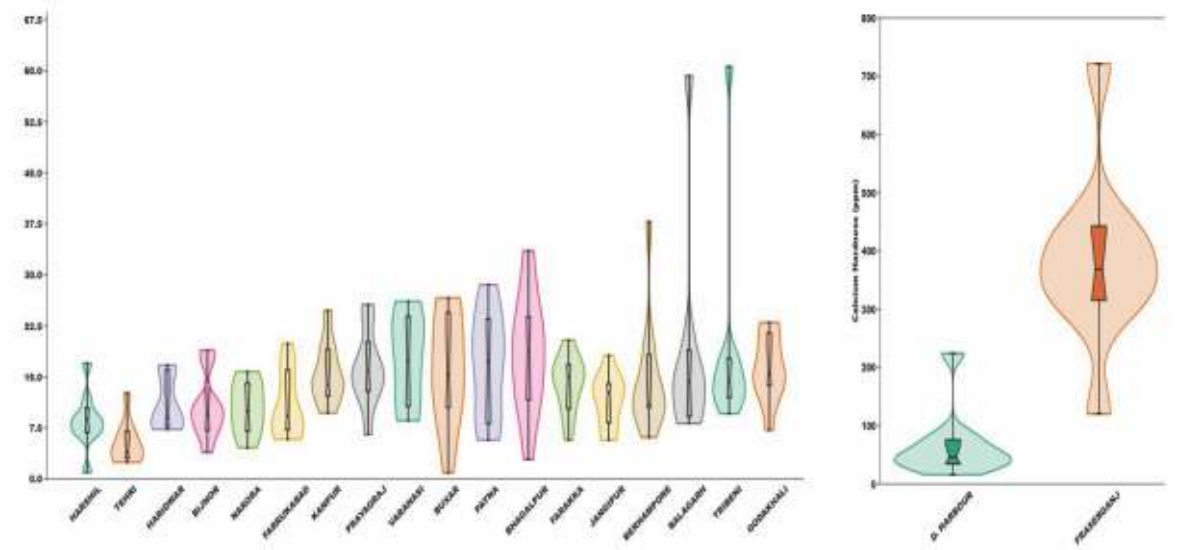

PRE MONSOON
40
30
20
10
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
PRE MONSOON
1500
1000
500
0
D. HARBOUR
FRASERGANJ


MONSOON
40
30
20
10
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
MONSOON
1600
1100
600
100
D. HARBOUR
FRASERGANJ


POST-MONSOON
26
21
16
11
6
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
POST MONSOON
650
550
450
350
250
150
50
D. HARBOUR
FRASERGANJ


WINTER
30
20
10
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
WINTER
1550
1050
550
50
D. HARBOUR
FRASERGANJ

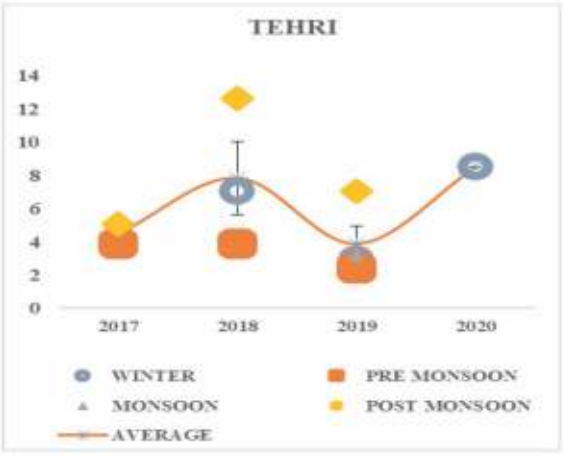
VIOLIN BOX PLOT ILLUSTRATING IN MAGNESIUM HARDNESS (ppm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

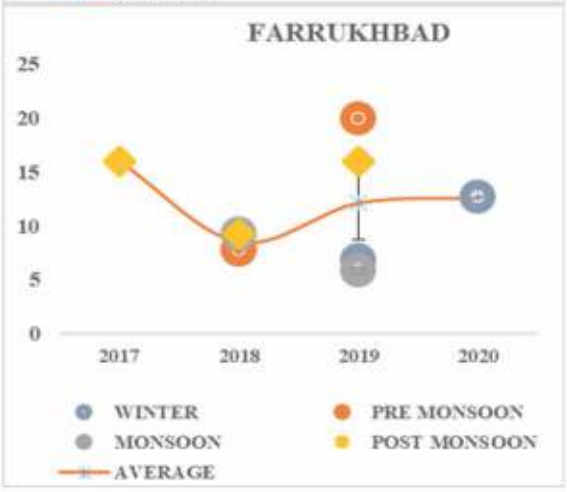


BRIEF DESCRIPTION

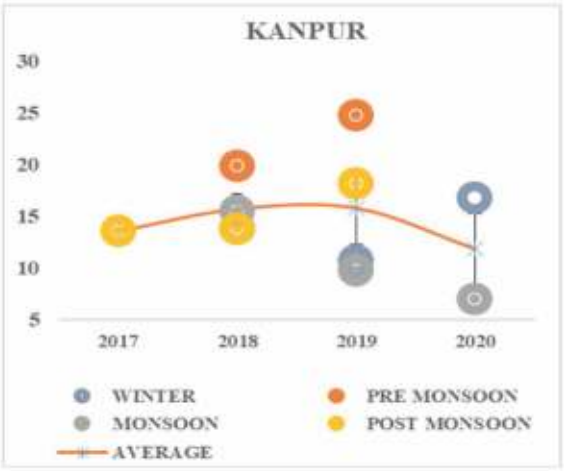
The mean magnesium hardness in the entire stretch was 78.05 ± 19.45 ppm. The value of magnesium hardness ranged from 8.56 ± 1.42 ppm to 1111.10 ± 186.50 ppm at Fraserganj. Among the different stretches, the higher magnesium hardness has been observed at estuarine stretch of the river, while the minimum magnesium hardness was recorded 9.48 ± 0.62 ppm in the upper stretch of the river. The middle and lower stretches have 16.72 ± 0.90 ppm and 18.78 ± 2.66 ppm of magnesium hardness respectively. Comparing among the different seasons the monsoon has the highest mean magnesium hardness of 105.89 ± 58.20 ppm and the minimum magnesium hardness was recorded 50.43 ± 19.19 ppm during post-monsoon. During winter and pre-monsoon season the mean magnesium hardness were72.02 ± 38.98 and 94.07 ± 45.58 ppm respectively.

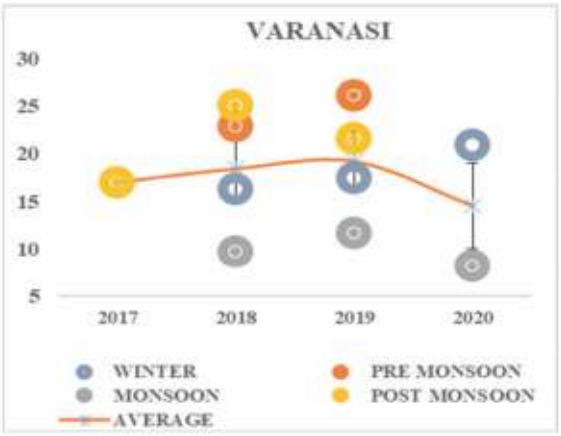
TIMESCALE CHANGES OF MAGNESIUM HARDNESS (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

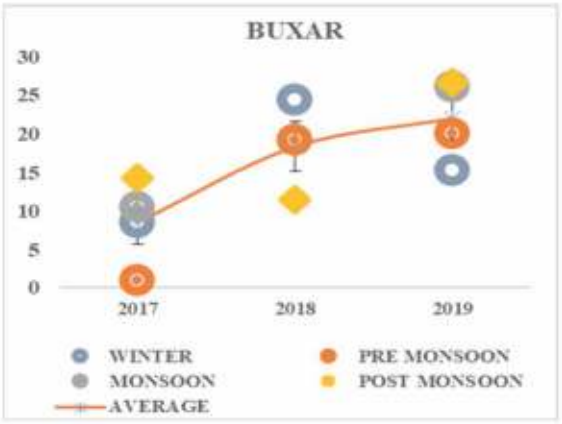


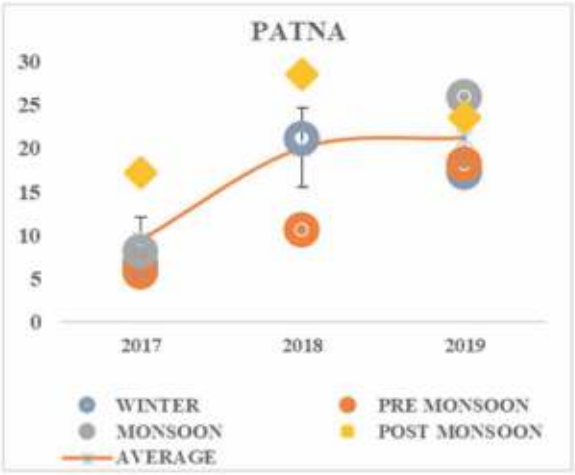


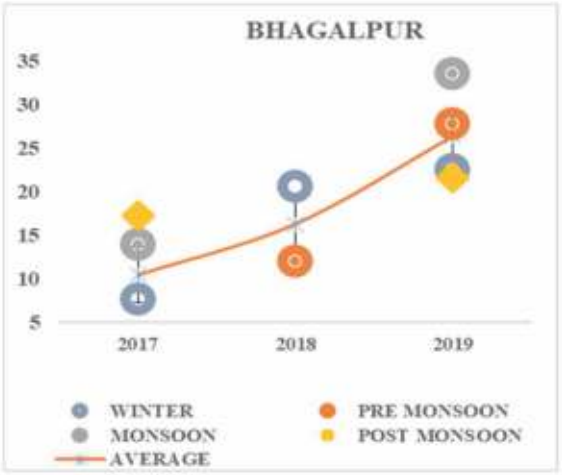
TIMESCALE CHANGES OF MAGNESIUM HARDNESS (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



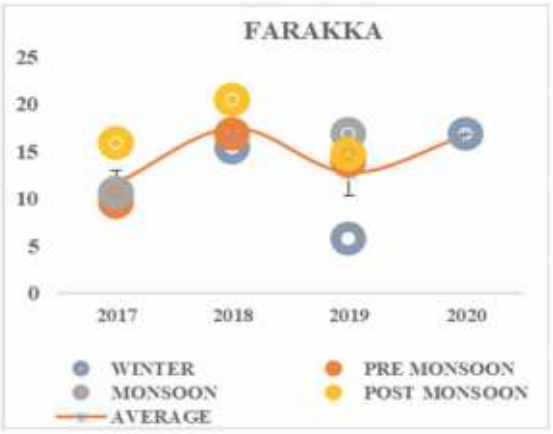


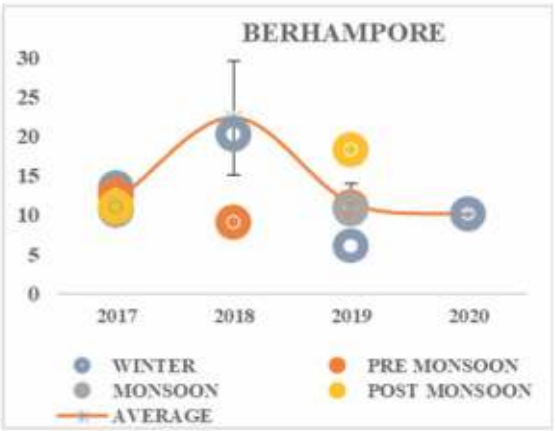


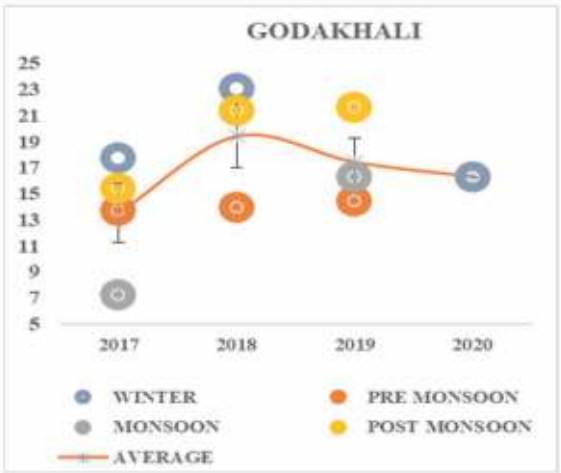




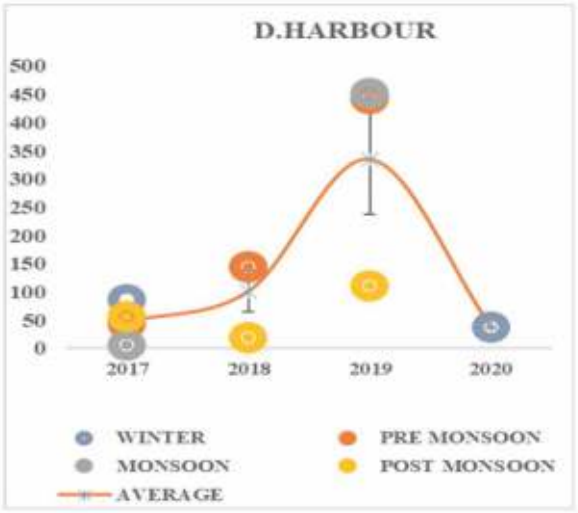
TIME-SCALE CHANGES OF MAGNESIUM HARDNESS (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

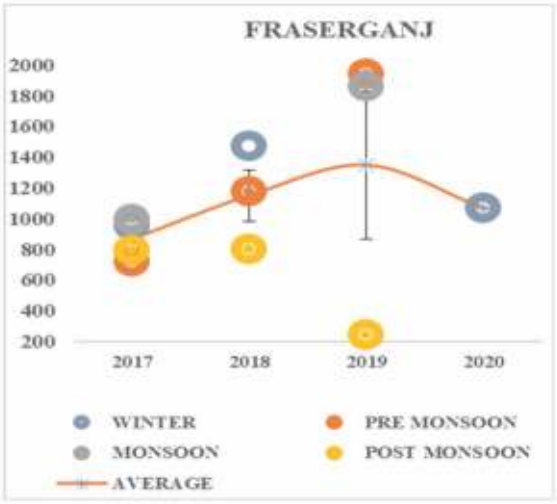






TIMESCALE CHANGES OF MAGNESIUM HARDNESS (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



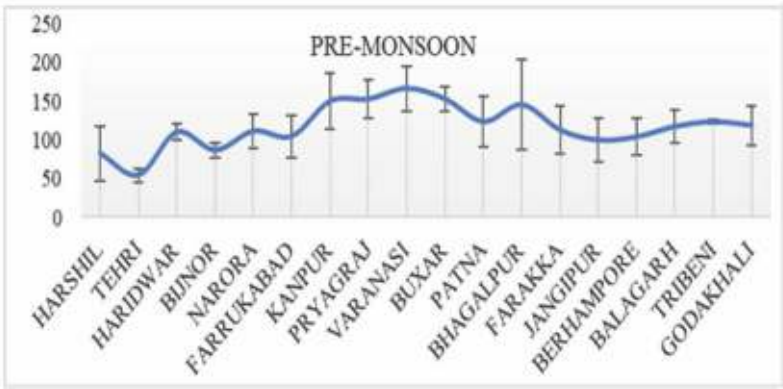


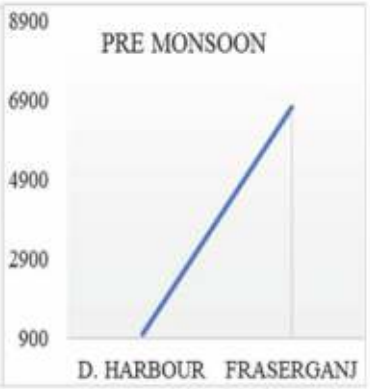
SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch, the increase in the magnesium hardness has been recorded at all the sampling sites except Narora and Farrukhabad from 2017 to 2020.
- In the middle stretch decrease in the magnesium hardness has been observed at Kanpur, Prayagraj, and Varanasi while rise in the magnesium hardness was observed at Buxar, Patna and Bhagalpur from 2017 to 2020.
- Among the sampling stations of lower stretch there was rise in magnesium hardness at Farakka, Jangipur and Godakhali while decrease value was recorded at Berhampore, Balagarh and Tribeni from 2017 to 2020.
- In the estuarine stretch, decrease in magnesium hardness have been recorded at D. harbor while the increase value was observed at Fraserganj from 2017 to 2020.

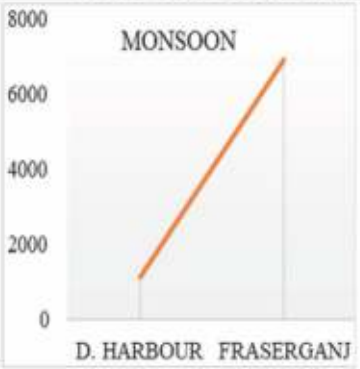
Total hardness (ppm)

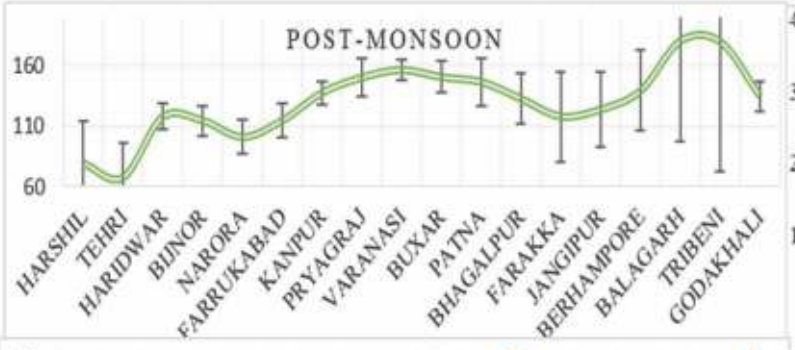
Total hardness in the water is measurement of divalent cations. The major contributor of them are calcium and magnesium. The hardness of the river system is mainly due to the leaching of sedimentary rocks which enhances the concentration of divalent ion in the water. The total hardness plays vital role in the growth and survival of aquatic organisms like fish. The reproductive and embryological function of the fish also gets affected by the alteration in the fish.

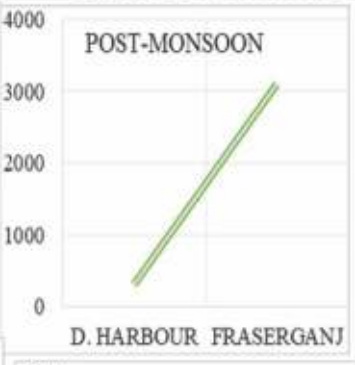

PRE-MONSOON
250
200
150
100
50
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI

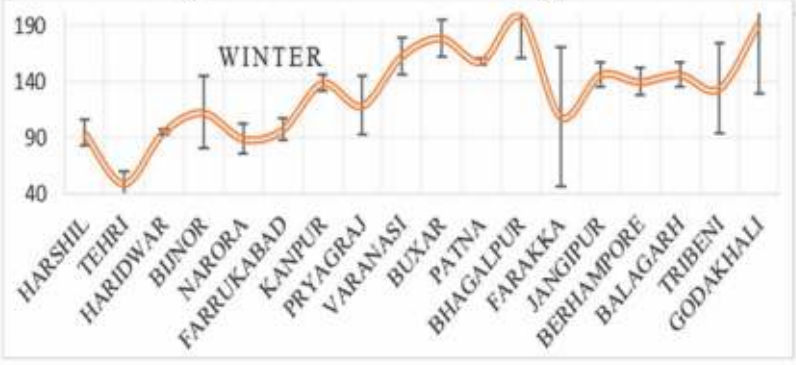

PRE MONSOON
8900
6900
4900
2900
900
D. HARBOUR
FRASERGANJ


MONSOON
190
140
90
40
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


MONSOON
8000
6000
4000
2000
0
D. HARBOUR
FRASERGANJ

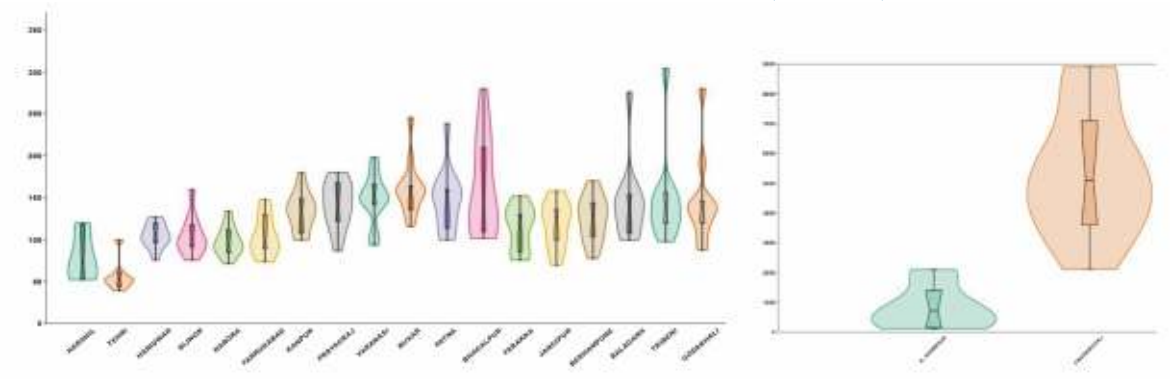

POST-MONSOON
160
110
60
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


POST-MONSOON
4000
3000
2000
1000
0
D. HARBOUR
FRASERGANJ


WINTER
190
140
90
40
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


WINTER
5500
4500
3500
2500
1500
500
D. HARBOUR
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING IN TOTAL HARDNESS (ppm) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



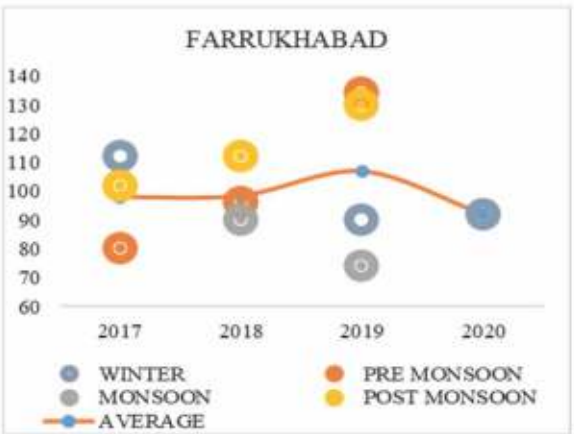
CHANGING PATTERN OF TOTAL HARDNESS OVER THE YEARS

Stretches	Period	Total Hardness (PPM)
Farrukhabad	1995-96	NA
	2016-20	104.72
	1960	128
	1987-88	176
	2001-06	182
	2016-20	133.72
Pryagraj	1960	122
	1987-88	152
	2001-06	164
	2016-20	139.81
Varanasi	1960	110
	1987-88	154
	2001-06	162
	2016-20	149.72
Patna	1960	120
	1987-88	118
	2001-06	148
	2016-20	148
Bhagalpur	1960	112
	1987-88	120
	2001-06	124
	2016-20	162.72
	2001-06	108
	2016-20	106.60
	2016-20	1208.90

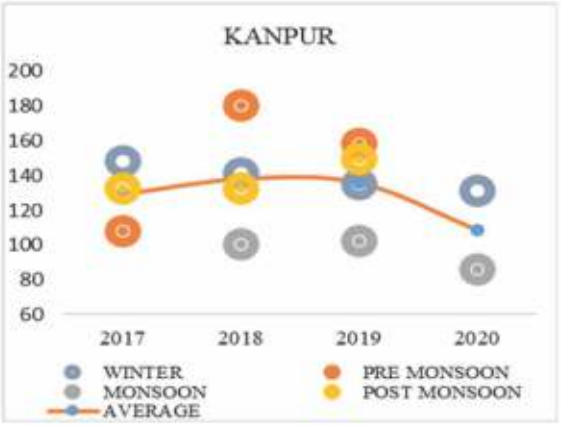
BRIEF DESCRIPTION

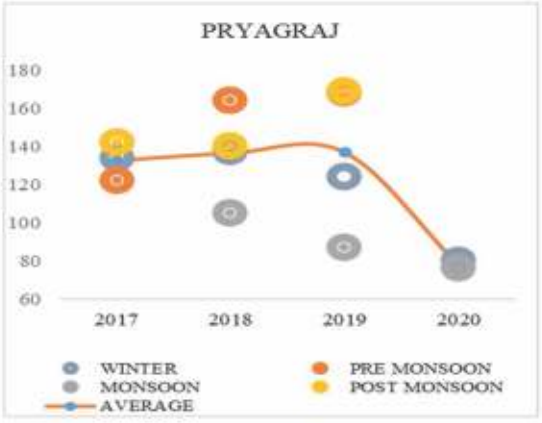
The mean total hardness in the entire stretch was 437.96 ± 88.48 ppm. The higher total hardness was recorded in the estuarine stretch of the river. The highest mean total hardness value was recorded 5401 ±720.40 ppm at Fraserganj. While, the lowest mean total hardness was recorded 55.88 ± 5.94 ppm at Tehri. Among the different stretches the lowest mean total hardness was recorded 92.48 ± 3.48 ppm in the upper stretch of the river, while the highest mean total hardness was recorded 3205.14 ± 618.36 ppm in the estuarine stretch of the river. The mean total hardness in the middle and lower stretch of the river are 149.34 ± 4.6 ppm and 142.25 ± 14.14 ppm respectively. Comparing among the different seasons the highest hardness was recorded in monsoon season, while the lowest hardness was recorded during post-monsoon.

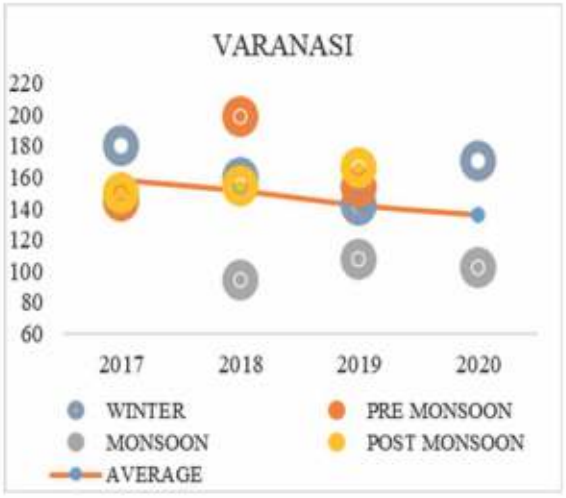
TIMESCALE CHANGES OF TOTAL HARDNESS (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

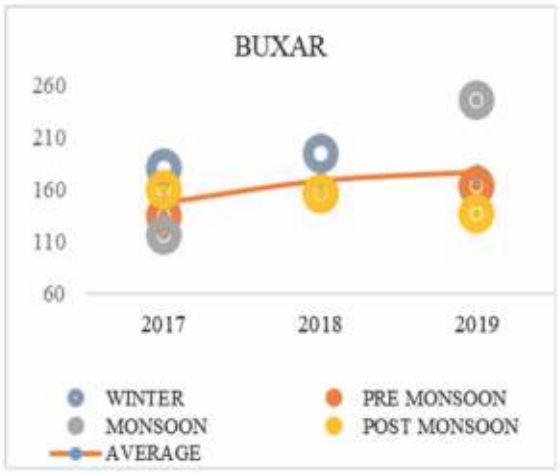


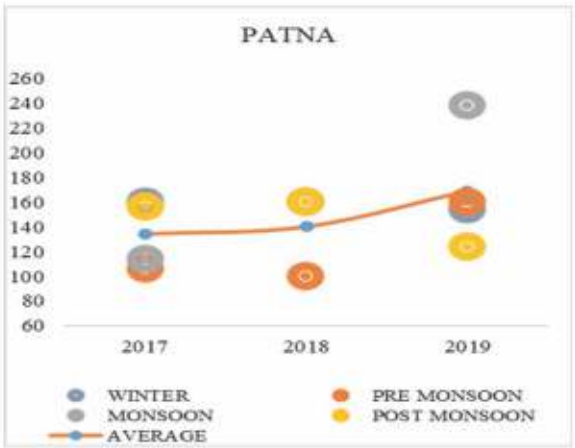
TIMESCALE CHANGES OF TOTAL HARDNESS (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

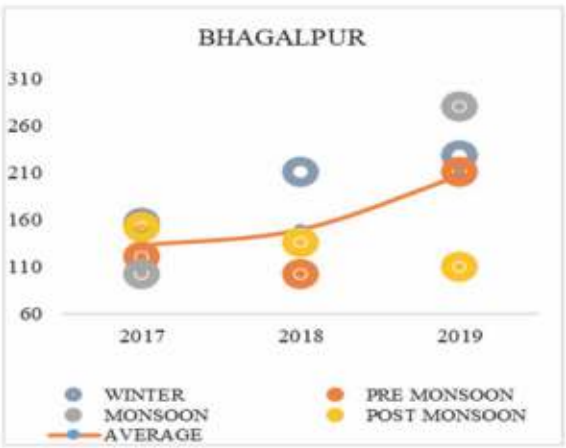




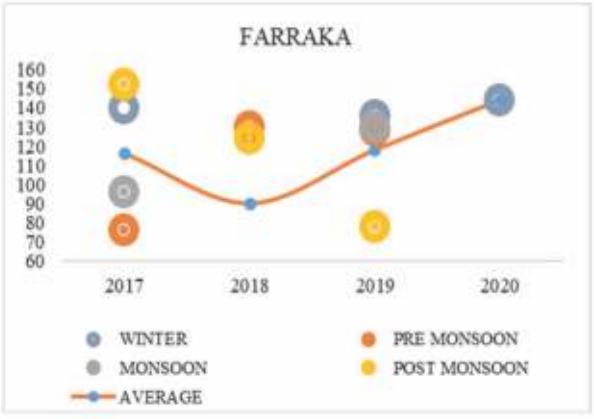


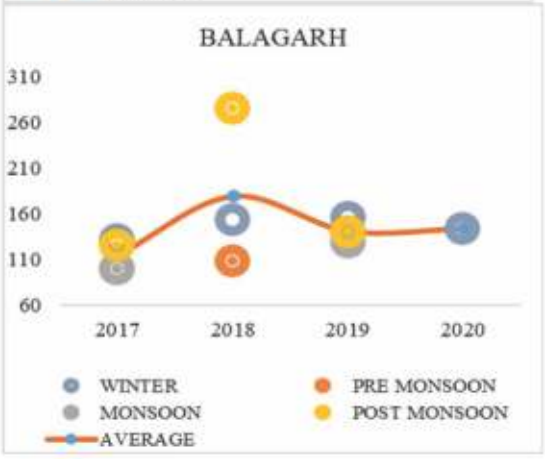


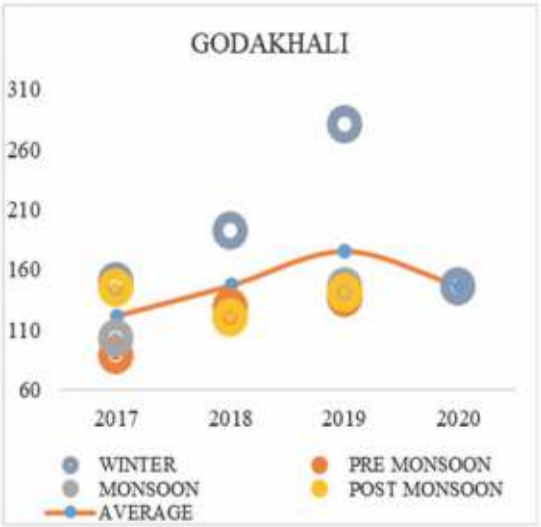




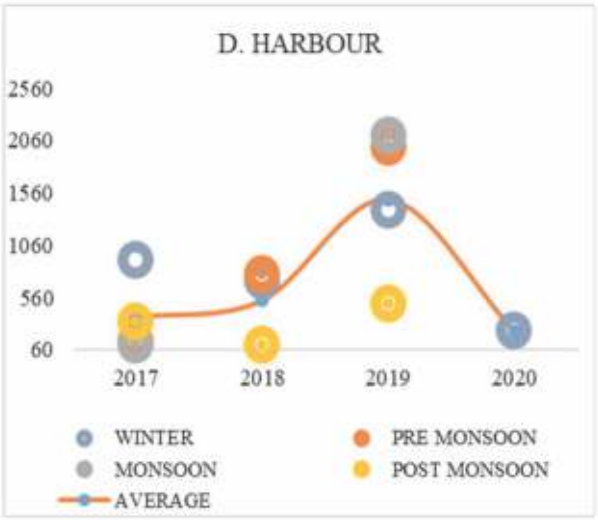
TIME-SCALE CHANGES OF TOTAL HARDNESS (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

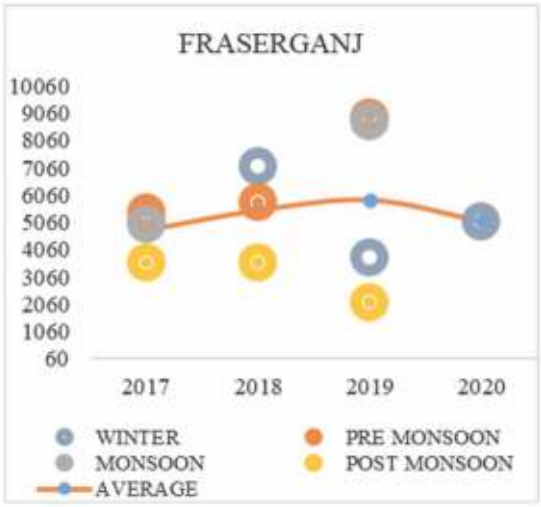






TIMESCALE CHANGES OF TOTAL HARDNESS (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



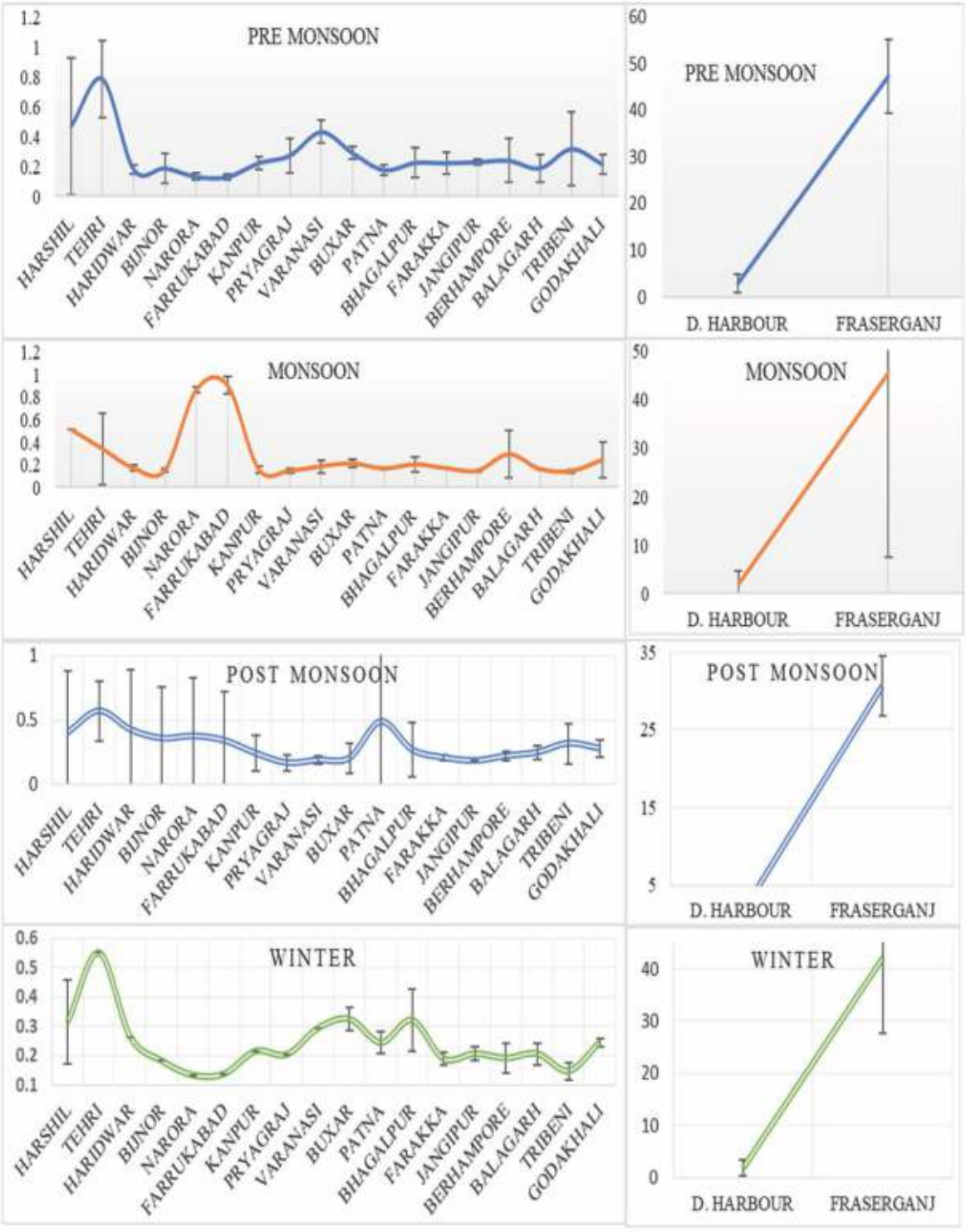


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch the rise in the total hardnesshas been recorded at all the sampling sites except Narora and Farrukhabad from 2017 to 2020.
- In the middle stretch, a decrease in the total hardnesshas been observed at Kanpur, Prayagraj, and Varanasi while, an increase in total hardness was recorded at Buxar, Patna, and Bhagalpur from 2017 to 2020.
- Among the sampling stations of the lower stretch there is an increase in thetotal hardnesshas been recorded at all the stations except Tribeni from 2017 to 2020.
- In the estuarine stretch decrease in total hardness was recorded at D. Harbour, while increase in total hardness have been recorded at Fraserganj.

Total dissolved solid (ppt)

Total dissolved solid is the measurement of concentration of dissolved substances in the water. The TDS in the water is due to organic and inorganic materials including various cations and anions. The increased concentration of TDS in the water signifies the increased pollution in the aquatic environment. The higher as well as lower TDS than the prescribed limit can affect the fish health, as the lower TDS value may affect the fish growth and development. The higher TDS level increases the stress level in the fish.


PRE MONSOON
1.2
1
0.8
0.6
0.4
0.2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
PRE MONSOON
60
50
40
30
20
10
0
D. HARBOUR
FRASERGANJ
MONSOON
1.2
1
0.8
0.6
0.4
0.2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
MONSOON
50
40
30
20
10
0
D. HARBOUR
FRASERGANJ
POST MONSOON
1
0.5
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
POST MONSOON
35
25
15
5
D. HARBOUR
FRASERGANJ
WINTER
0.6
0.5
0.4
0.3
0.2
0.1
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
WINTER
40
30
20
10
0
D. HARBOUR
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING IN TOTAL DISSOLVED SOLID (ppt) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

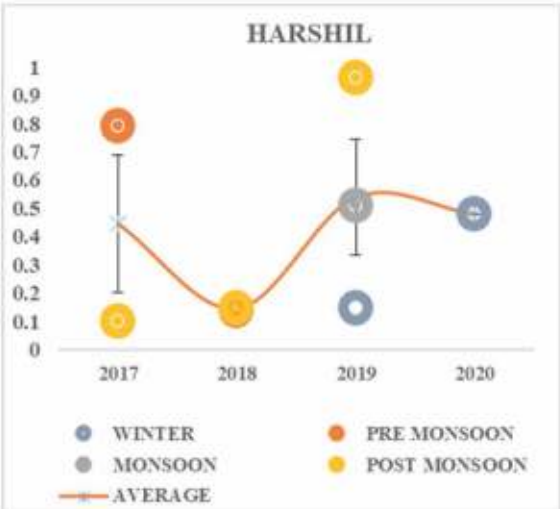
CHANGING PATTERN OF TDS OVER THE YEARS

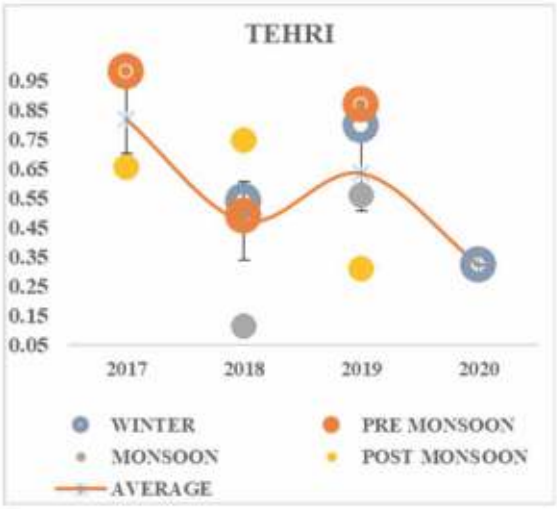
Stretches	Period	TDS(g/l)
	1960	0.170
	1987-88	0.278
	2001-06	0.285
	2016-20	0.13
Pryagraj	1960	0.148
	1987-88	0.206
	2001-06	0.253
	2016-20	0.15
Varanasi	1960	0.130
	1987-88	0.216
	2001-06	0.234
	2016-20	0.17
Patna	1960	0.148
	1987-88	0.138
	2001-06	0.155
	2016-20	0.27
Bhagalpur	1960	0.134
	1987-88	0.158
	2001-06	0.164
	2016-20	0.25
	2001-06	0.121
	2016-20	0.20

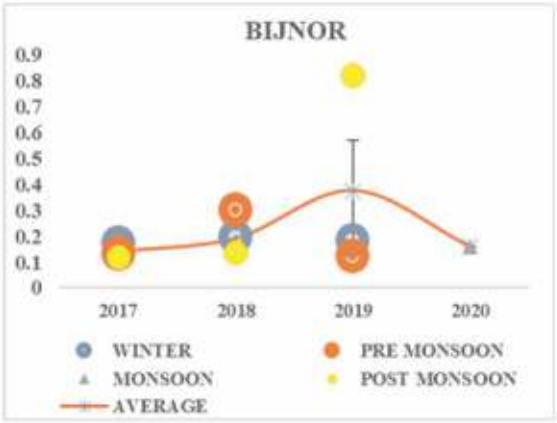
BRIEF DESCRIPTION

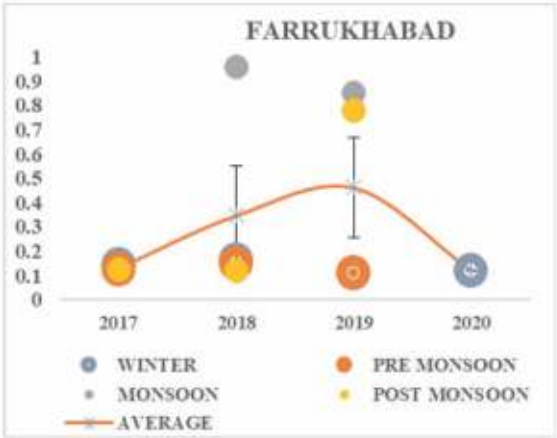
The mean total dissolved solid in the entire stretch is 2.92 ± 0.75 ppt. The total dissolved solid in the entire stretch ranged from 0.162 ± 0.05 ppt at Tehri to 40.95 ± 5.02 ppt at Fraserganj which lie in the estuarine stretch. Among the different stretches, the upper stretch has the least mean total dissolved solid value of 0.21 ± 0.02 ppt, while the highest mean total dissolved solid was observed (26.73 ± 5.23 ppt) in the estuarine stretch of the river. The mean total dissolved solid in the middle and lower stretches were 0.25 ± 0.18 ppt and 0.28 ± 0.05 ppt respectively. Among the different seasons, the highest mean total dissolved solid was recorded 3.34 ± 1.51 ppt during the post-monsoon season, while the lowest mean total dissolved solid was recorded 2.62 ± 1.89 ppt during the monsoon season.

TIMESCALE CHANGES OF TOTAL DISSOLVED SOLID (ppt) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

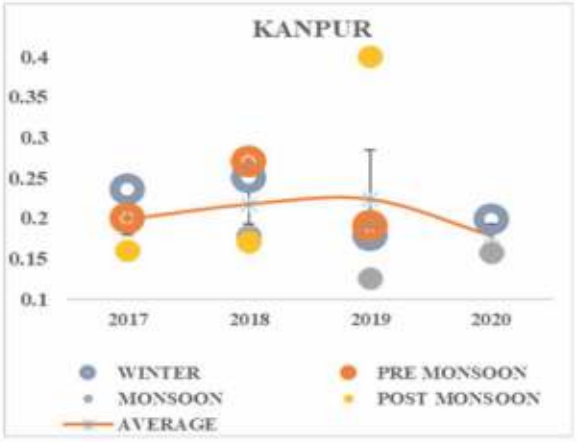


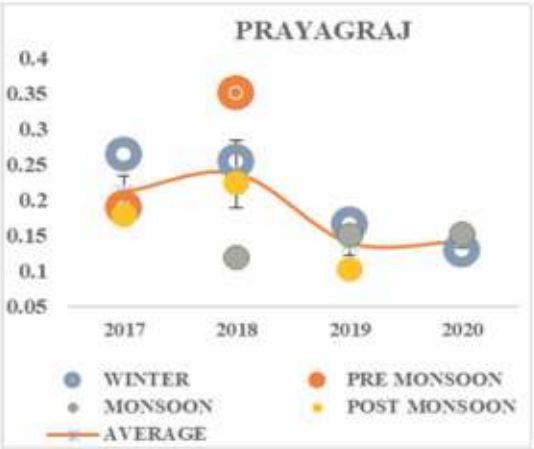


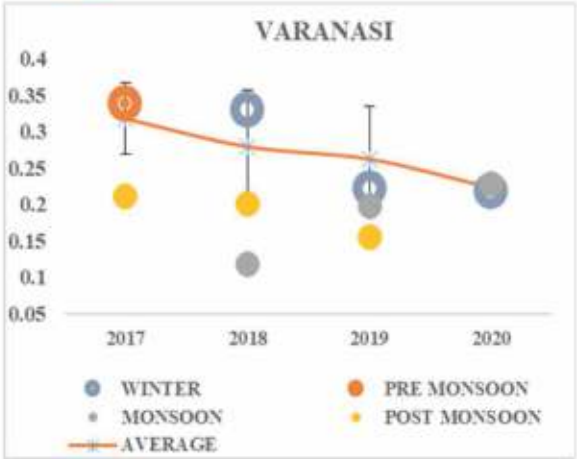


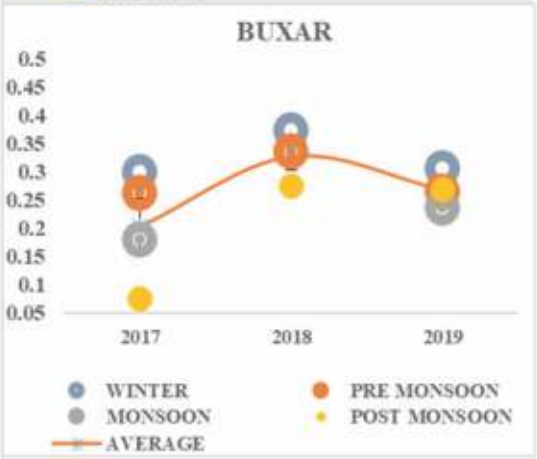


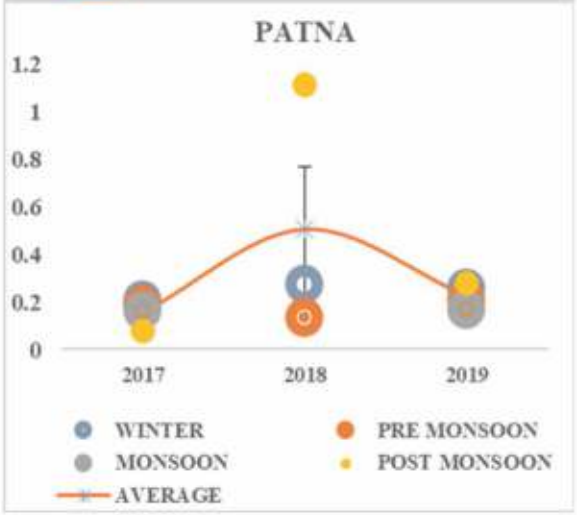
TIMESCALE CHANGES OF TOTAL DISSOLVED SOLID (ppt) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)

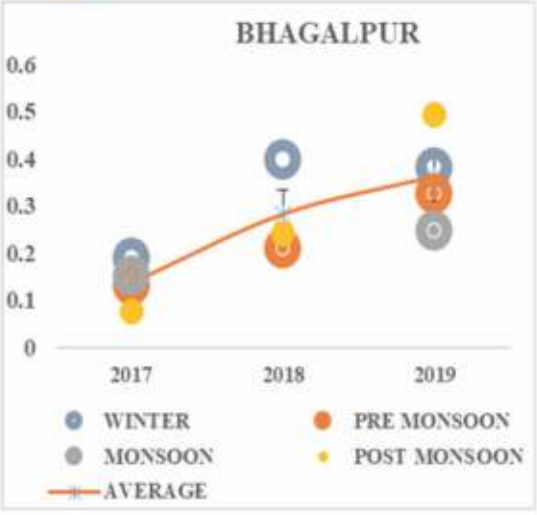




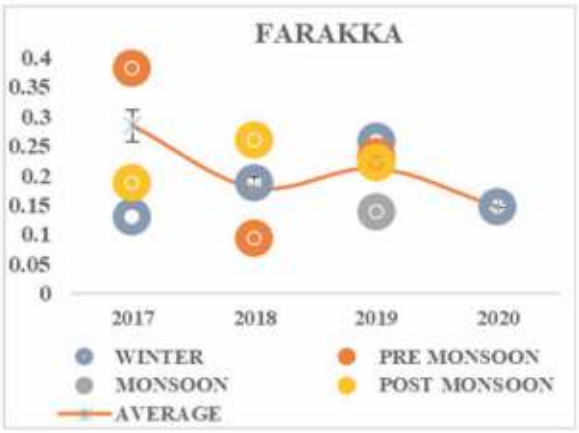


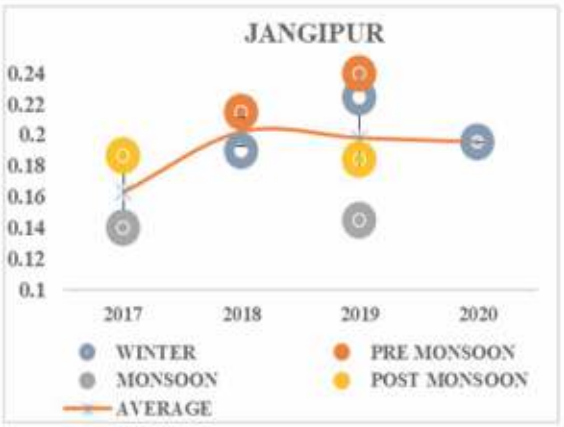


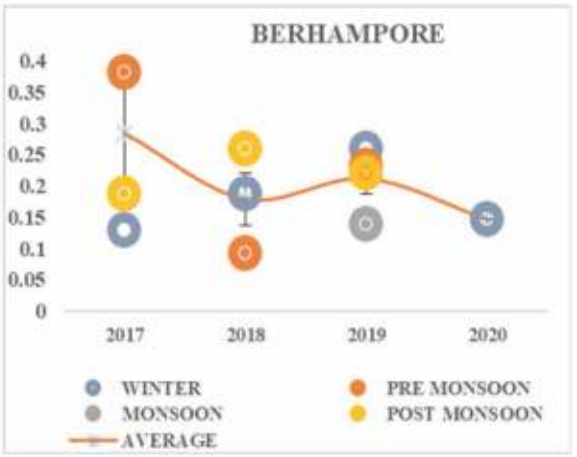


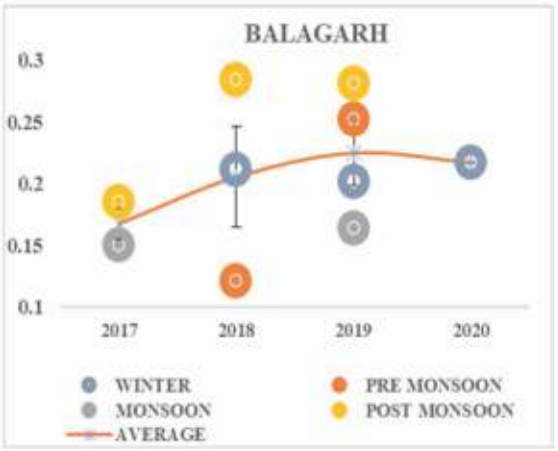


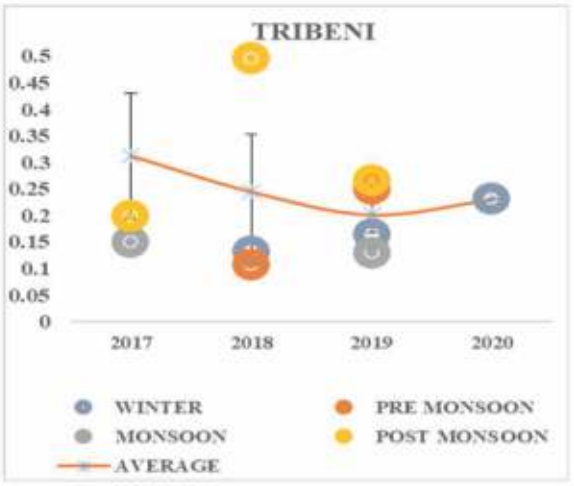
TIME-SCALE CHANGES OF TOTAL DISSOLVED SOLID (ppt) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

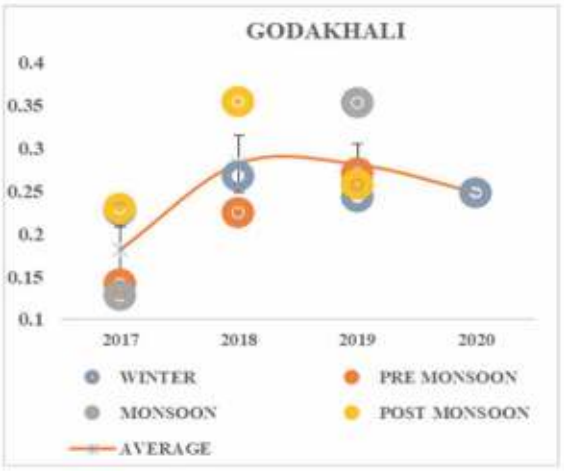




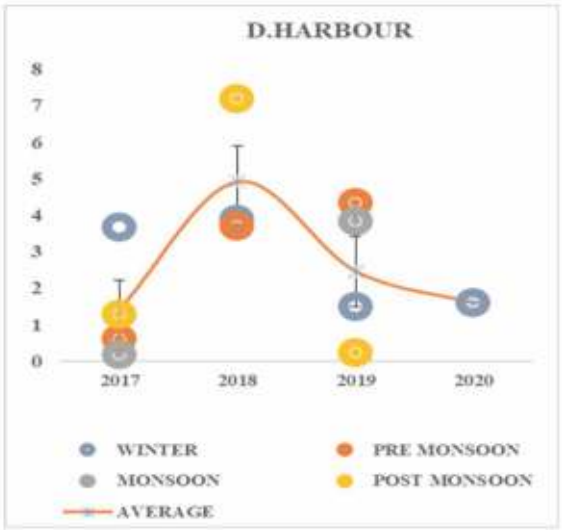


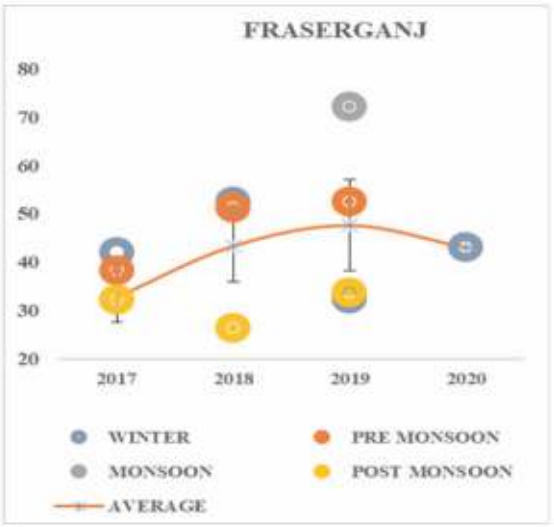






TIMESCALE CHANGES OF TOTAL DISSOLVED SOLID (ppt) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



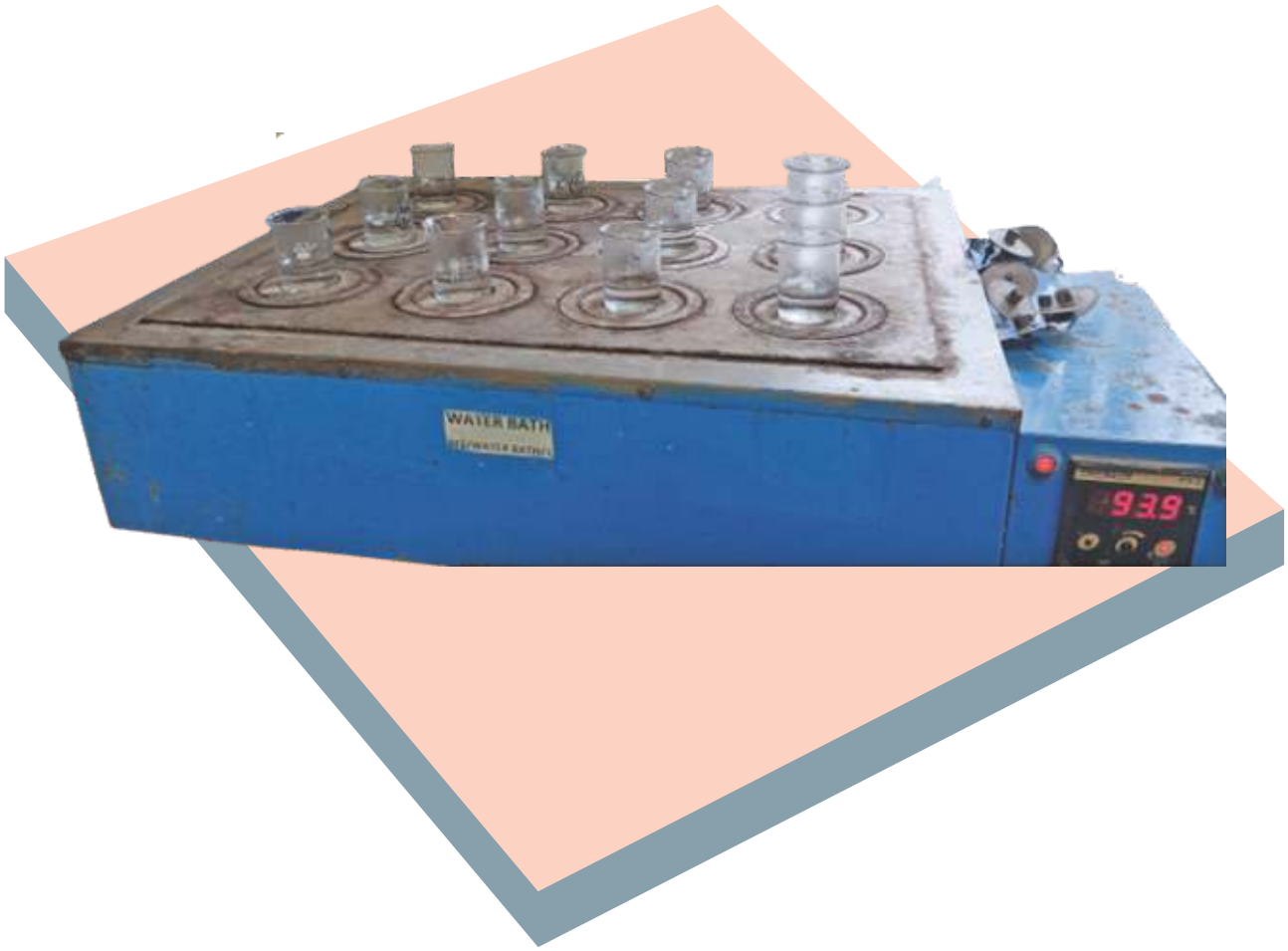


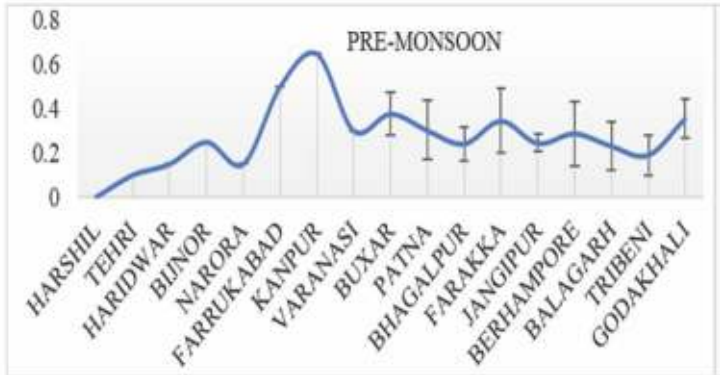
SALIENT TIMESCALE OBSERVATIONS

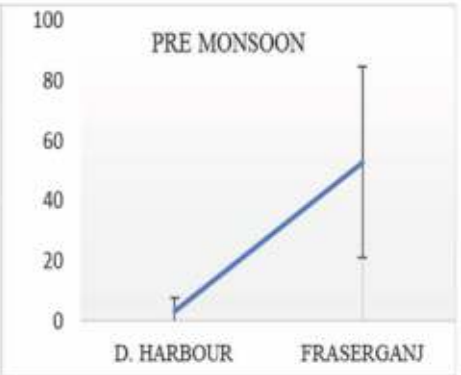
- In the upper stretch a decrease in the total dissolved solid has been recorded at majority of the sampling sites except Harshil and Haridwar from 2017 to 2020.
- In the middle stretch a decrease in the total dissolved solid has been observed at Kanpur, Prayagraj, and Varanasi while the value increased at Buxar, Patna, and Bhagalpur from 2017 to 2020.
- Among the sampling stations of a lower stretch there was a decrease in the total dissolved solidhas been recorded at Farakka, Berhampore and Tribeni while increases at Jangipur, Balagarh, and Godakhali from 2017 to 2020.
- In the estuarine stretch the value of total dissolved solid value increased at all the stations from 2017 to 2020.

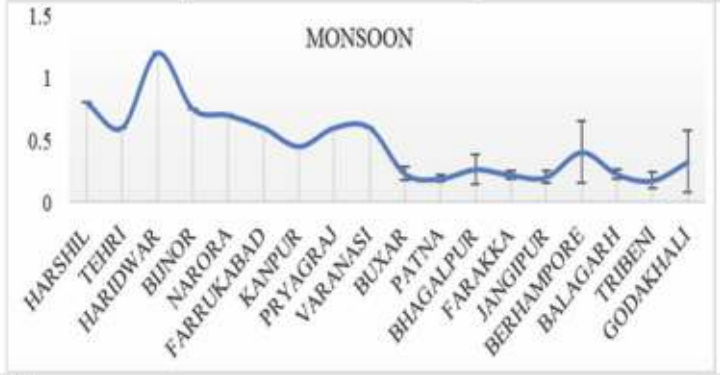
Total solid (ppt)

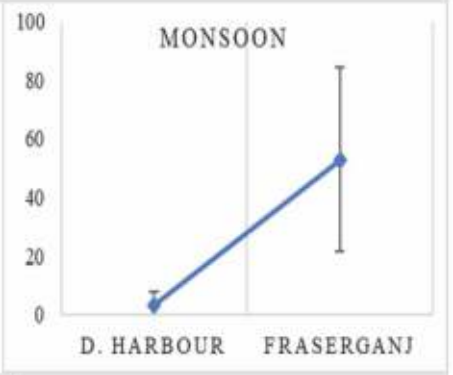
Total solid refers to entire dissolved solid and settleable in the form of inorganic and organic matter in the water. The total solid in the water mainly comprises calcium, iron, sulfate, nitrate and phosphorus etc. The alteration in the total solid may affect the TDS and indirectly to the pollution status of the river.

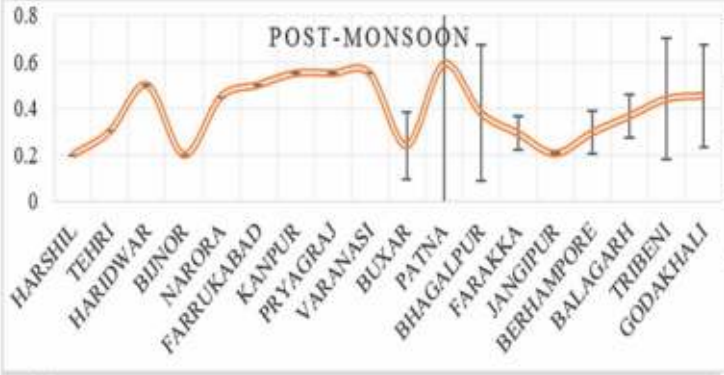


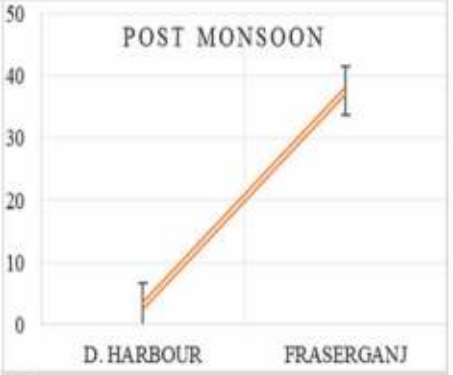

PRE-MONSOON
0.8
0.6
0.4
0.2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI

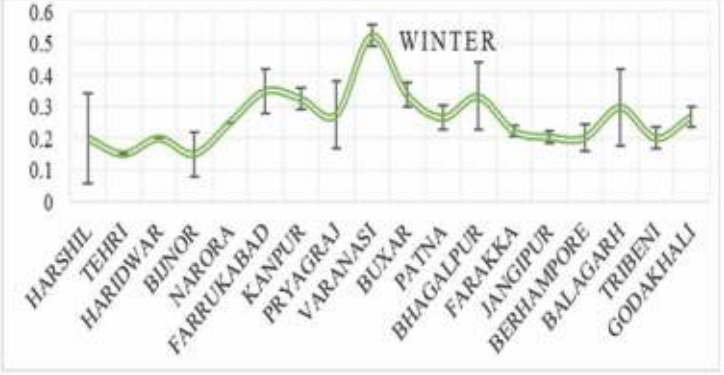

PRE MONSOON
100
80
60
40
20
0
D. HARBOUR
FRASERGANJ


MONSOON
1.5
1
0.5
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


MONSOON
100
80
60
40
20
0
D. HARBOUR
FRASERGANJ

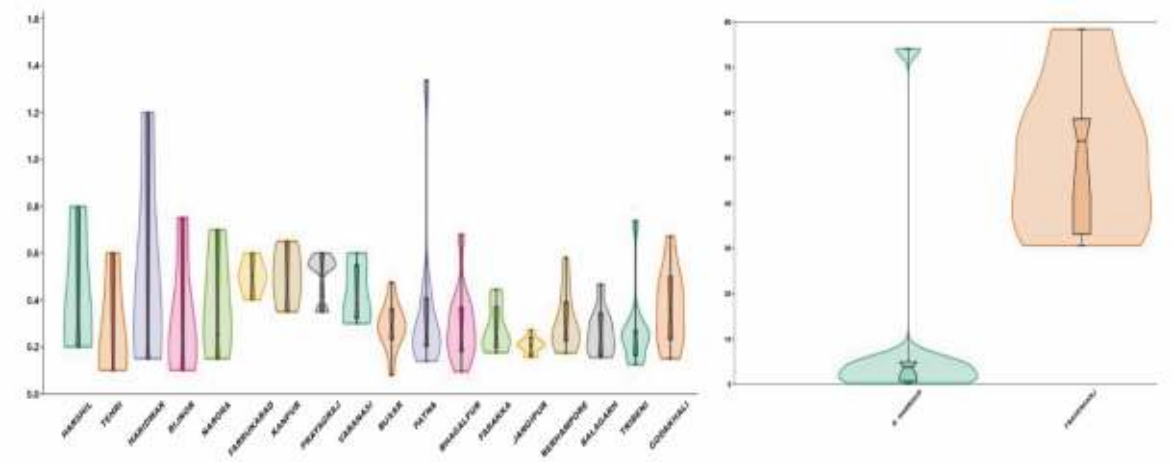

POST-MONSOON
0.8
0.6
0.4
0.2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


POST MONSOON
50
40
30
20
10
0
D. HARBOUR
FRASERGANJ


WINTER
0.6
0.5
0.4
0.3
0.2
0.1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI


WINTER
60
50
40
30
20
10
0
D. HARBOUR
FRASERGANJ

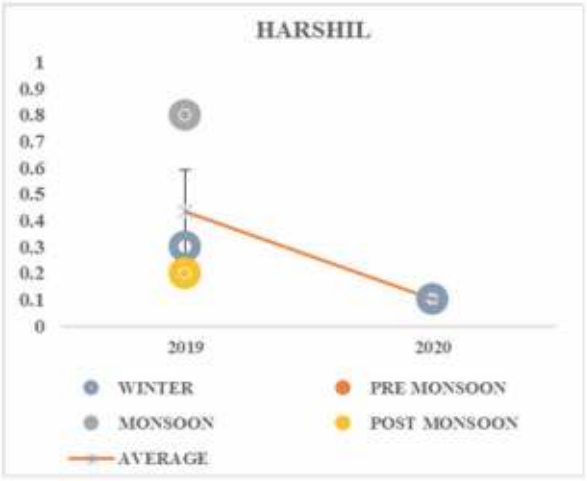
VIOLIN BOX PLOT ILLUSTRATING VARITIION IN TOTAL SOLID (ppt) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

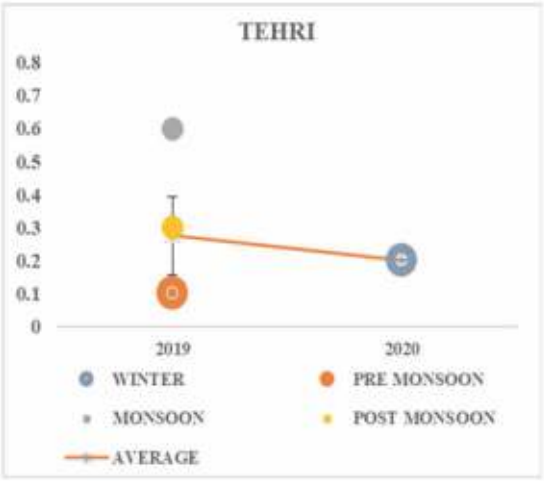


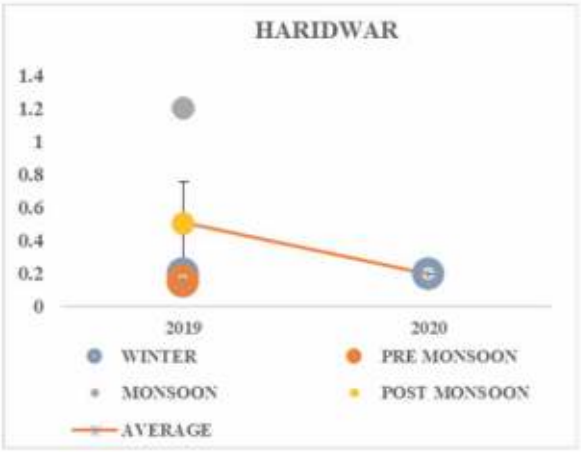
BRIEF DESCRIPTION

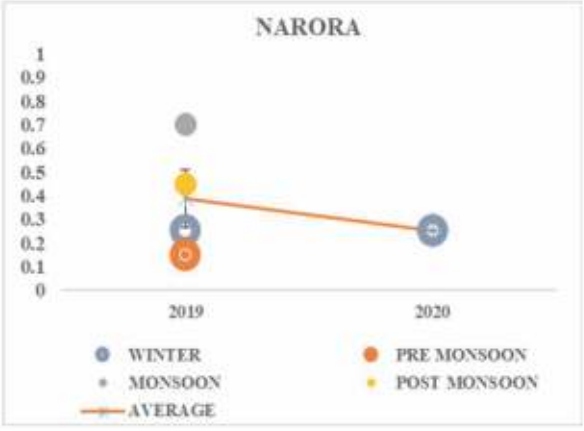
The average total solid in the entire stretch was 4.70 ± 1.22 ppt. The value of total solid ranged from 0.20 ± 0.11 ppt at Jangipur to 49.58 ± 5.4 ppt at Fraserganj. Among the different stretches, the lowest mean total solid was observed 0.35 ppt in the lower stretch of the river, while the highest total solid was recorded 30.95 ± 6.17 ppt in the estuarine stretch of the river. In the upper and middle stretch of the river the observed total solid was 0.40 ± 0.05 ppt and 0.36± 0.03 ppt respectively. Among the different seasons the highest mean total solid was recorded 5.53 ± 2.85 ppt during the pre-monsoon season, while the lowest total solid was recorded 3.97 ± 2.56 ppt during the monsoon season. The total solid during winter and post monsoon were 4.26 ± 2.18 ppt and 4.92 ± 2.31 ppt respectively.

TIMESCALE CHANGES OF TOTAL SOLID (ppt) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

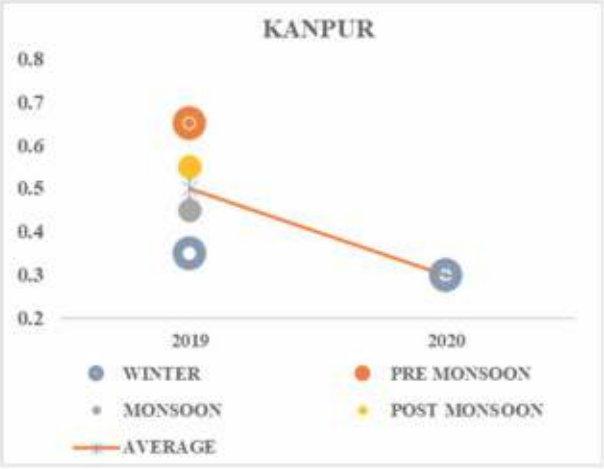


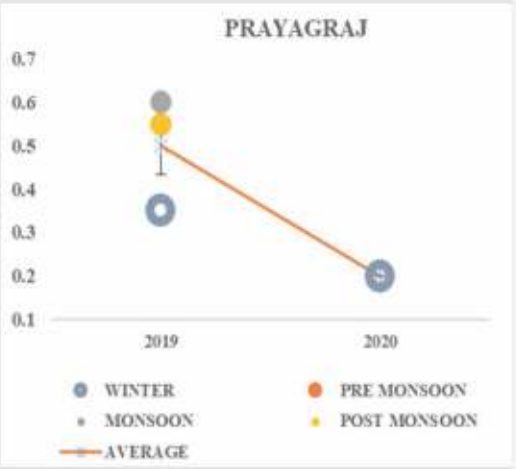


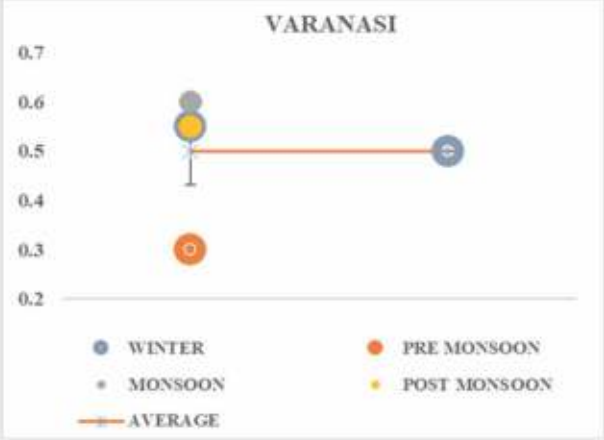


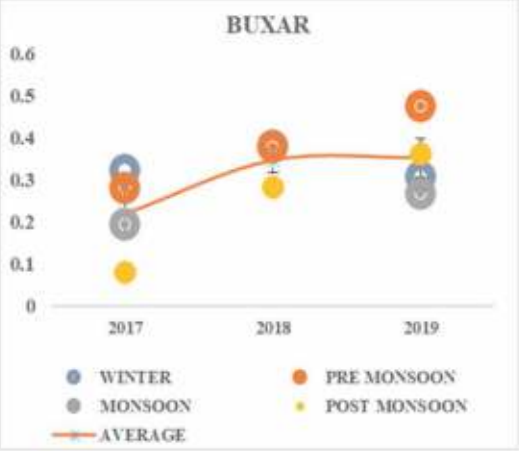


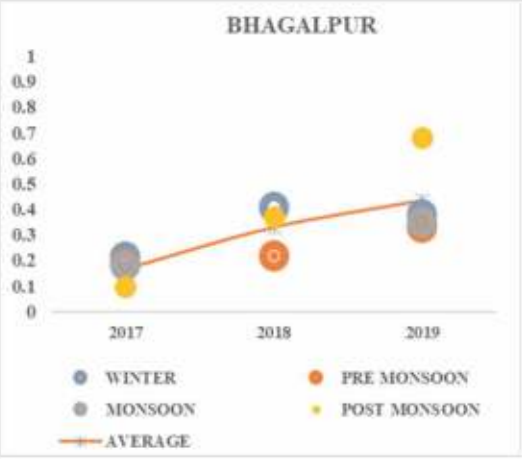
TIMESCALE CHANGES OF TOTAL SOLID (ppt) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



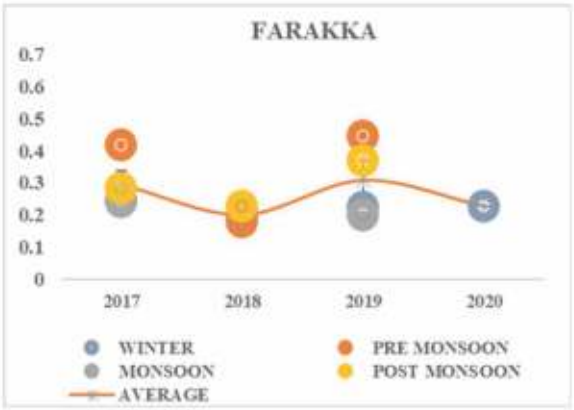


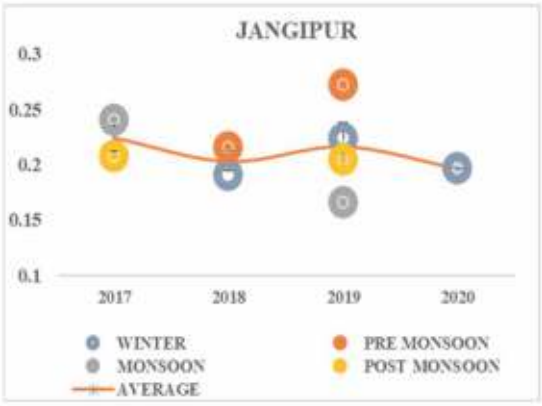


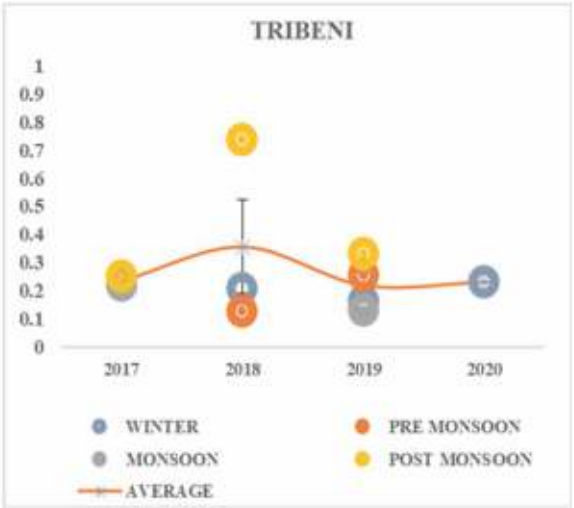


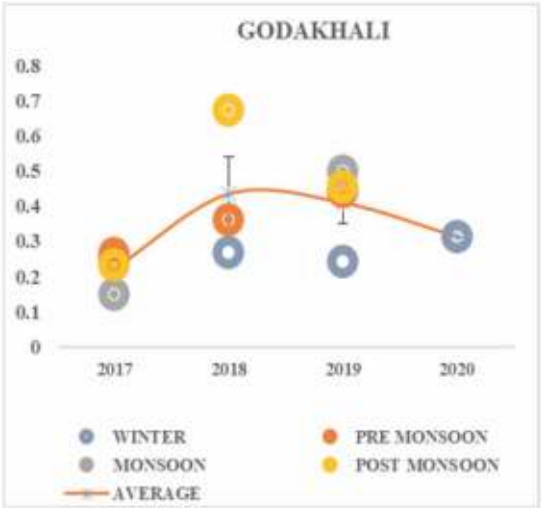


TIME-SCALE CHANGES OF TOTAL SOLID IN (ppt) THE LOWER STRETCH OF RIVER GANGA (2016-20)

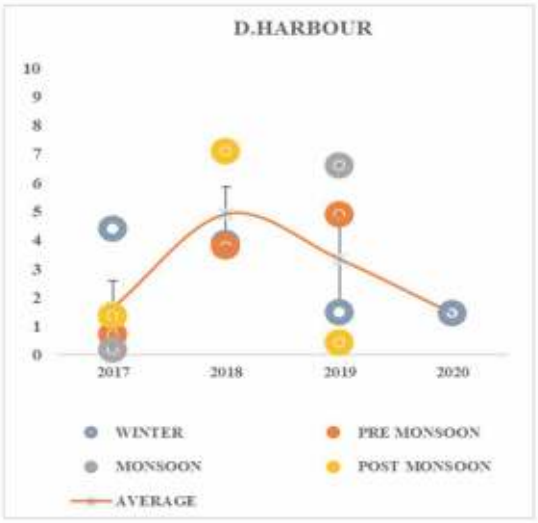


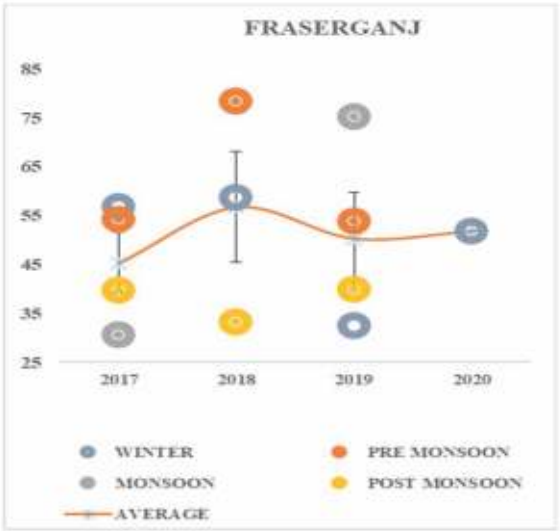






TIMESCALE CHANGES OF TOTAL SOLID (ppt) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)





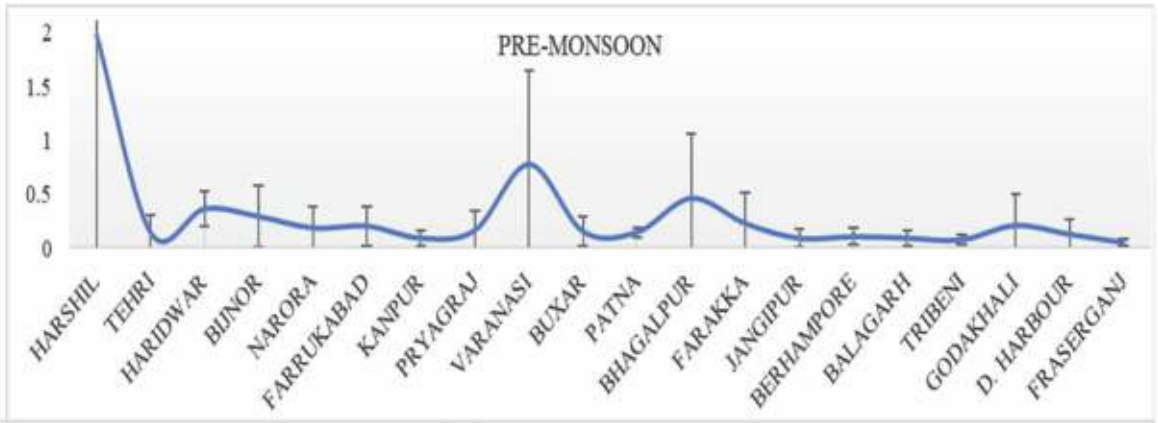
SALIENT TIMESCALE OBSERVATIONS

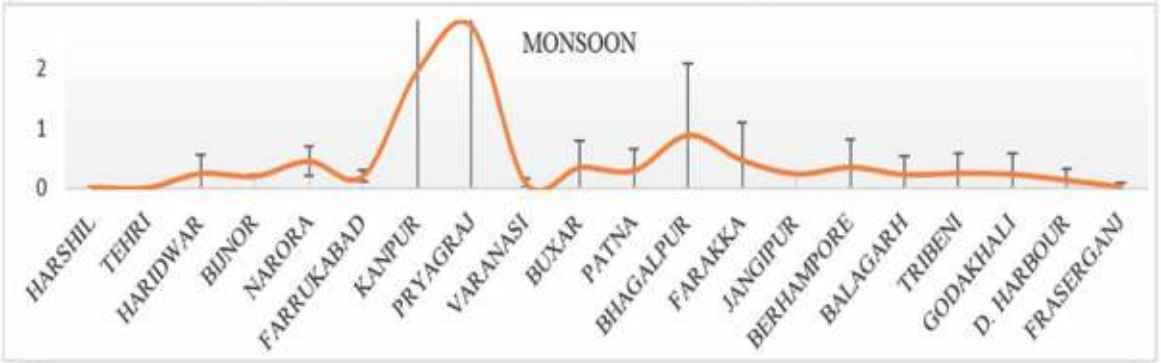
- In the upper stretch, a decrease in the total solid value was recorded at all the sampling sites except at Bijnor from 2017 to 2020.
- In the middle stretch decrease in the value of total solid has been observed at Kanpur, Prayagraj Varanasi, and Patna while an increase in total solid has been observed at Buxar and Bhagalpur from 2017 to 2020.
- Among the sampling stations of lower stretch, a decrease in total solid has been recorded at all the stations except Balagarh and Godakhali from 2017 to 2020.
- In the estuarine stretch an increase in total solid has been recorded at all the stations from 2017 to 2020.

NUTRIENT PARAMETERS

Total phosphorus (ppm)

Total phosphorus is the common nutrient of the water, which helps in the nutrient enhancement. The main source of total phosphorus in the water is domestic and agricultural runoff. The over increment in the phosphorus can lead to eutrophication as well as plankton bloom in the river system.


PRE-MONSOON
2
1.5
1
0.5
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
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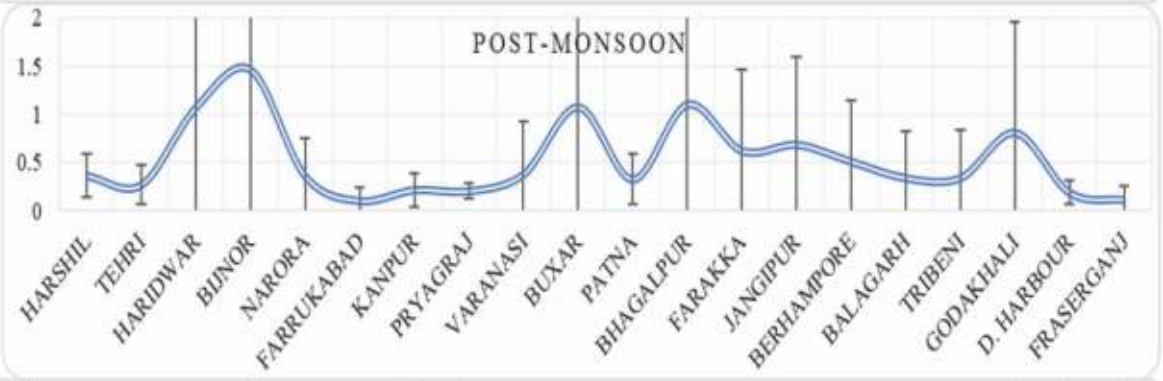
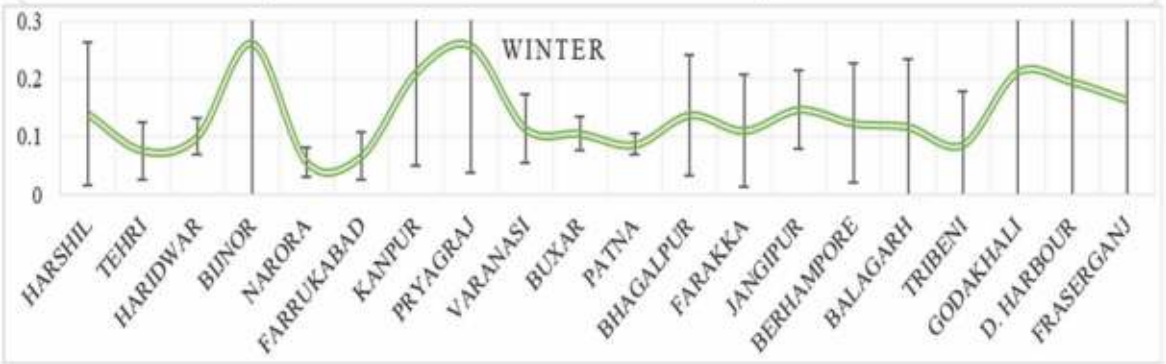
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
2
1.5
1
0.5
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
0.3
0.2
0.1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
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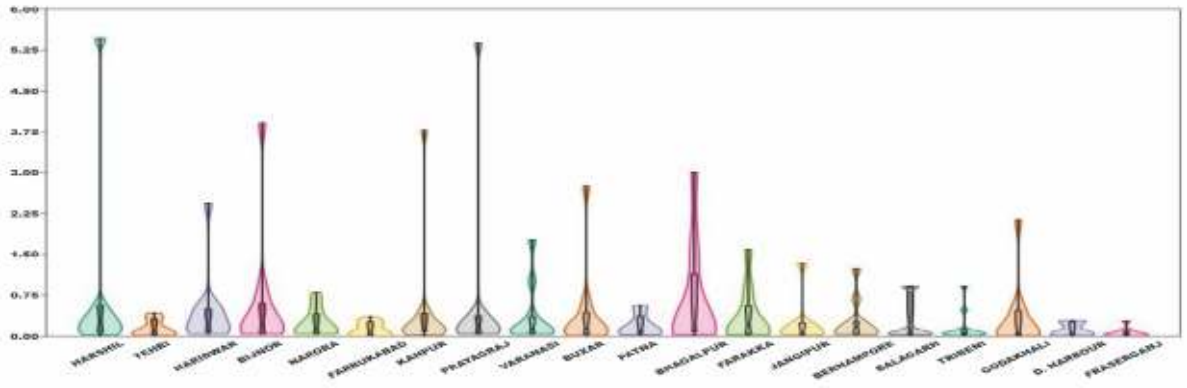
FRASERGANJ

VIOLIN BOX PLOT ILLUSTRATING IN TOTAL PHOSPHORUS (ppm) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



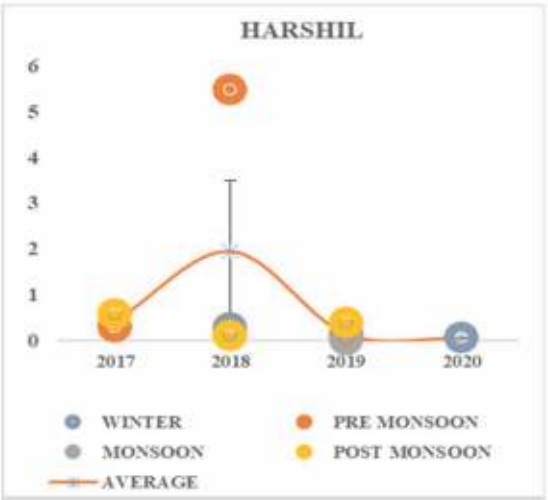
CHANGING PATTERN OF TOTAL PHOSPHORUS OVER THE YEARS

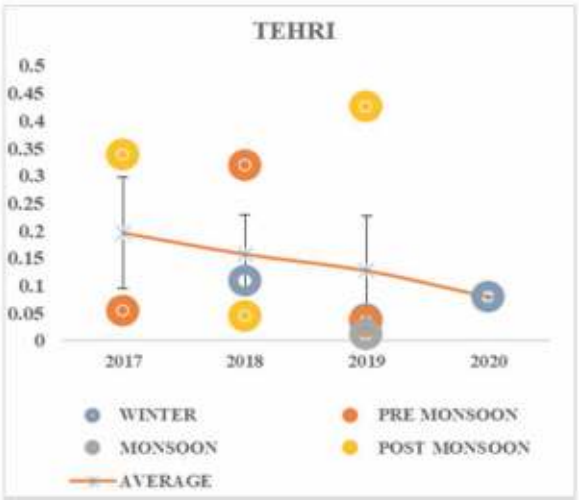
Stretches	Period	Total Phosphorus (PPM)
	1960	0.14
	1987-88	0.18
	2001-06	0.14
	2016-20	0.49
Pryagraj	1960	0.15
	1987-88	0.18
	2001-06	0.12
	2016-20	0.65
Varanasi	1960	0.04
	1987-88	0.17
	2001-06	0.1
	2016-20	0.38
Patna	1960	0.1
	1987-88	0.18
	2001-06	0.12
	2016-20	0.19
Bhagalpur	1960	0.09
	1987-88	0.12
	2001-06	0.1
	2016-20	0.65
	2001-06	0.12
	2016-20	0.37

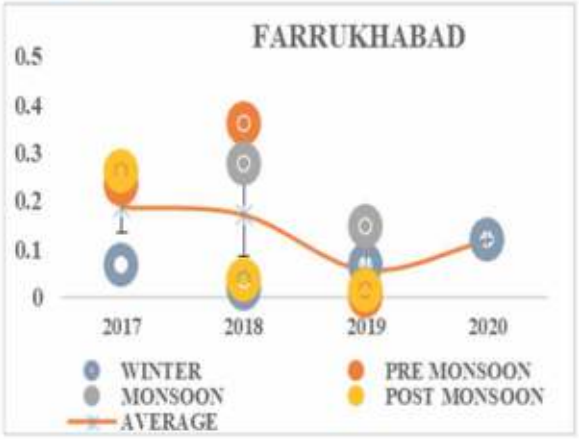
BRIEF DESCRIPTION

The mean total P in the entire stretch was 0.39 ± 0.06 ppm. The value of total P ranged from 0.07± 0.02 ppm at Fraserganj to 1.16 ± 1.00 ppm at Balagarh. Among the different stretches the highest mean total P was observed 0.46 ± 0.11 in the middle stretch of the river. The lowest mean total P was observed 0.09 ± 0.02 ppm in the estuarine stretch of the river. The mean total P in the upper and lower stretch of the river is 0.39 ± 0.10 ppm and 0.42 ± 0.11 ppm respectively. Among the different seasons the highest mean, total P was observed 0.73 ± 0.29 ppm during the monsoon season, while the lowest total P was observed 0.11 ± 0.01 ppm during the winter. The observed mean total P during pre-monsoon and post monsoon were 0.29 ± 0.09 ppm and 0.52 ± 0.10 ppm respectively.

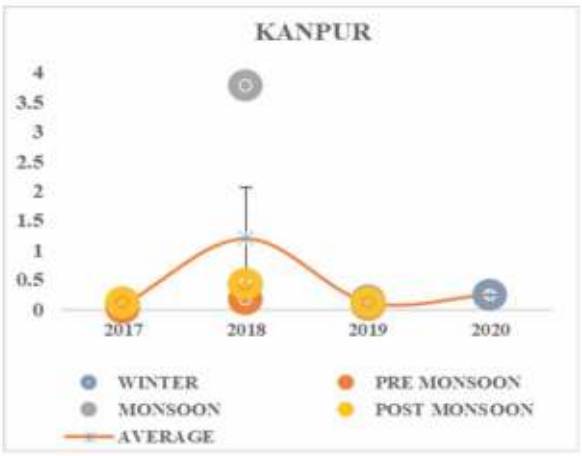
TIMESCALE CHANGES OF TOTAL PHOSPHORUS (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

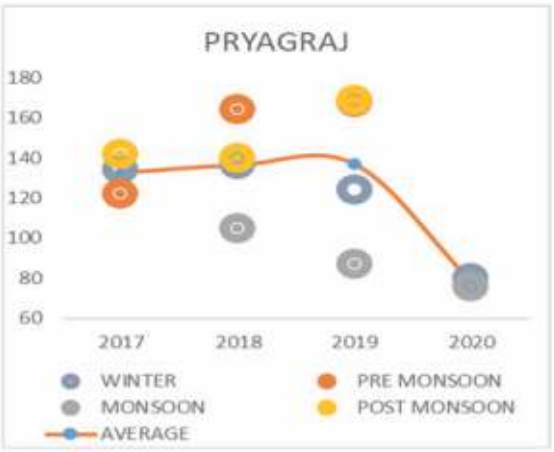


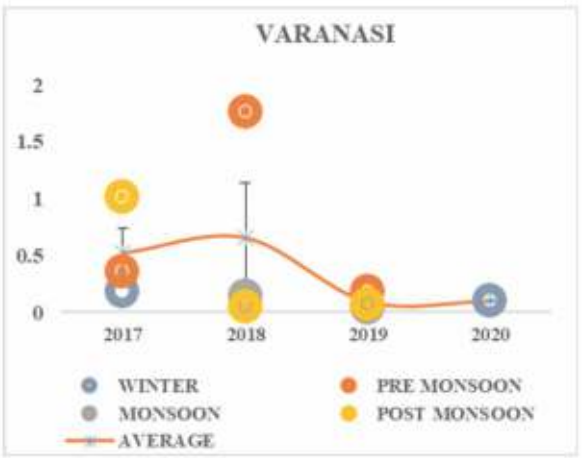


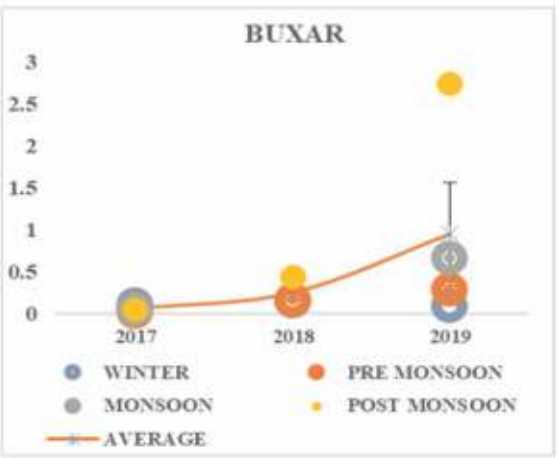


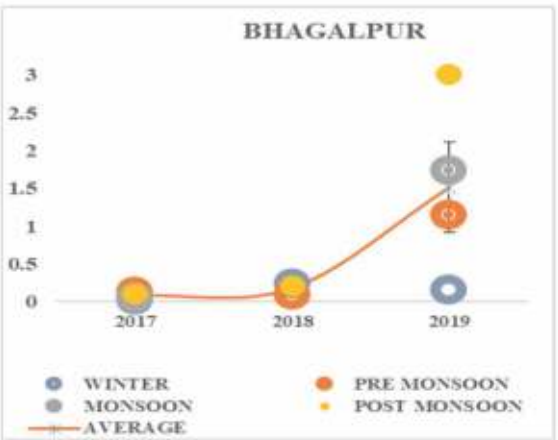
TIMESCALE CHANGES OF TOTAL PHOSPHORUS (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



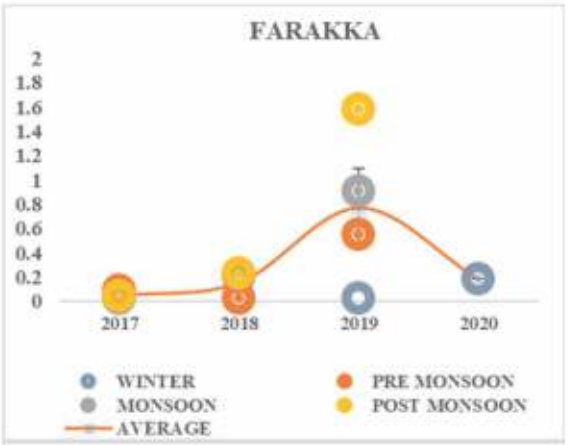


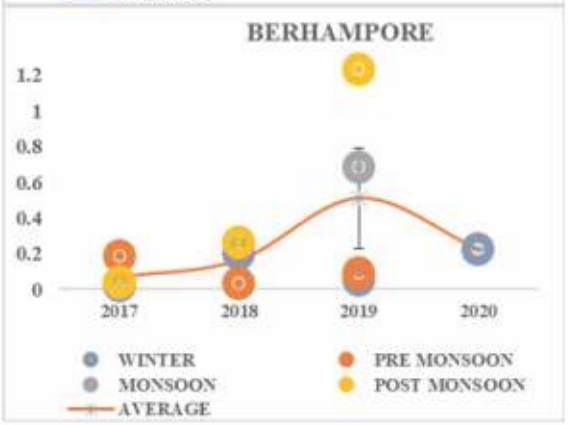


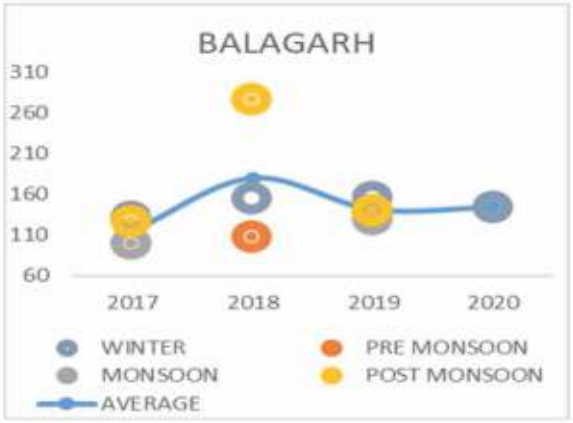


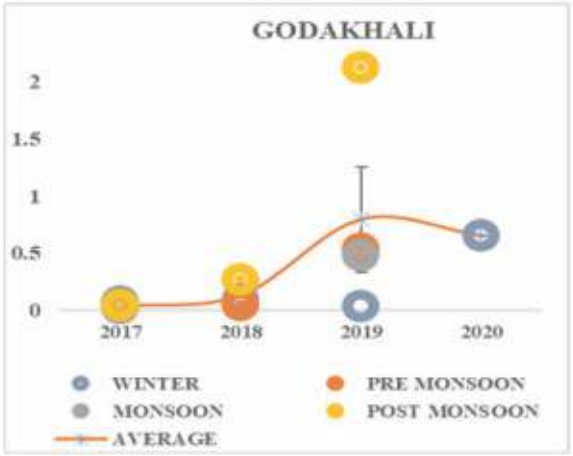


TIME-SCALE CHANGES OF TOTAL PHOSPHORUS (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

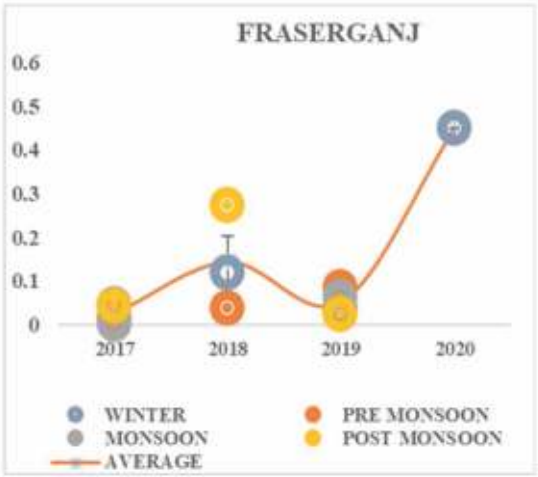








TIMESCALE CHANGES OF TOTAL PHOSPHORUS (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

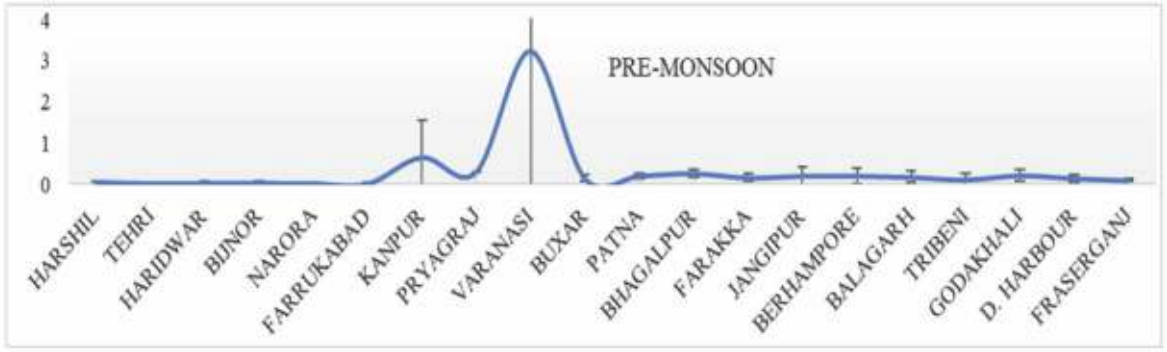


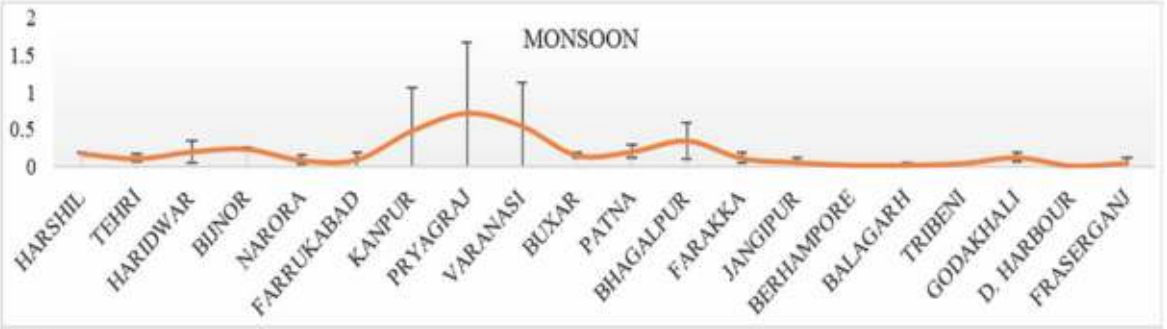
SALIENT TIMESCALE OBSERVATIONS

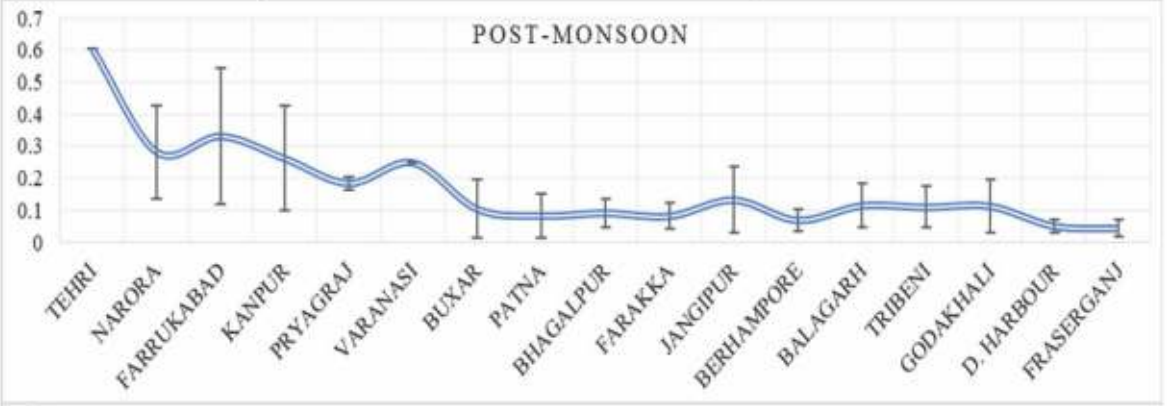
- Among the sampling stations of the upper stretch a decrease in total P has been recorded at all the sampling sites from 2017 to 2020.
- Among the sampling stations of the middle stretch an increase in total P has been observed at all the stations except at Prayagraj and Varanasi from 2017 to 2020
- At majority of the sampling sites the increase in the total P has been recorded in 2020 as compared to 2017.

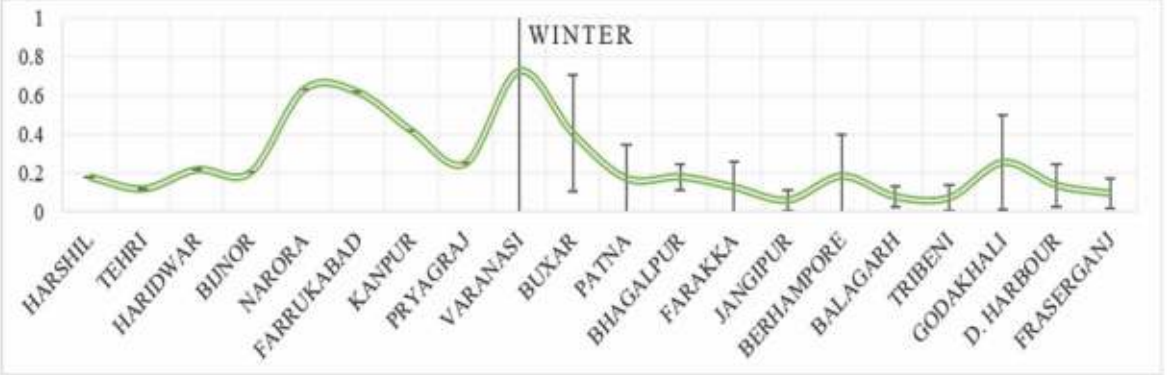
Nitrate nitrogen (ppm)

Nitrate N is the important nutrient which help in increment of river productivity. The over decomposition of nitrate via sewage and other eutrophication activities may increase the pollution status in the river system. The nitrate N is present in the water is dissolved in the form of mineralized nitrogen.


PRE-MONSOON
4
3
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
2
1.5
1
0.5
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
TEHRI
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
1
0.8
0.6
0.4
0.2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
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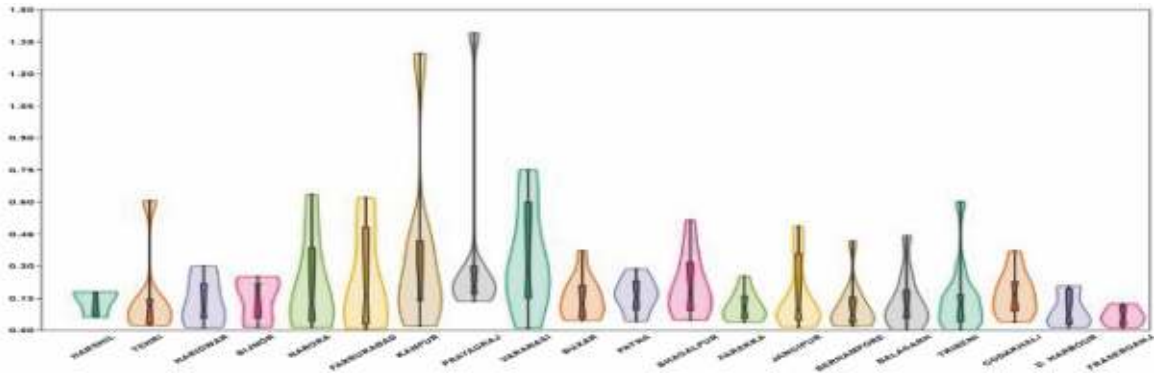
VIOLIN BOX PLOT ILLUSTRATING VARIATIONS IN NITRATE-NITROGEN (ppm) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



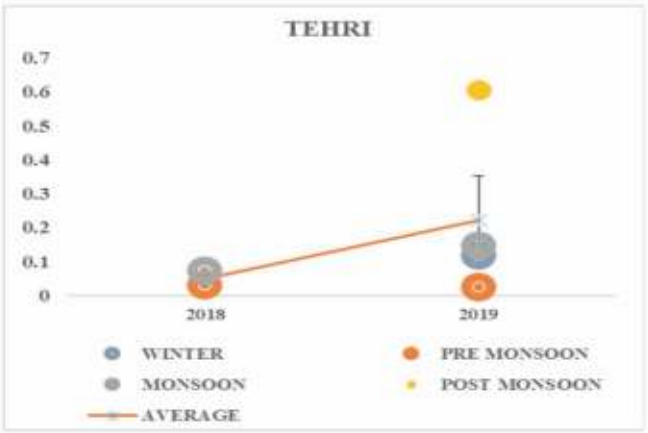
CHANGING PATTERN OF TOTAL NITROGEN OVER THE YEARS

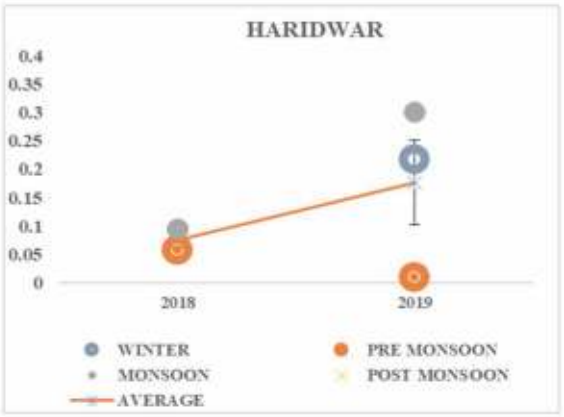
Stretches	Period	Available Nitrogen (PPM)
Haridwar	1995-96	0.01-0.24
	2016-20	0.13
	1960	0.14
	1987-88	0.28
	2001-06	0.18
	2016-20	0.36
Pryagraj	1960	0.17
	1987-88	0.19
	2001-06	0.18
	2016-20	0.20
Varanasi	1960	0.1
	1987-88	0.22
	2001-06	0.11
	2016-20	1.32
Patna	1960	0.14
	1987-88	0.22
	2001-06	0.16
	2016-20	0.14
Bhagalpur	1960	0.14
	1987-88	0.18
	2001-06	0.16
	2016-20	0.21
	2001-06	0.14
	2016-20	0.13
	2016-20	0.093

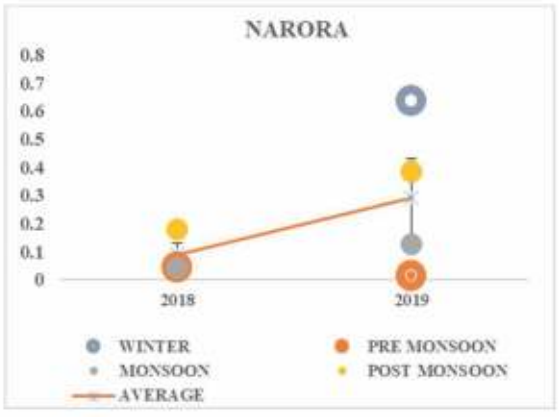
BRIEF DESCRIPTION

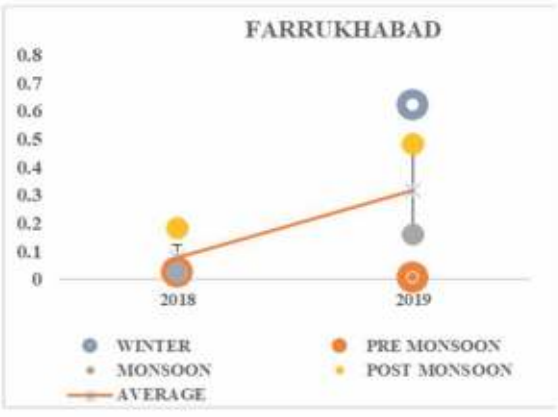
The mean nitrate nitrogen in the entire stretch was 0.21 ± 0.04 ppm. The average nitrate nitrogen varied from 0.07± 0.01 ppm at Fraserganj to 1.32 ± 0.87 ppm at Varanasi. Among the different stretches the highest mean nitrate nitrogen was recorded 0.36 ± 0.12 ppm in the middle stretch of the river. The lowest nitrate nitrogen was recorded 0.08 ± 0.01 ppm in the estuarine stretch of the river. The mean available nitrogen in the upper and lower stretches of the river are 0.17 ± 0.03 ppm and 0.14 ± 0.01 ppm respectively. Among the different seasons the highest mean nitrate nitrogen was recorded 0.30 ± 0.13 ppm during the pre-monsoon season, while the lowest nitrate nitrogen was recorded 0.14 ± 0.02 ppm in monsoon and 0.14 ± 0.02 ppm in post monsoon. During the winter season the observed nitrate nitrogen was 0.25 ± 0.04 ppm.

TIMESCALE CHANGES OF NITRATE-NITROGEN (ppm) IN THE UPPER STRETCH OF RIVER GANGA (2016-20)

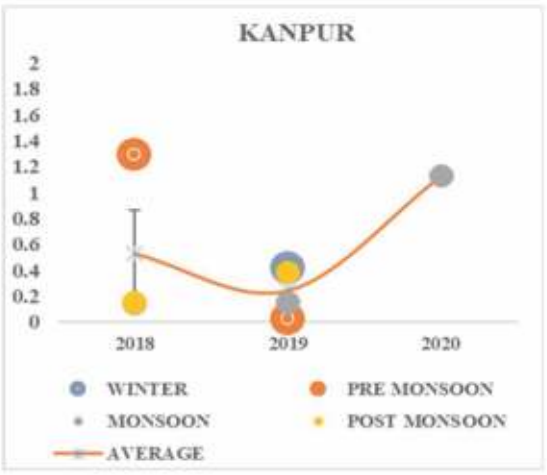


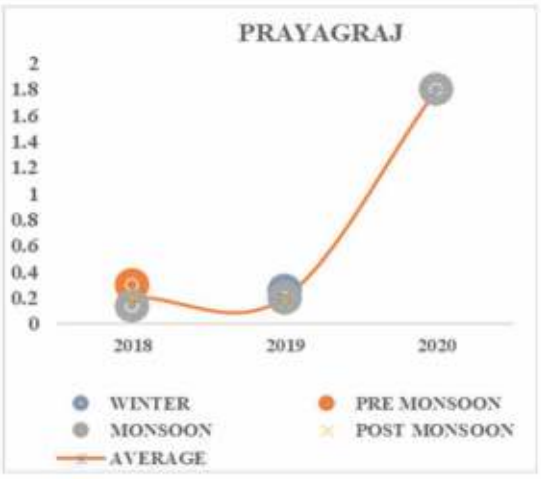


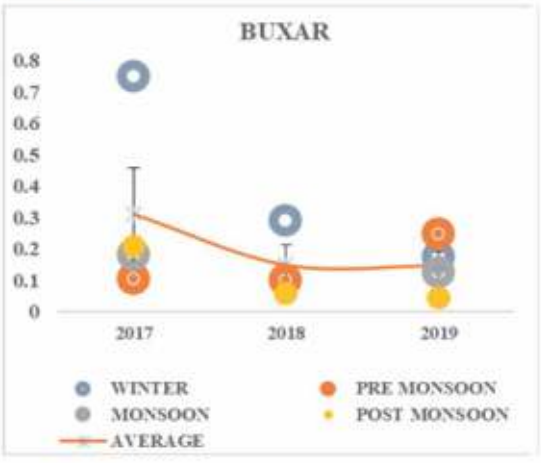


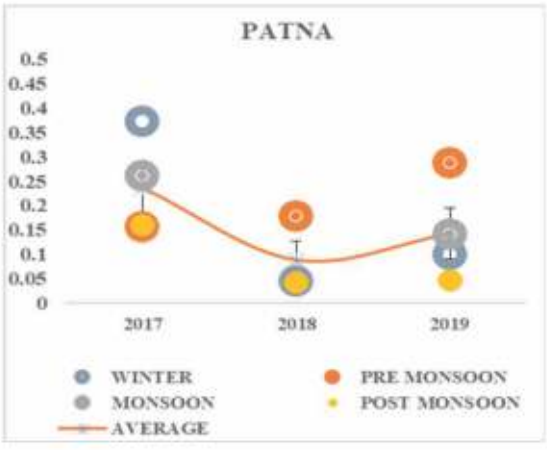


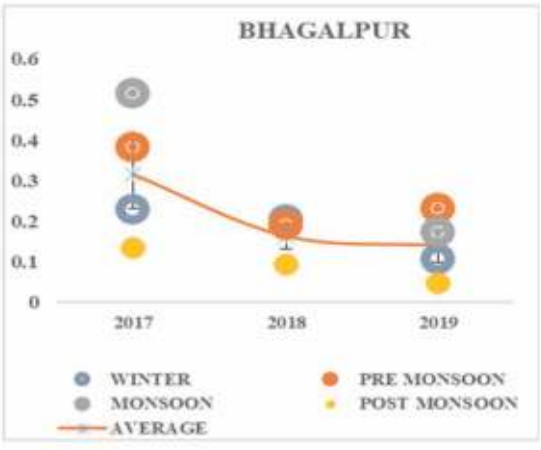
TIMESCALE CHANGES OF NITRATE-NITROGEN (ppm) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



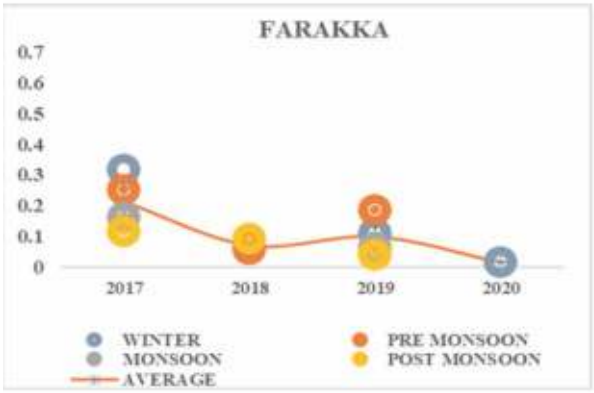


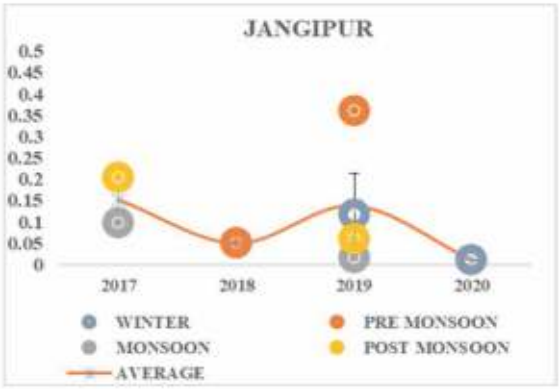


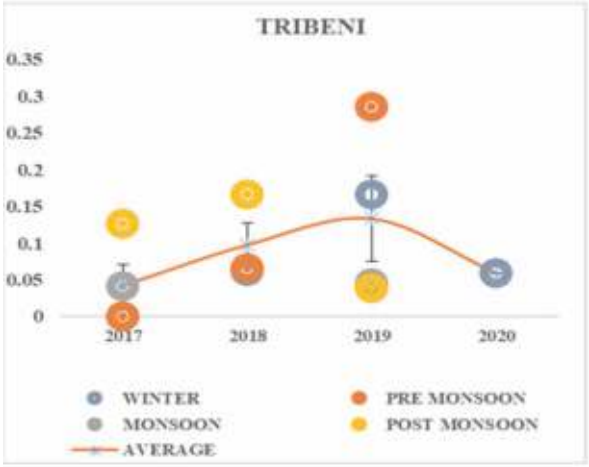


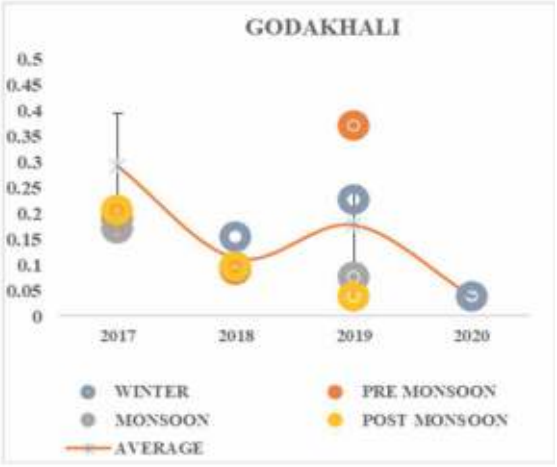


TIME-SCALE CHANGES OF NITRATE-NITROGEN (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

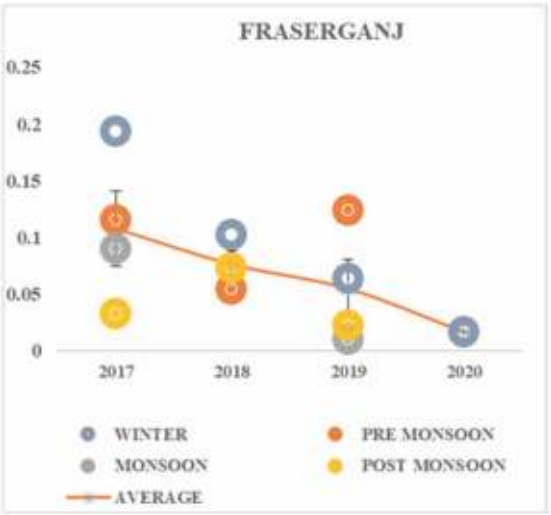








TIMESCALE CHANGES OF NITRATE-NITROGEN (ppm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

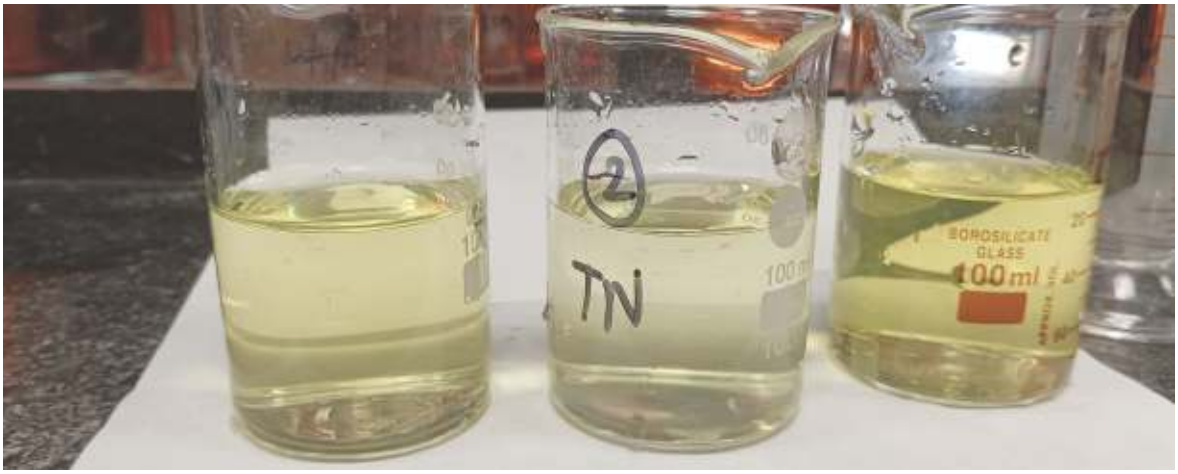


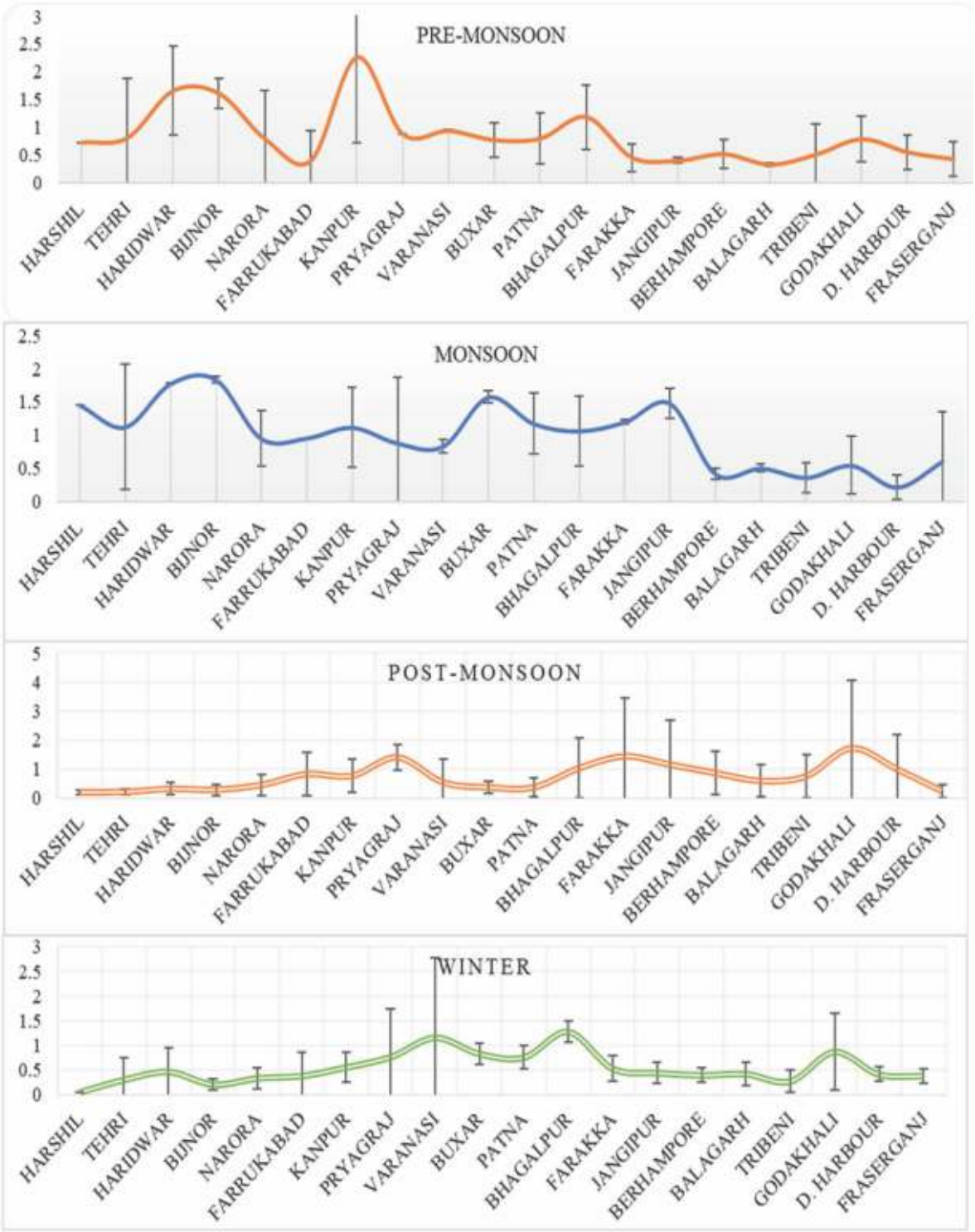
SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch the increase in nitrate nitrogen has been recorded at all the sampling sites from 2017 to 2020.
- In the middle stretch a decrease in nitrate nitrogen has been observed at Varanasi. Buxar, Bhagalpur, and Patna while the increase in the nitrate nitrogen is recorded at Kanpur, and Prayagraj from 2017 to 2020.
- Among the sampling stations of a lower stretch there is a decrease in nitrate-nitrogen has been recorded at all the stations except at Tribeni from 2017 to 2020.
- In the estuarine stretch at all the sampling sites a decrease in the nitrate-nitrogen has been recorded from 2017 to 2020.

Total nitrogen (ppm)

Total N is the important nutrient which includes nitrate, nitrite and ammonia which help in maintenance of river productivity. The over decomposition of Total N via sewage, agricultural runoff and other eutrophication activities may increase the pollution status in the river system. The Total N is organic and reduced nitrogen.




PRE-MONSOON
MONSOON
POST-MONSOON
WINTER
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
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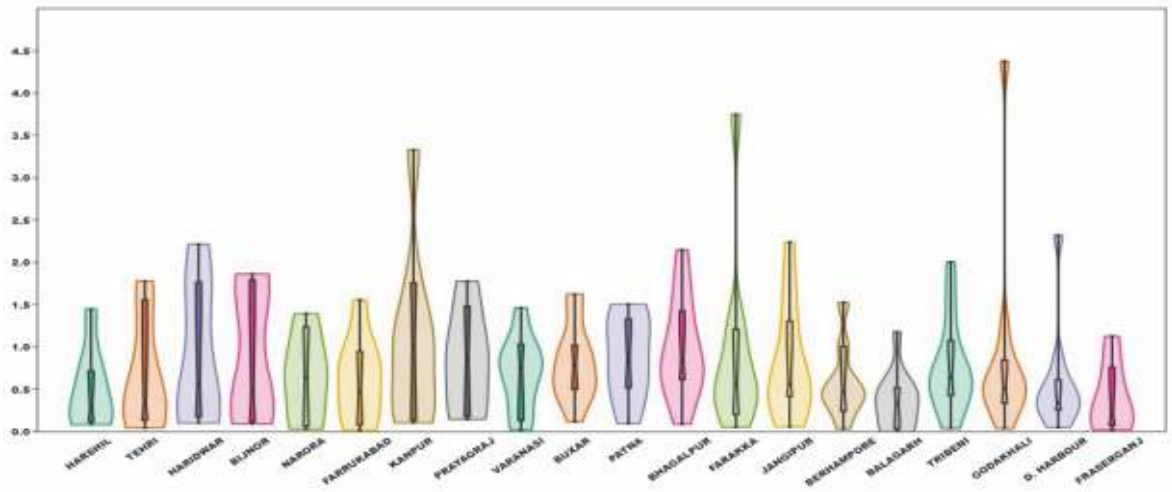
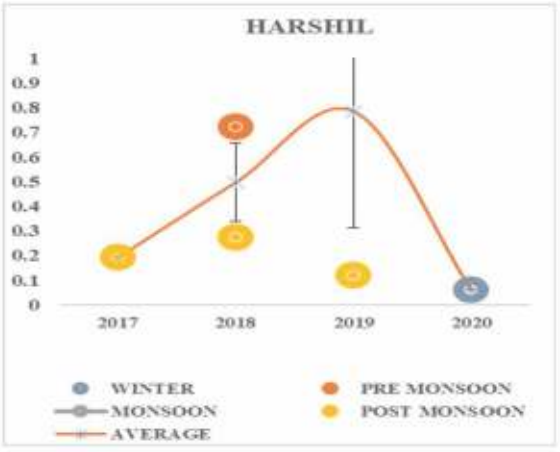
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN TOTAL NITROGEN IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

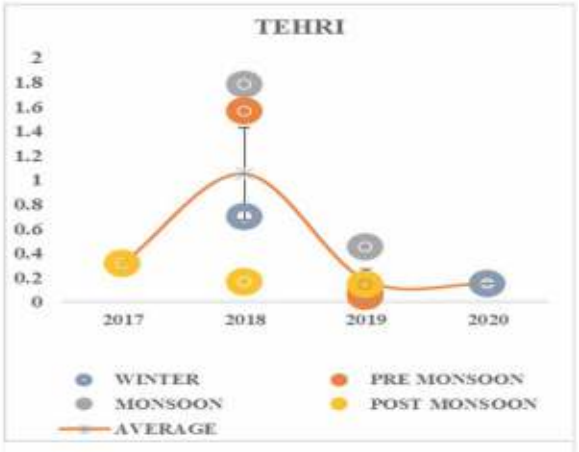


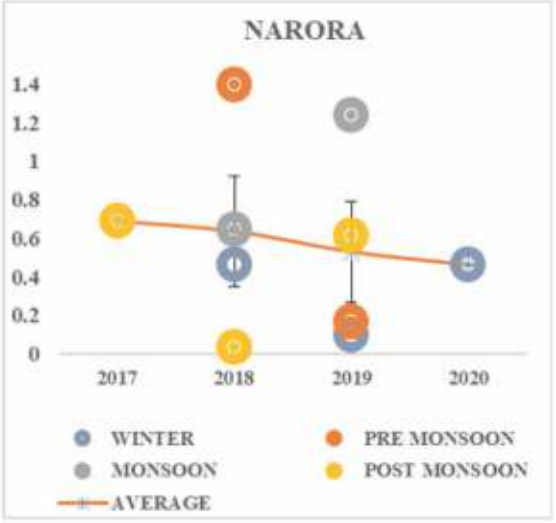
BRIEF DESCRIPTION

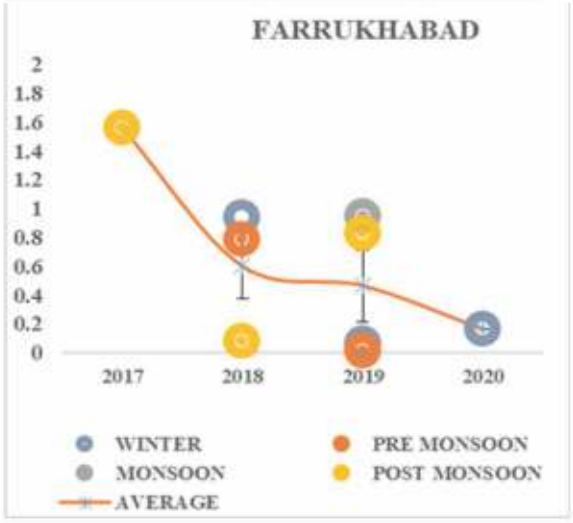
The mean total nitrogen in the entire stretch was 0.75 ± 0.05 ppm. The value of total nitrogen in the entire stretch ranged from 0.41 ±0.10 ppm at Fraserganj to 1.10 ± 0.32 ppm at Kanpur. Among the different stretches the highest mean total nitrogen was recorded 0.87 ± 0.09 ppm in the middle stretch of the river. The lowest mean total nitrogen was recorded 0.50 ± 0.10 ppm in the estuarine stretch of the river. The mean total nitrogen in the upper and lower stretches was 0.73 ± 0.09 ppm and 0.73 ± 0.10 ppm respectively. Among the different seasons, the highest mean total nitrogen was recorded 0.96 ± 0.09 ppm during the monsoon season. The lowest total nitrogen was recorded 0.57 ± 0.06 ppm during winter. The total nitrogen in pre-monsoon and post -monsoon was 0.80 ± 0.09 ppm and 0.71 ± 0.11 ppm respectively.

TIMESCALE CHANGES OF TOTAL NITROGEN (ppm) IN UPPER STRETCH OF RIVER GANGA (2016-20)

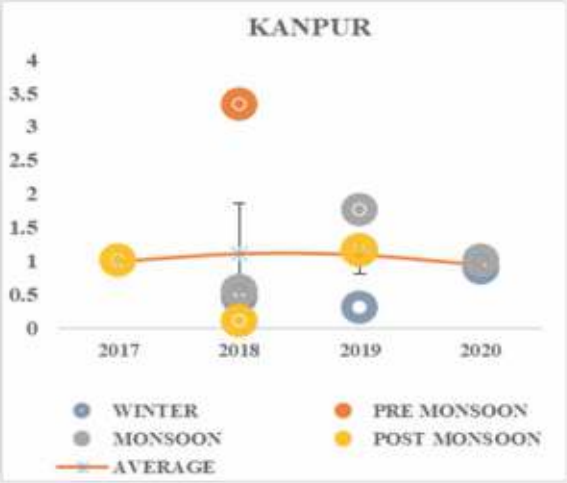


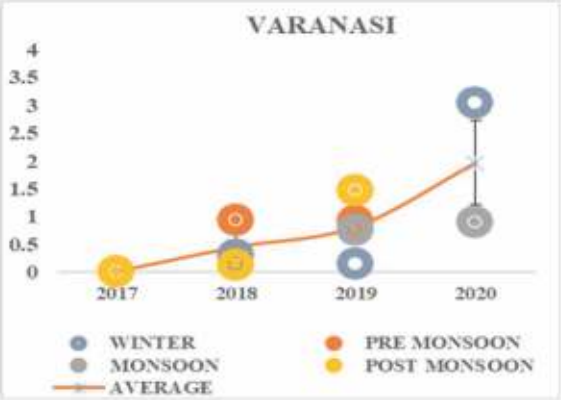


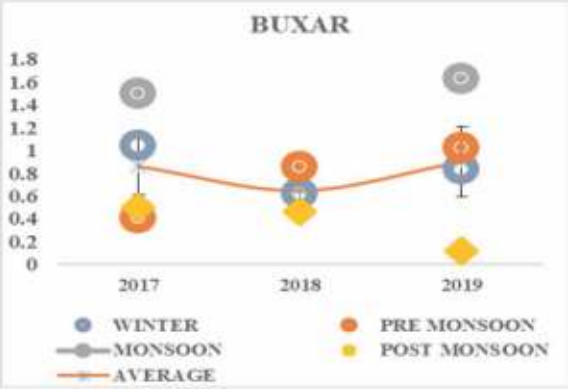


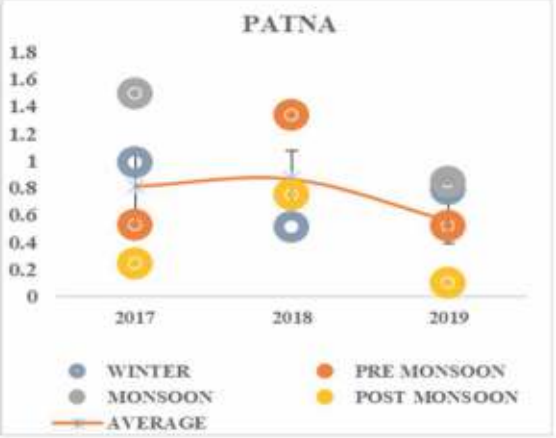


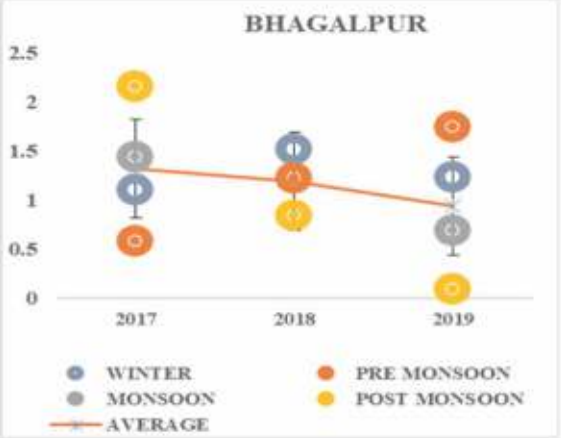
TIMESCALE CHANGES OF TOTAL NITROGEN (ppm) IN MIDDLE STRETCH OF RIVER GANGA (2016-20)



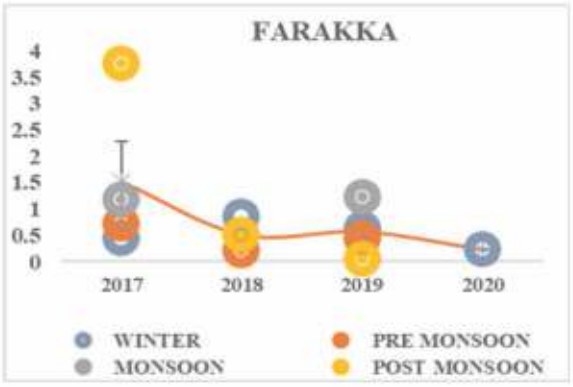


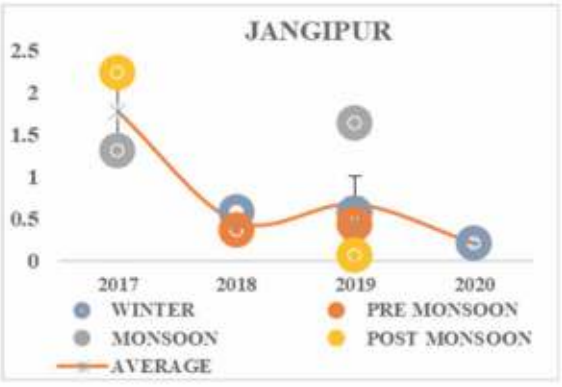


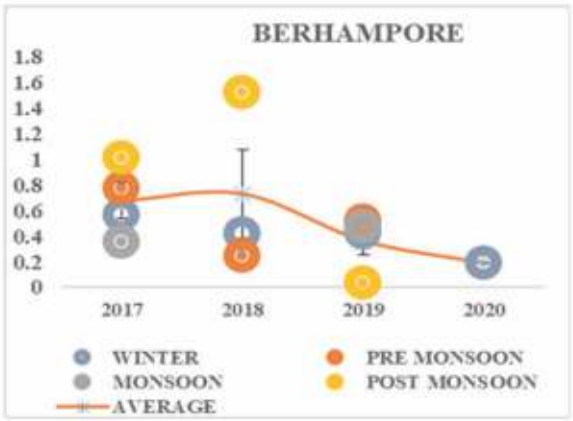


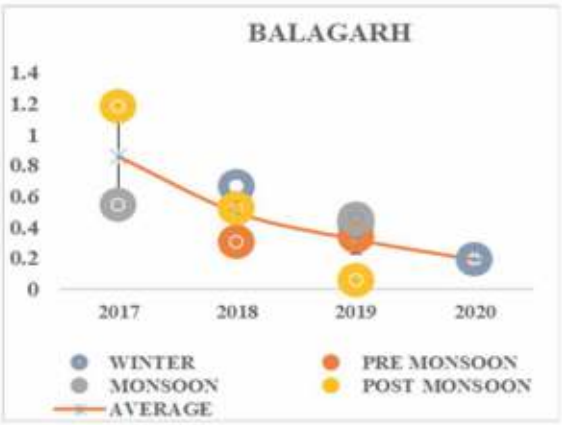


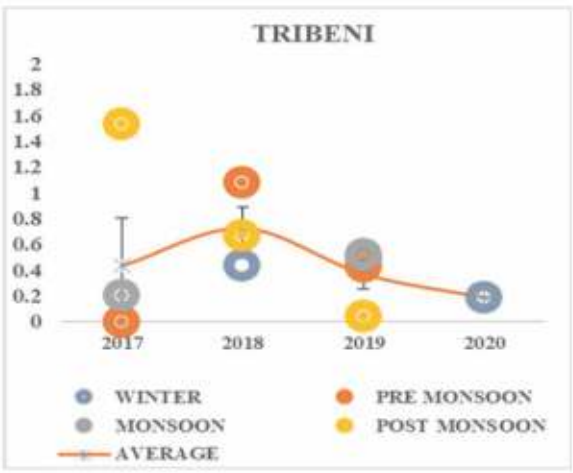
TIME-SCALE CHANGES OF TOTAL NITROGEN (ppm) IN THE LOWER STRETCH OF RIVER GANGA (2016-20)

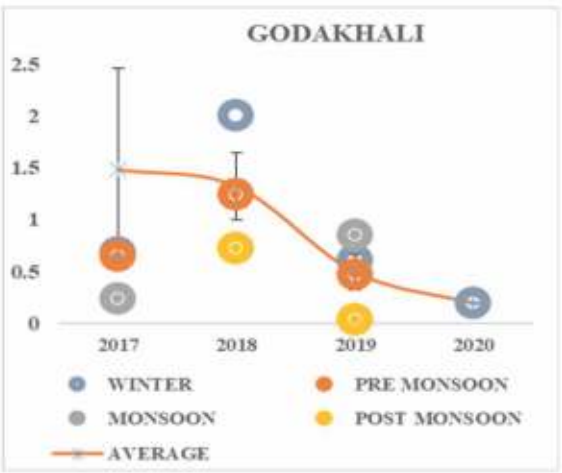




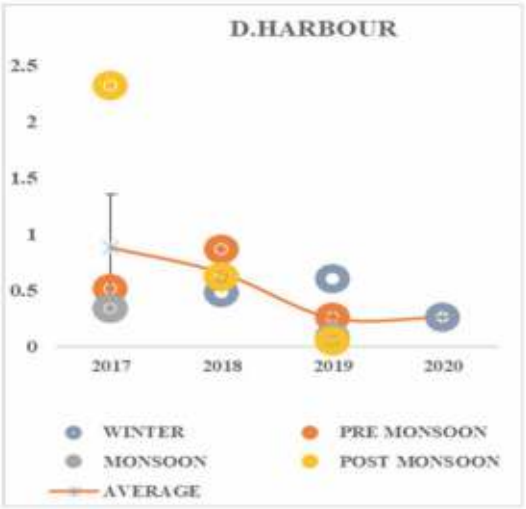


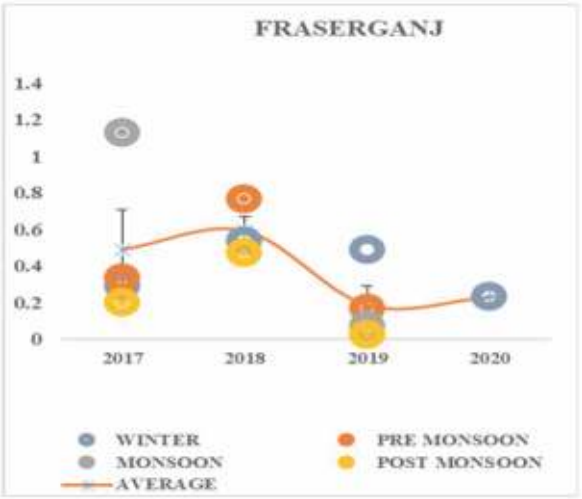






TIMESCALE CHANGES OF TOTAL NITROGEN (ppm) IN ESTUARINE STRETCH OF RIVER GANGA (2016-20)



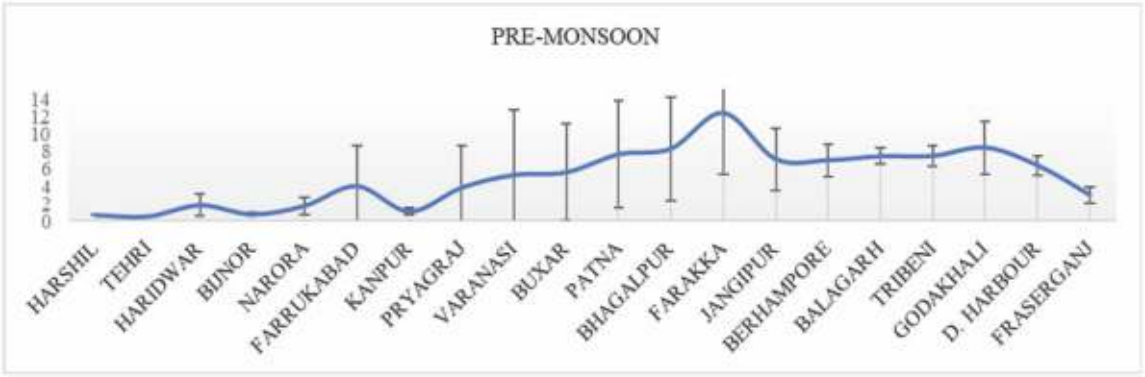


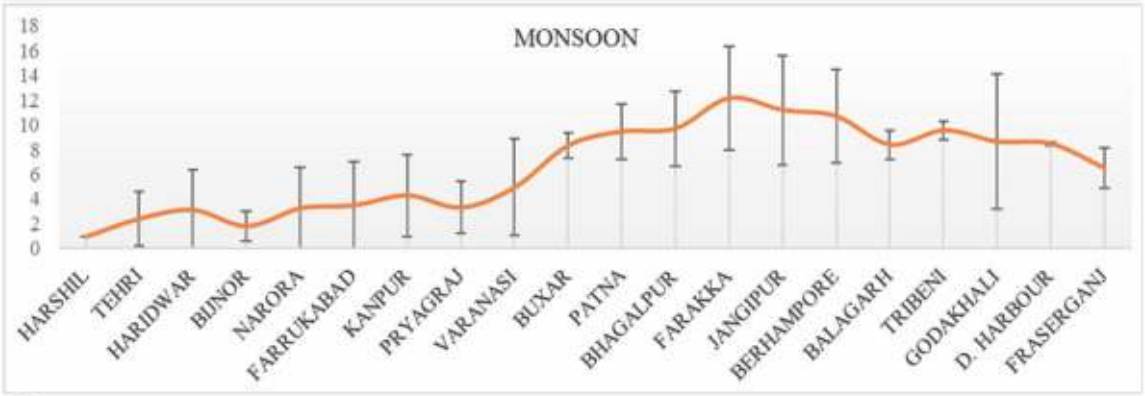
SALIENT TIMESCALE OBSERVATIONS

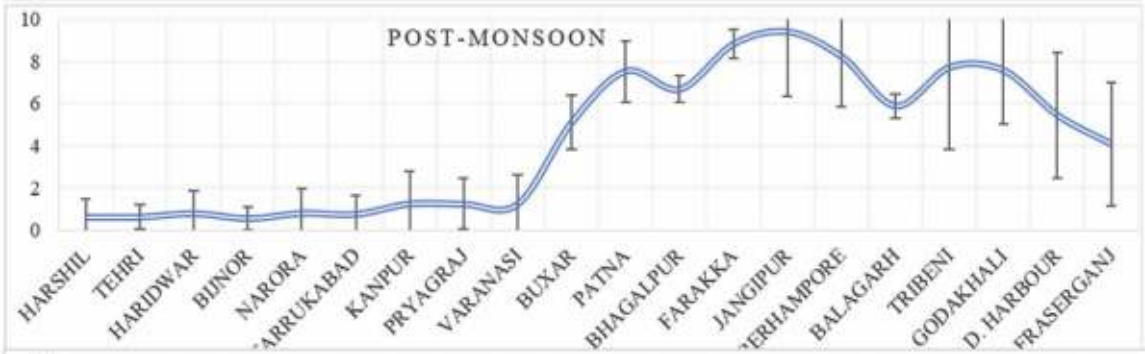
- In the upper stretch the decrease in total nitrogen has been recorded at all the sampling sites except at Bijnor from 2017 to 2020.
- In the middle stretch a decrease in total nitrogen has been observed at Kanpur, Patna, and Bhagalpur while an increase has been recorded at Prayagraj, Varanasi, and Buxar from 2017 to 2020.
- Among the sampling stations of the lower stretch a decrease in total nitrogen has been recorded at all the stations from 2017 to 2020.
- In the estuarine stretch a decrease in total nitrogen was observed at all the sampling sites from 2017 to 2020.

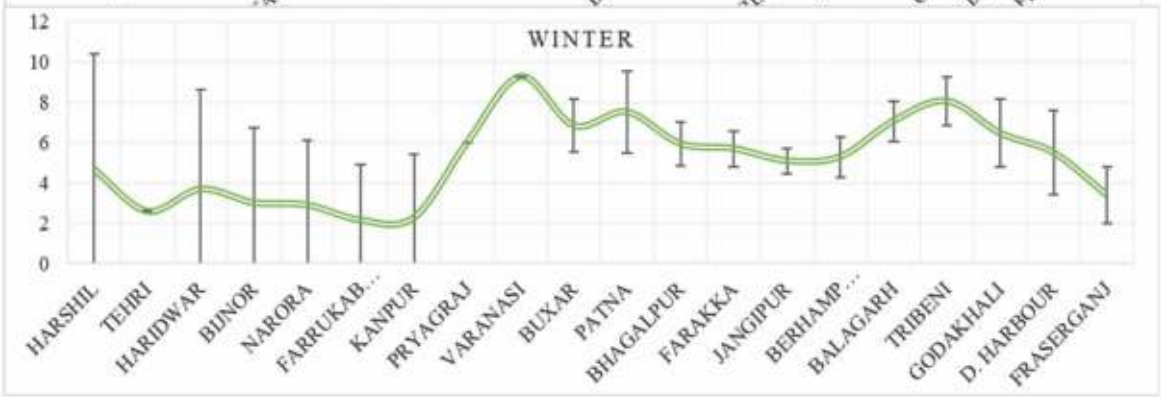
Silicate (ppm)

Silicate is the essential element present in the river water mainly due to weathering of minerals and rocks. The natural factor which influences the element is salt content in the water. The alteration in the silicate content in the river may alter the of aquatic organisms, chiefly phytoplankton.

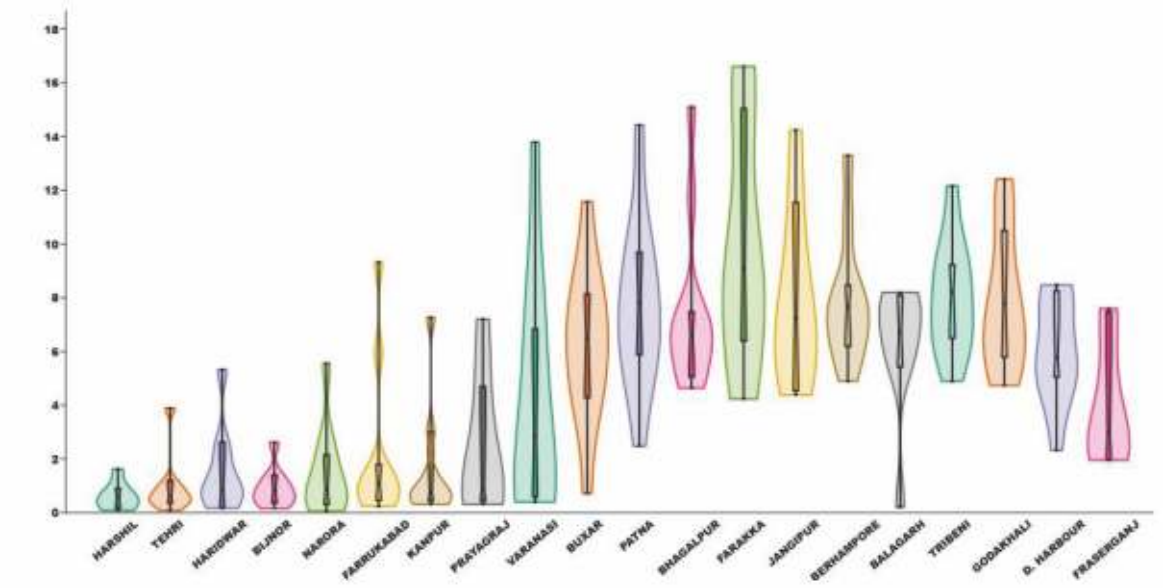

PRE-MONSOON
14
12
10
8
6
4
2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
18
16
14
12
10
8
6
4
2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
10
8
6
4
2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
12
10
8
6
4
2
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

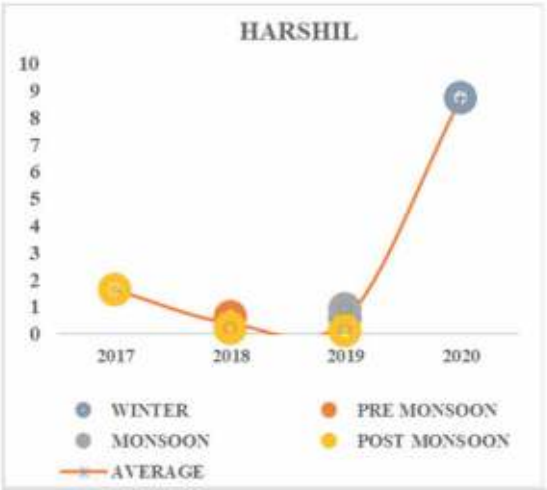
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN SILICATE (ppm) IN THE VARIOUS STRETCHES OF RIVER GANGA (2016-20)

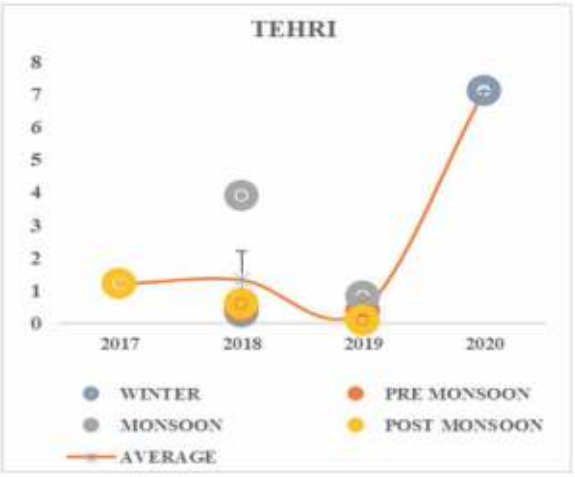


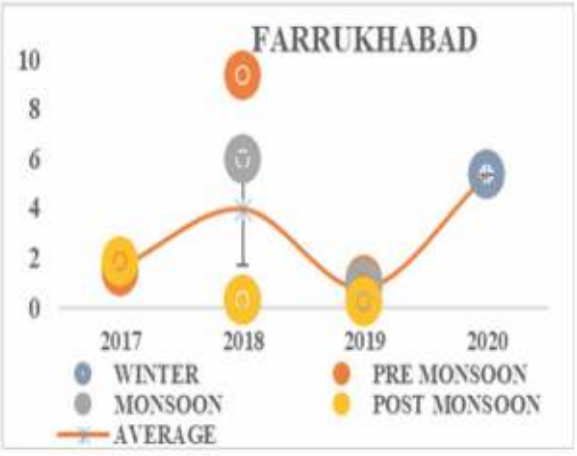
BRIEF DESCRIPTION

The mean silicon in the entire stretch was 4.99 ± 0.28 ppm. The mean silicate in the entire stretch varies from 0.66 ± 0.22 ppm at Harshil to 8.17 ± 0.65 ppm at the Tribeni sampling site. Among the different stretches the highest mean silicate was observed 7.96 at the lower stretch of the river, while the lowest mean silicate was observed 1.36 ± 0.23 ppm at the upper stretch of the river. The silicate in the middle and estuarine stretches of the river was 5.16 ± 0.51 ppm and 5.25 ± 0.50 ppm. Among the different seasons, the highest mean silicate was observed 6.32 ± 0.67 ppm during monsoon. The lowest mean silicate was noticed 4.13 ± 0.46 ppm during the post-monsoon. The mean silicate during winter and pre-monsoon were 4.62 ± 0.45 and 5.25 ± 0.64 ppm respectively.

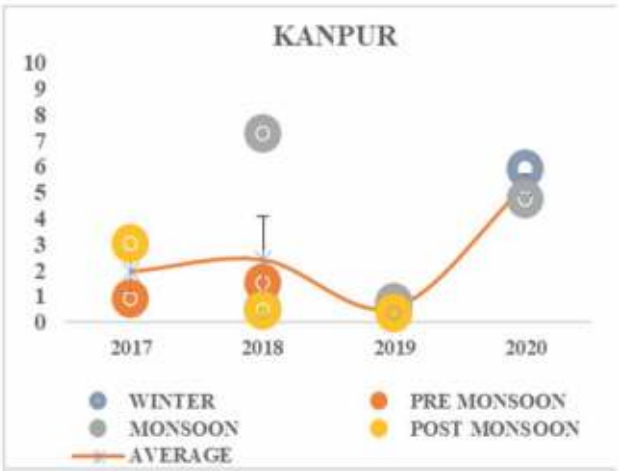
TIMESCALE CHANGES OF SILICATE (ppm) IN UPPER STRETCH OF RIVER GANGA (2016-20)

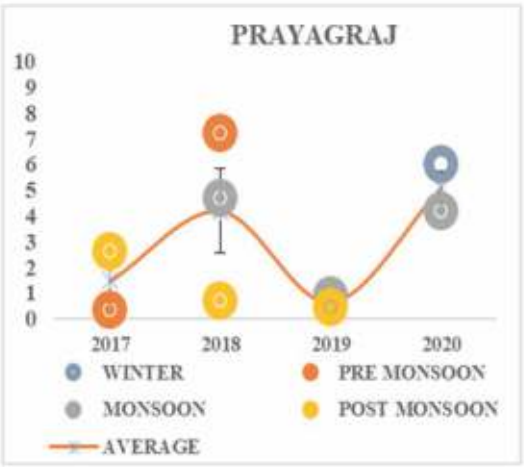


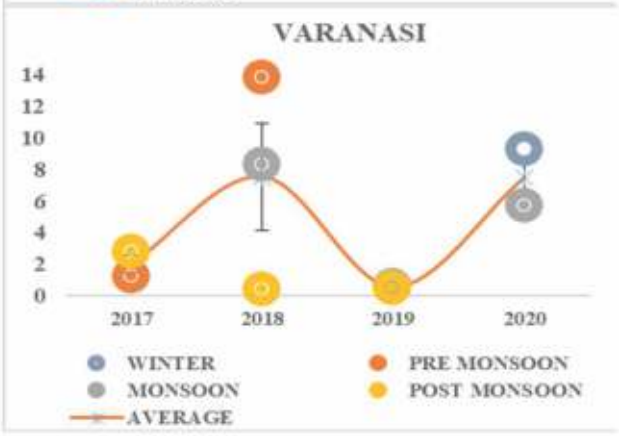


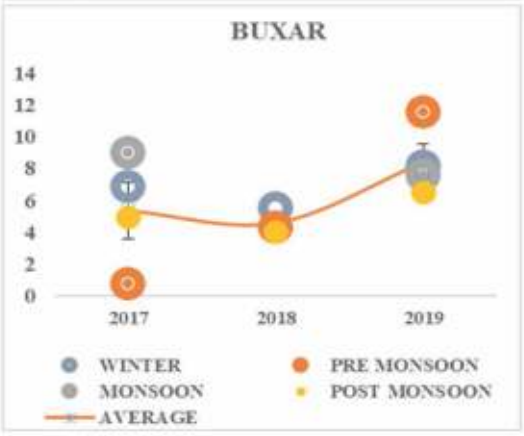


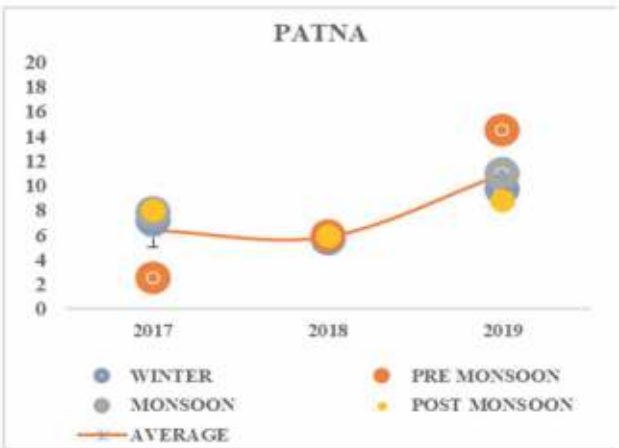
TIMESCALE CHANGES OF SILICATE (ppm) IN MIDDLE STRETCH OF RIVER GANGA (2016-20)

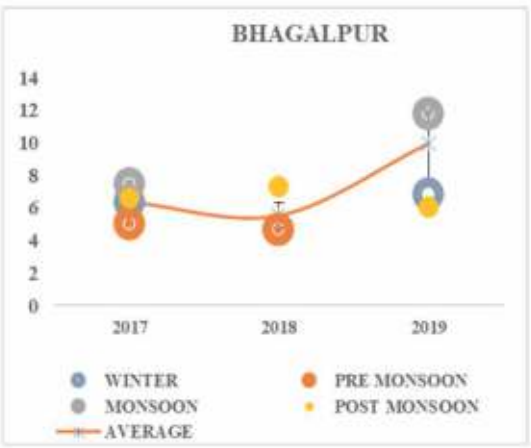




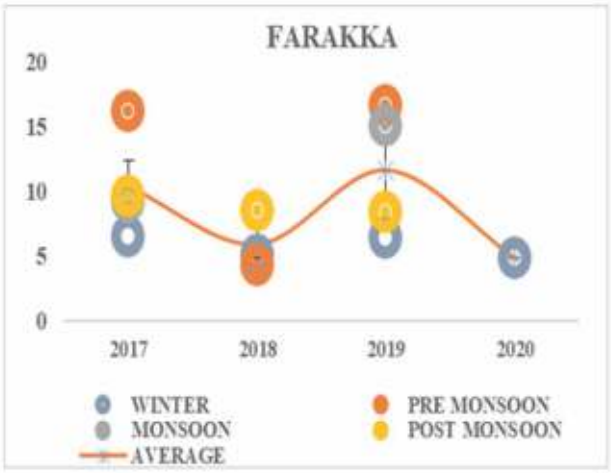


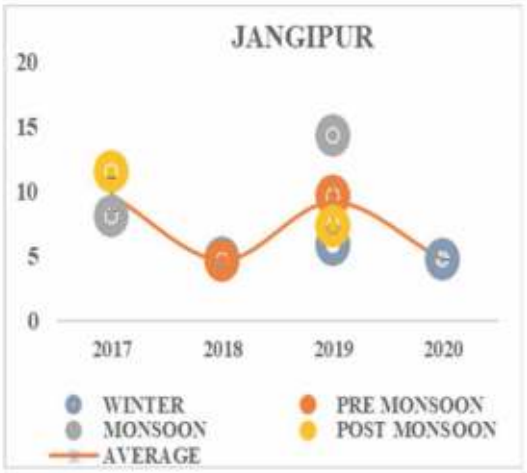


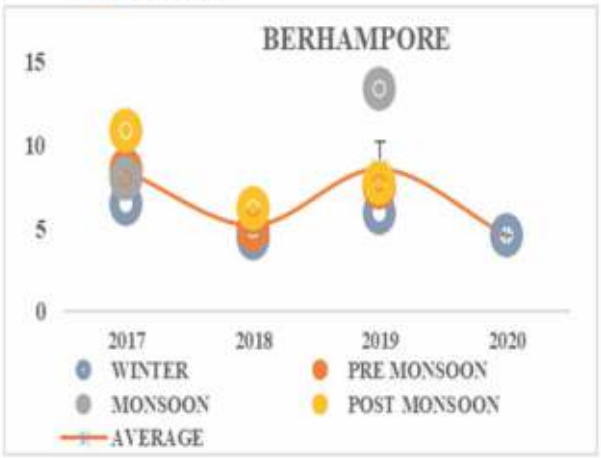


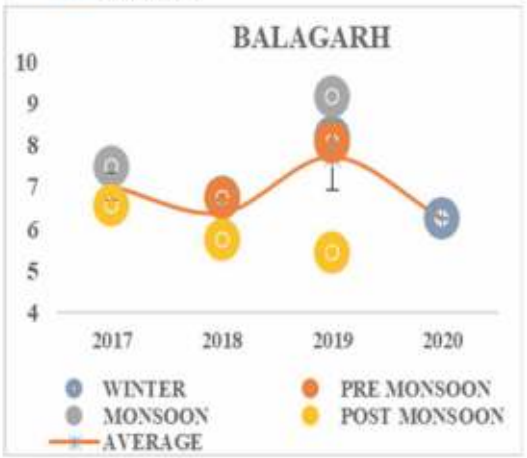


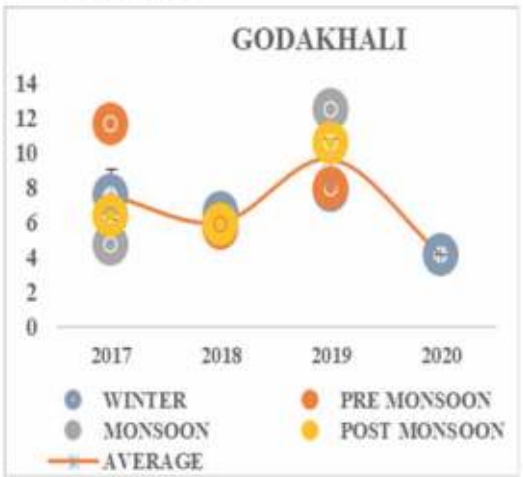
TIME-SCALE CHANGES OF SILICATE (ppm) IN LOWER STRETCH OF RIVER GANGA (2016-20)



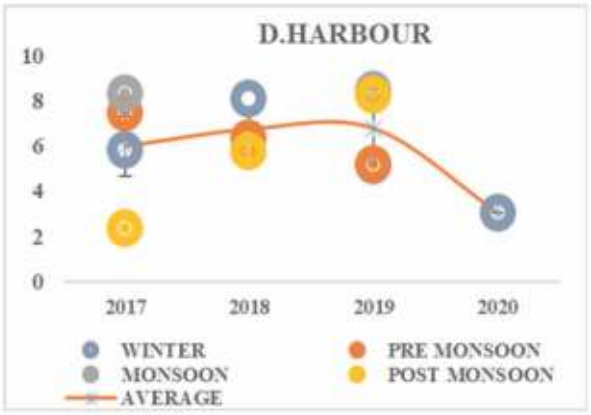


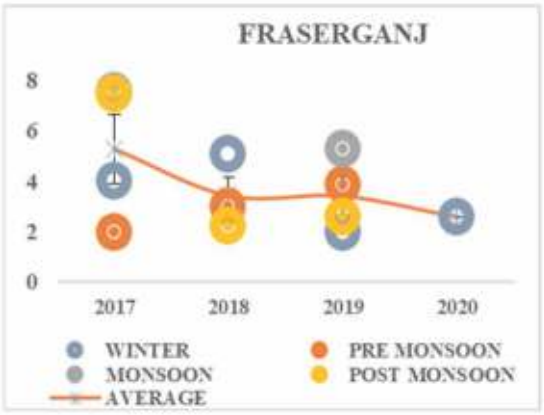






TIMESCALE CHANGES OF SILICATE (ppm) IN ESTUARINE STRETCH OF RIVER GANGA (2016-20)





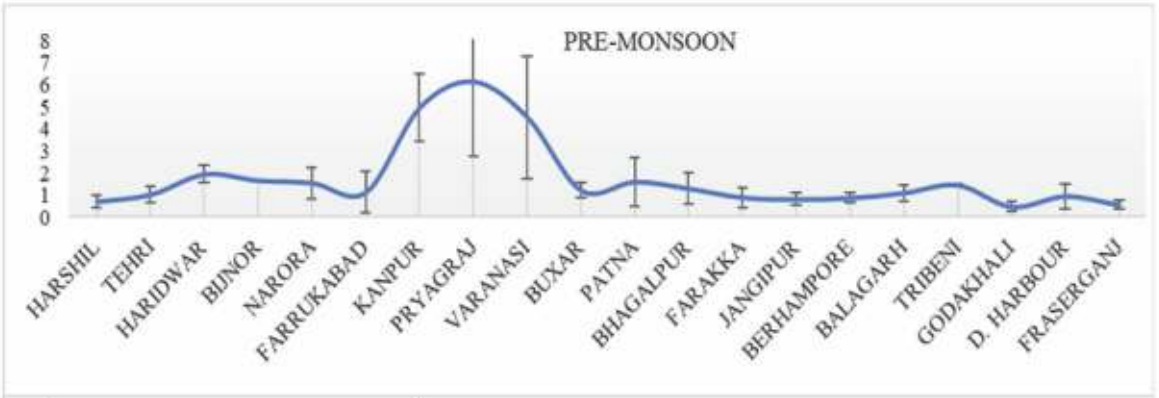
SALIENT TIMESCALE OBSERVATIONS

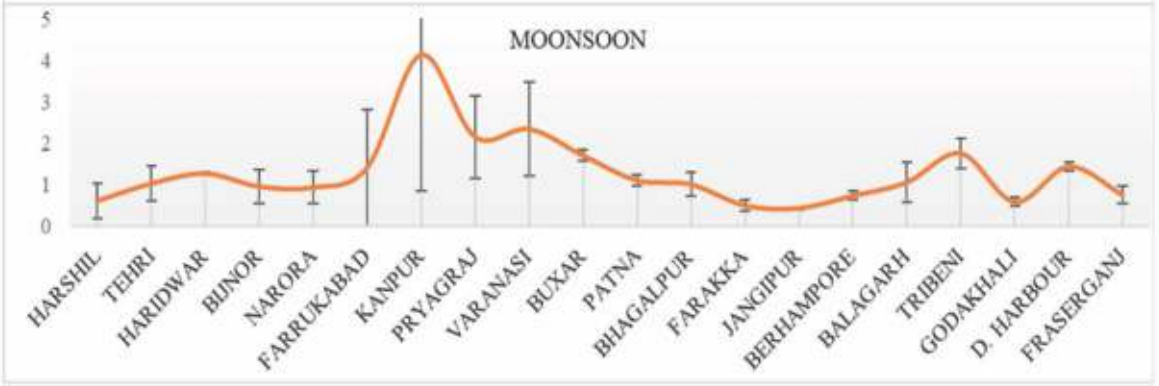
- In the upper stretch, an increase in silicate was recorded at all the sampling sites from 2017 to 2020.
- Similar to the upper stretch of the river in the middle stretch also an increase in silicate was observed at all the stations from 2017 to 2020.
- Among the sampling stations of lower stretch, decrease in silicate was recorded at all the sites from 2017 to 2020.
- In the estuarine stretch, a decrease in silicate was noticed at all the stations from 2017 to 2020.

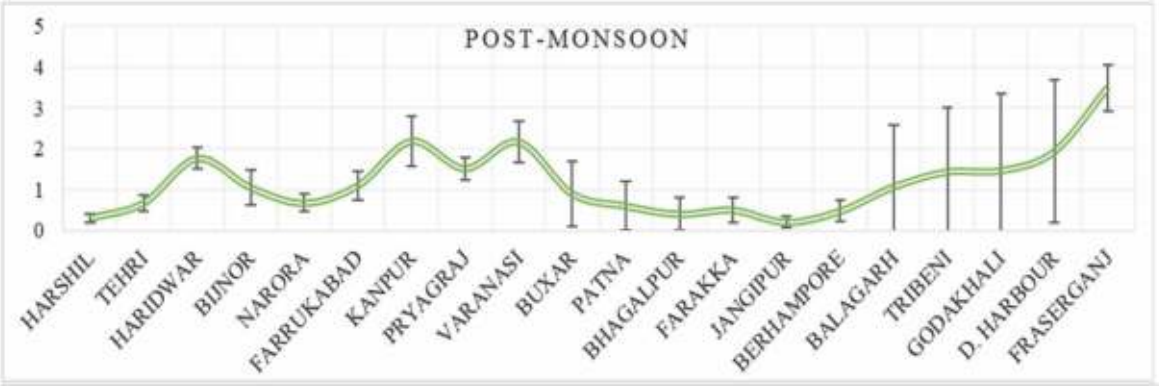
POLLUTION PARAMETERS

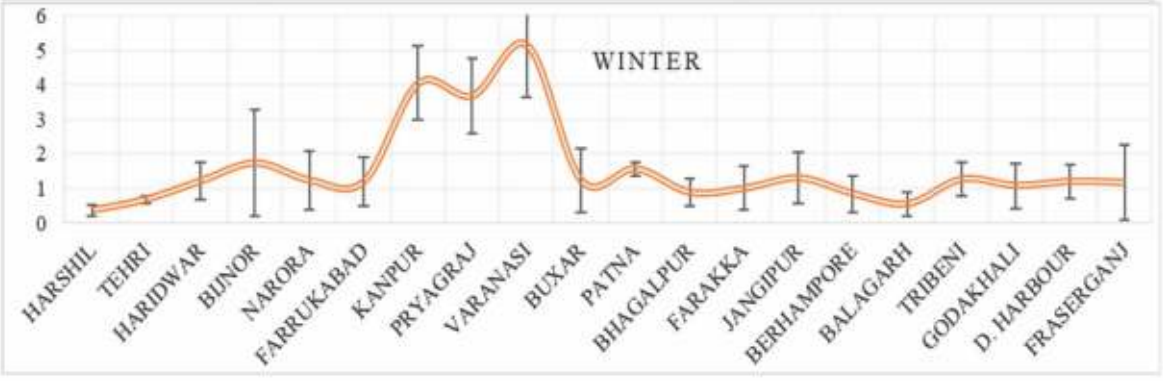
Biochemical oxygen demand (ppm)

Biochemical oxygen demand (BOD) is the oxygen needed by all the organic matter, which is degraded by natural processes. It is the important pollution indicating parameter. The rise in BOD can amplify the pollution load in the river, and can negatively affect the aquatic flora and fauna. There are many studies available which demonstrates that the rise in BOD level has affected the aquatic population including fish.

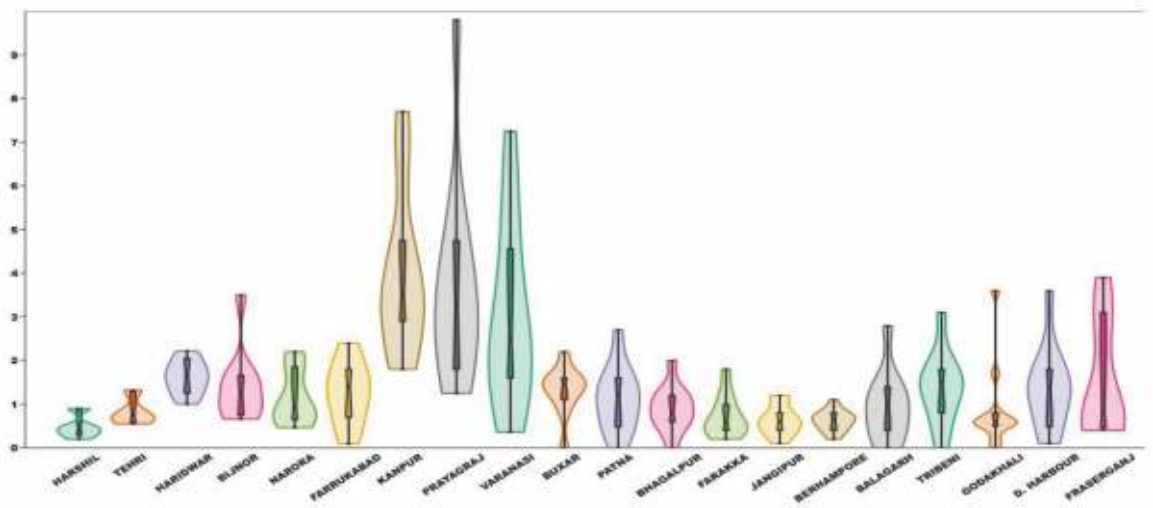

PRE-MONSOON
8
7
6
5
4
3
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MOONSOON
5
4
3
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
5
4
3
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

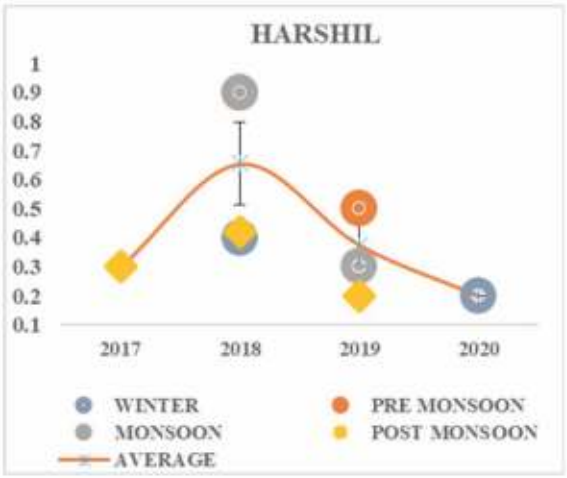

WINTER
6
5
4
3
2
1
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

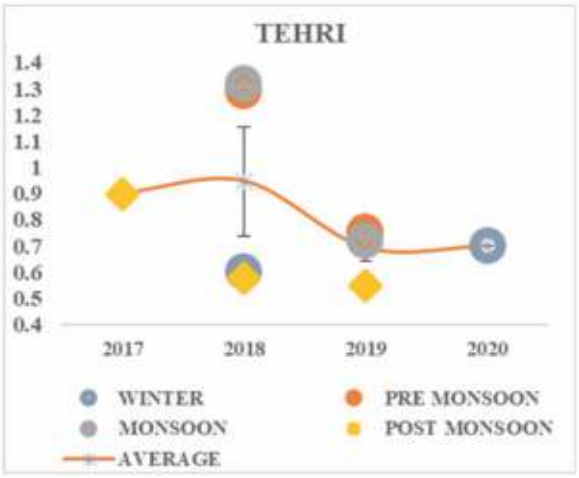
VIOLIN BOX PLOT ILLUSTRATING VARIATION IN BOD IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



BRIEF DESCRIPTION

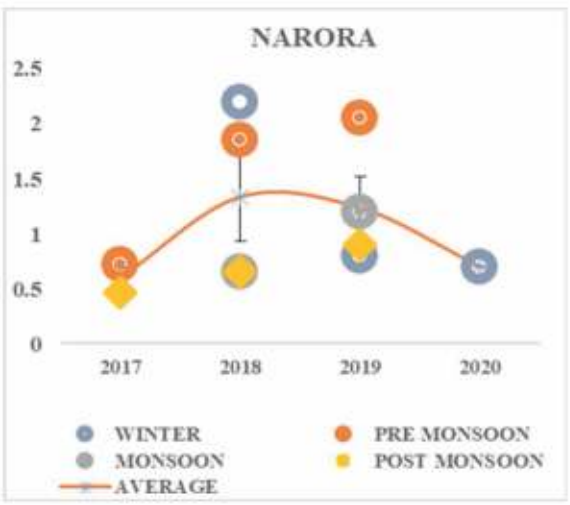
The mean BOD in the entire stretch was 1.44 ± 0.10 ppm. The average BOD varied from 0.49 ± 0.08 ppm to 3.97 ± 0.60 ppm at Kanpur. Among the different stretches of the river, the highest mean BOD was observed 2.29 ± 0.25 ppm at the middle stretch of the river. The lowest mean BOD was observed 0.86 ± 0.09 ppm in the lower stretch of the river. In the upper and estuarine stretches the mean BOD was 1.13 ± 0.08 ppm and 1.43 ± 0.25 ppm respectively. Among the different seasons, the highest mean BOD was observed 1.77 ± 0.25 ppm during the pre-monsoon season. The lowest mean BOD was observed 1.17 ± 0.13 ppm during post-monsoon season. During winter and monsoon, the mean BOD was 1.48 ± 0.18 ppm and 1.36 ± 0.20 ppm respectively.

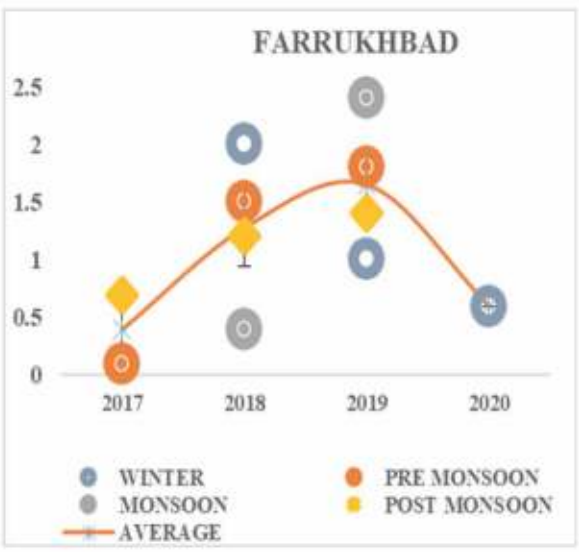

HARSHIL
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE


TEHRI
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

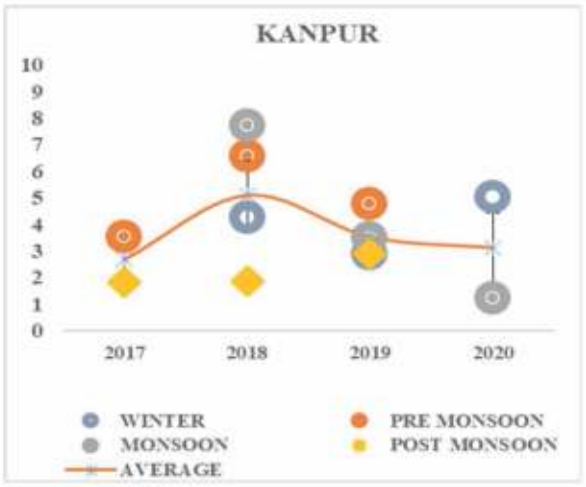

HARIDWAR
2.5
2
1.5
1
0.5
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

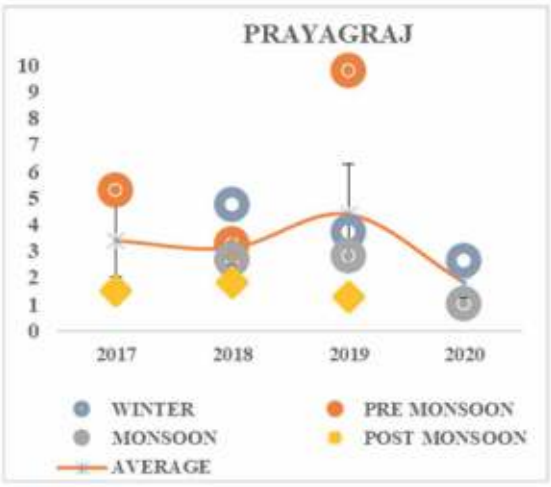

BIJNOR
4
3.5
3
2.5
2
1.5
1
0.5
0
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

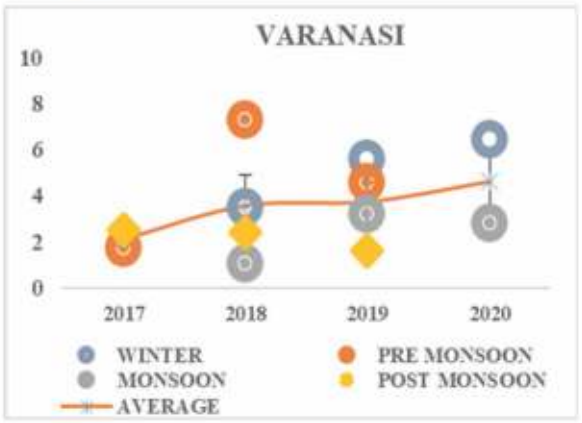

NARORA
2.5
2
1.5
1
0.5
0
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

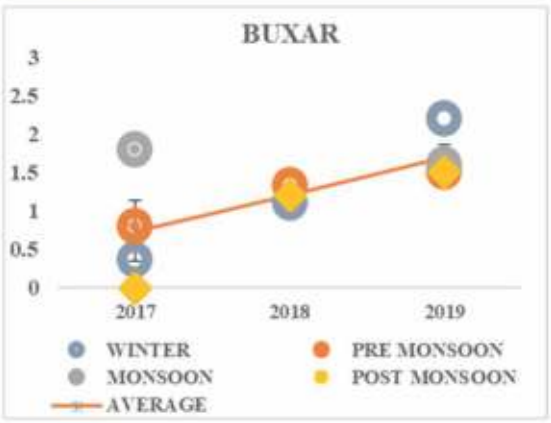

FARRUKHBAD
2.5
2
1.5
1
0.5
0
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

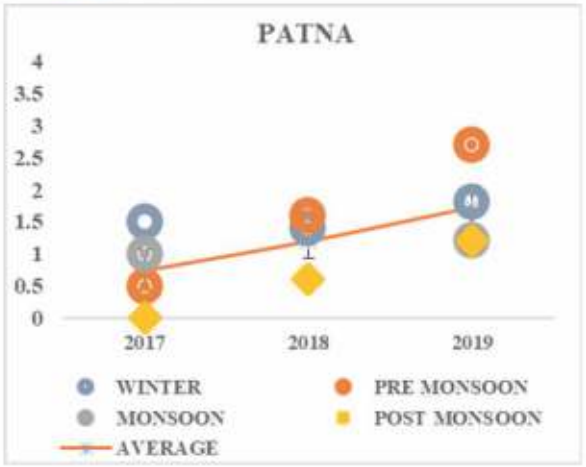
TIMESCALE CHANGES OF BOD (ppm) IN MIDDLE STRETCH OF RIVER GANGA (2016-20)

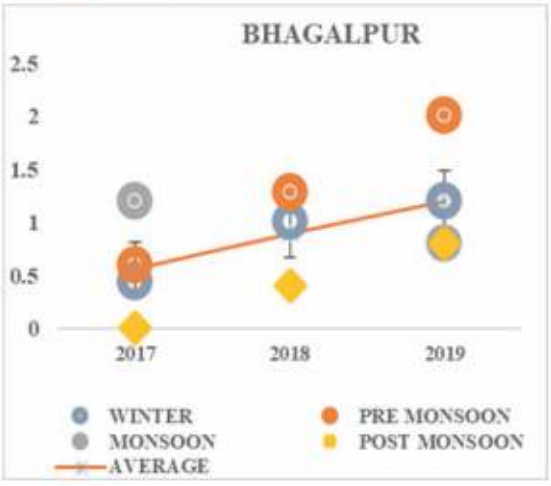




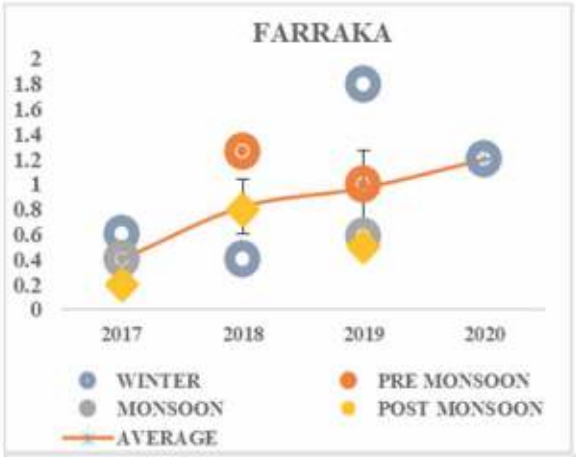


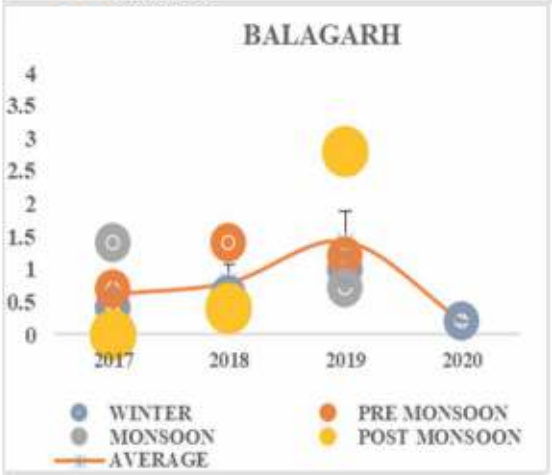


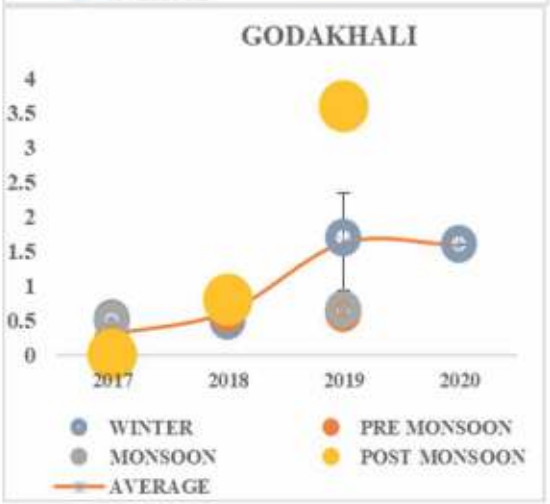




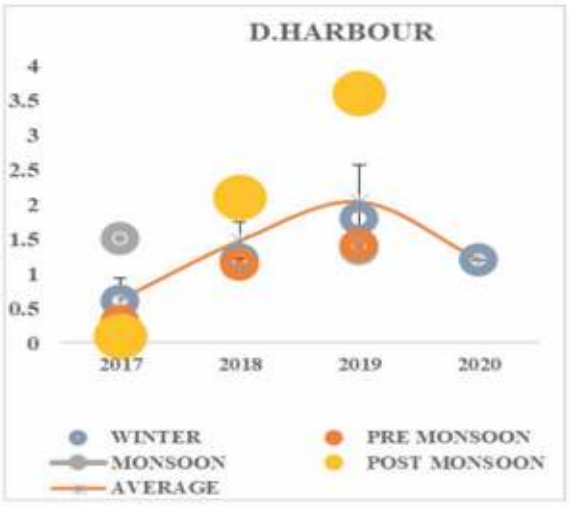
TIME-SCALE CHANGES OF BOD (ppm) IN LOWER STRETCH OF RIVER GANGA (2016-20)

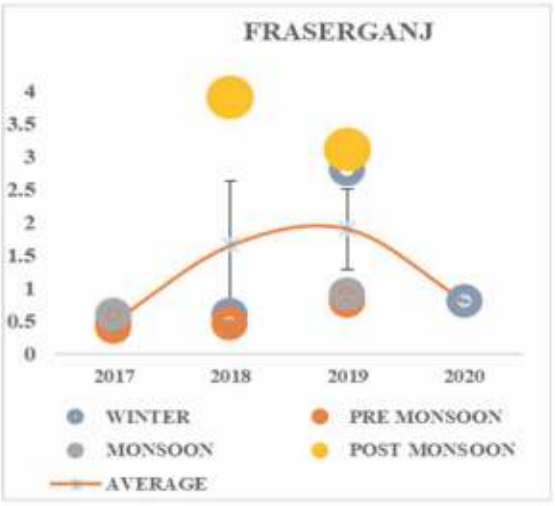






TIMESCALE CHANGES OF BOD (ppm) IN ESTUARINE STRETCH RIVER GANGA (2016-20)





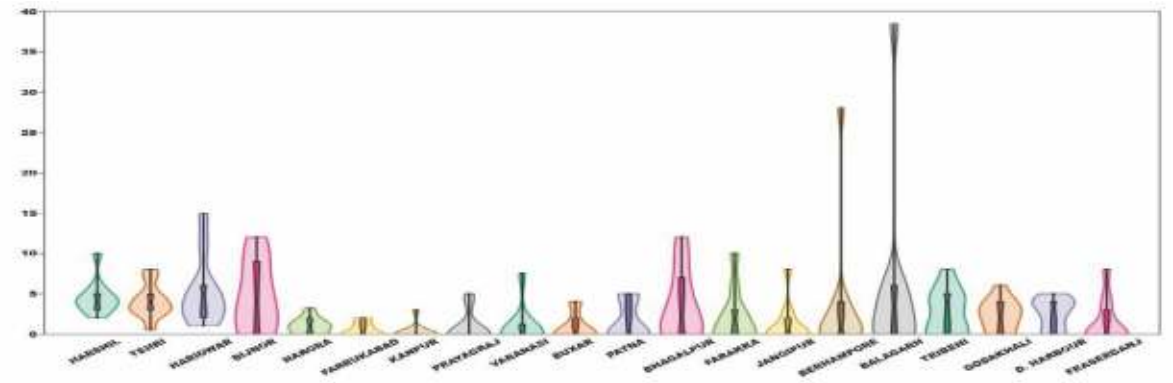
SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch the decrease in BOD has been recorded at all the sampling sites except at Farrukhabad from 2017 to 2020.
- In the middle stretch increase in BOD has been observed at all the sampling sites except at Kanpur and Prayagraj from 2017 to 2020.
- Among the sampling stations of the lower stretch increase in BOD has been recorded at all the stations except at Balagarh from 2017 to 2020.
- In the estuarine stretch, an increase in BOD has been encountered at all the sampling stations.

Free carbon dioxide (ppm)

Free carbon-dioxide is the significant pollution indicating water quality parameter. The Fco_2 in the water supports the process of photosynthetic process for the aquatic plants. The FCO_2 helps in increasing the productivity of the aquatic ecosystem. The rise of FCO_2 beyond the permissible limit in aquatic system may lead to formation of carbonic acid, which may harm the aquatic organisms by lowering the water pH.

VIOLIN BOX PLOT ILLUSTRATING VARIATIONS IN FREE CARBON DIOXIDE (ppm) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



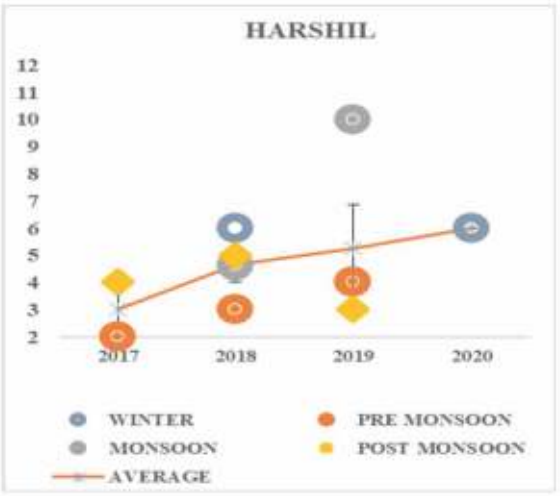
CHANGING PATTERN OF FREE CO_2 OVER THE YEARS

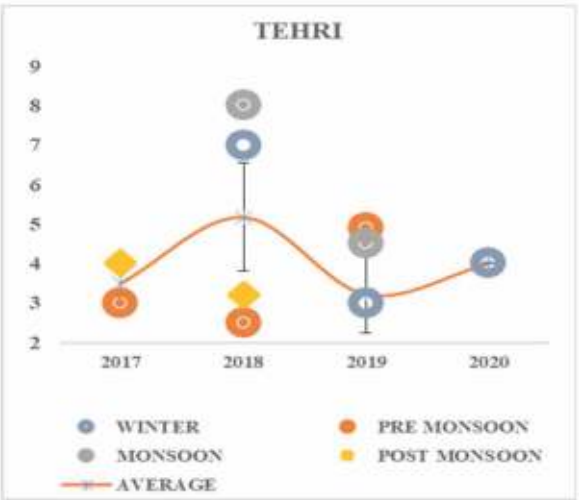
Stretches	Period	CO_2 (PPM)
	1960	2.2
	1987-88	12.4
	2001-06	3.2
	2016-20	0.33
Pryagraj	1960	1.5
	1987-88	4.6
	2001-06	1.8
	2016-20	1
Varanasi	1960	3.1
	1987-88	8.8
	2001-06	2.4
	2016-20	0.87
Patna	1960	4
	1987-88	2
	2001-06	2.6
	2016-20	1.63
Bhagalpur	1960	2.3
	1987-88	2.5
	2001-06	2.2
	2016-20	3.5
	2001-06	2.6
	2016-20	2.26
Diamond Harbour	1995-96	3.5-8
	2016-20	2.60

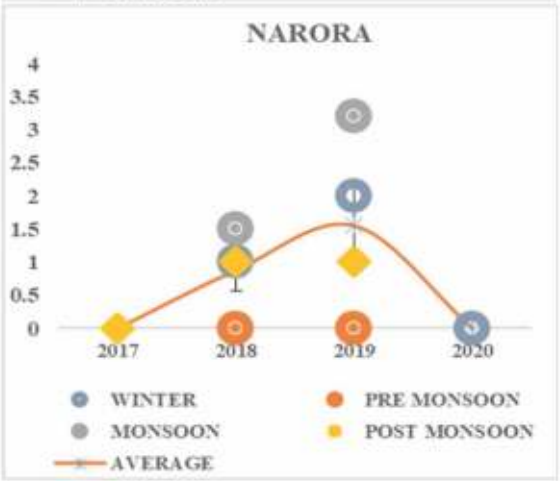
BRIEF DESCRIPTION

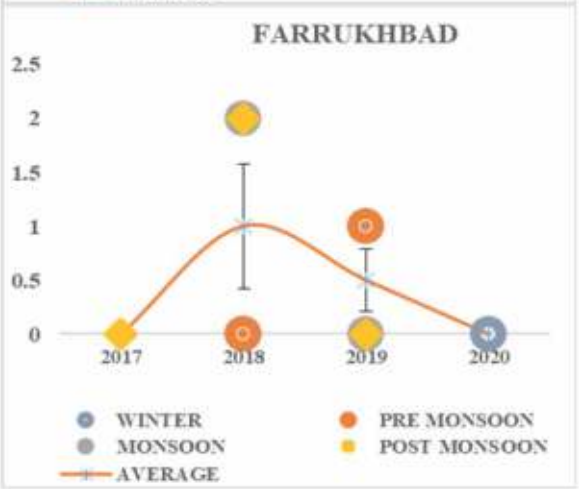
The mean FCO_2 in the entire stretch was 2.59 ± 0.30 ppm. The free CO_2 ranged from 0.33 ± 0.3 ppm at Kanpur to 5.35 ± 1.39 ppm at Haridwar. Among the different stretches the highest mean FCO_2 was observed 3.49 ± 0.44 ppm in the upper stretch of the river. The lowest mean FCO_2 was observed 1.45 ± 0.34 ppm in the middle stretch of the river. At lower and estuarine stretches the mean FCO_2 was 3.06 ± 0.78 ppm and 2.10 ± 0.51 ppm. Among the different seasons, the highest FCO_2 was observed 4.61 ± 1.00 ppm in monsoon, while the lowest FCO_2 was observed 1.23 ± 0.29 ppm in winter. During pre-monsoon and post-monsoon seasons, the mean FCO_2 was observed 2.65 ± 0.36 ppm and 2.32 ± 0.60 ppm respectively.

TIMESCALE CHANGES OF FREE CARBON DIOXIDE (ppm) IN UPPER STRETCH OF RIVER GANGA (2016-20)

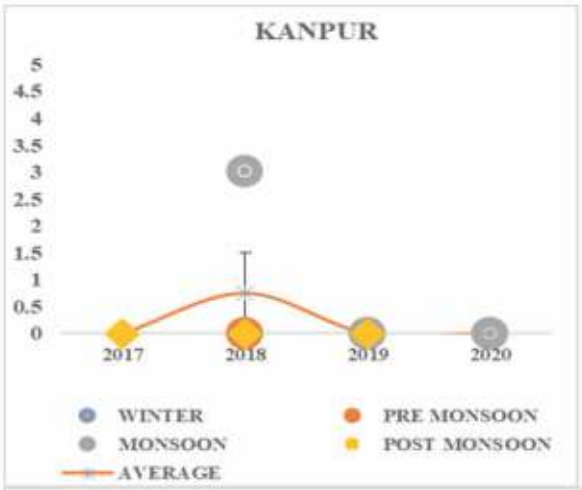


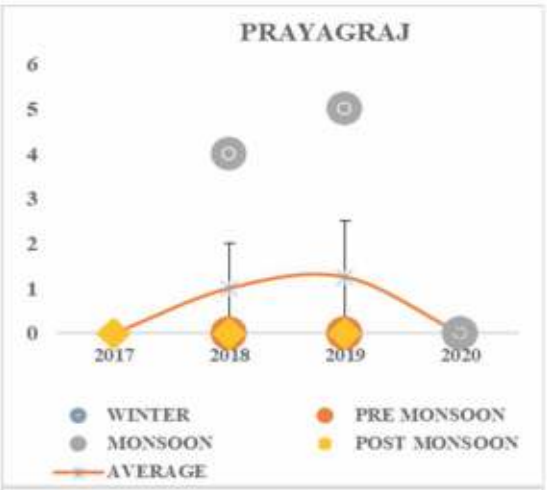


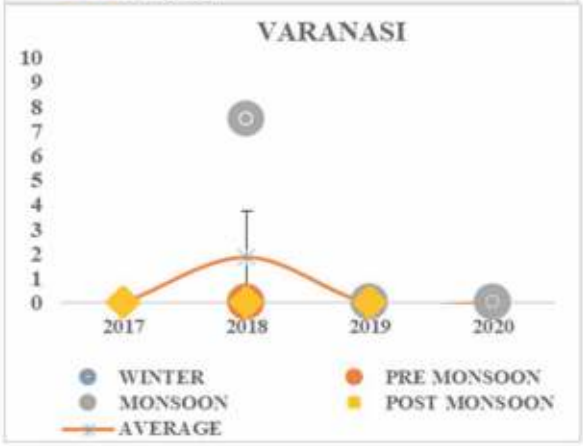


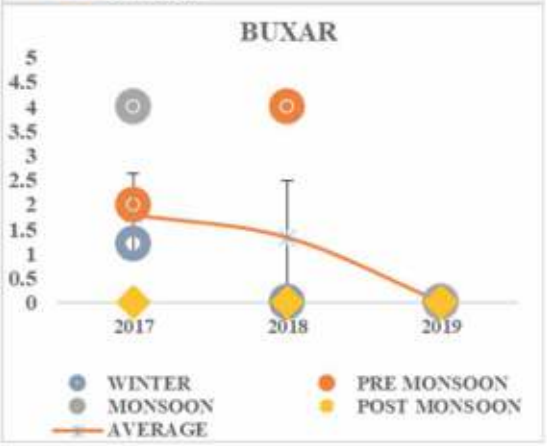


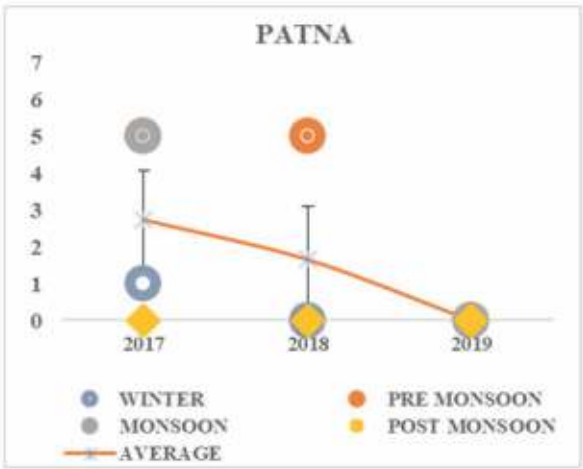
TIMESCALE CHANGES OF FREE CARBON DIOXIDE (ppm) IN MIDDLE STRETCH OF RIVER GANGA (2016-20)

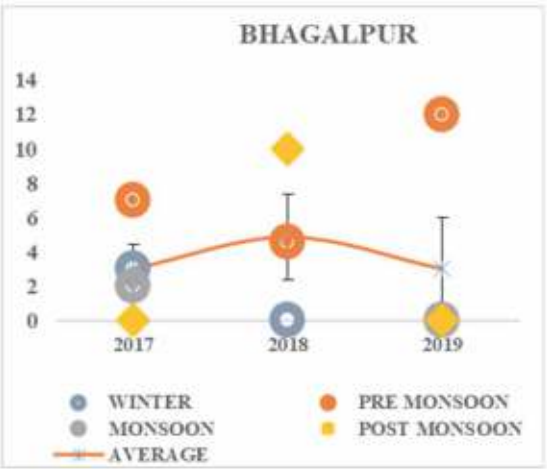




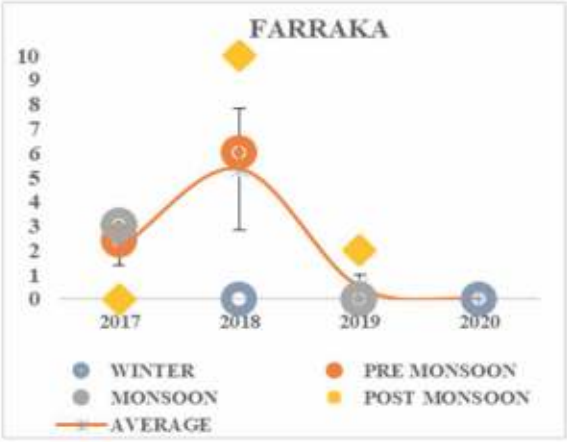


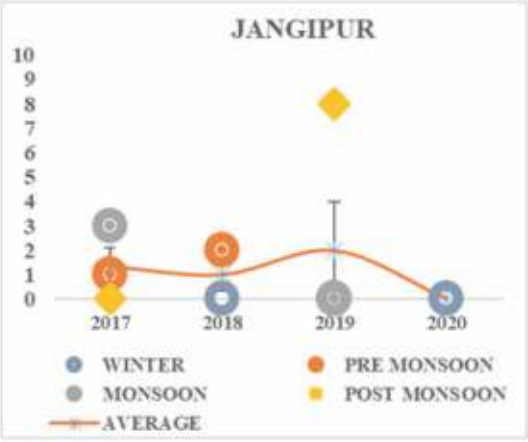


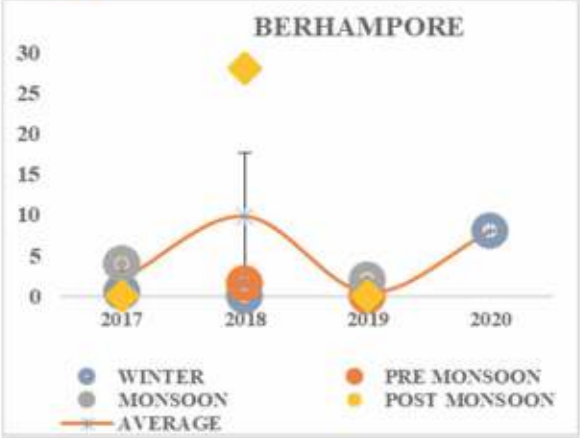


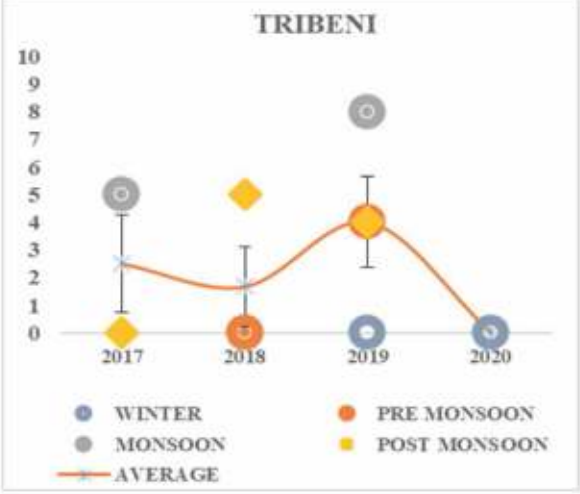


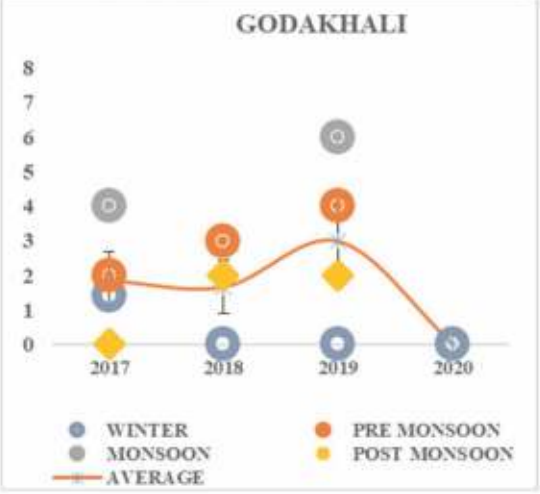
TIME-SCALE CHANGES OF FREE CARBON DIOXIDE (ppm) IN LOWER STRETCH OF RIVER GANGA (2016-20)



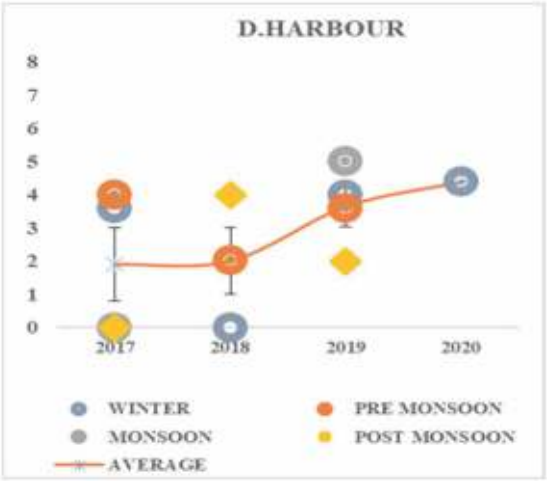


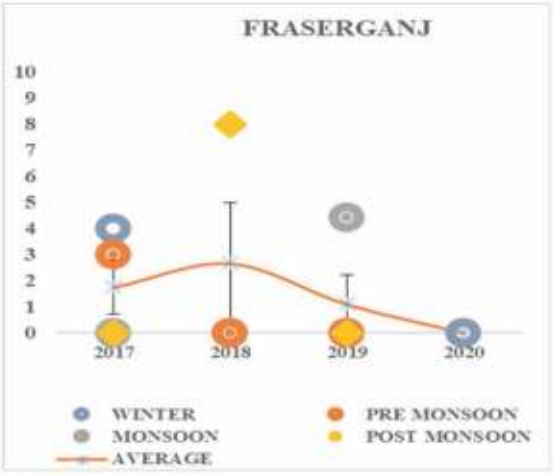






TIMESCALE CHANGES OF FREE CARBON DIOXIDE (ppm) IN ESTUARINE STRETCH OF RIVER GANGA (2016-20)



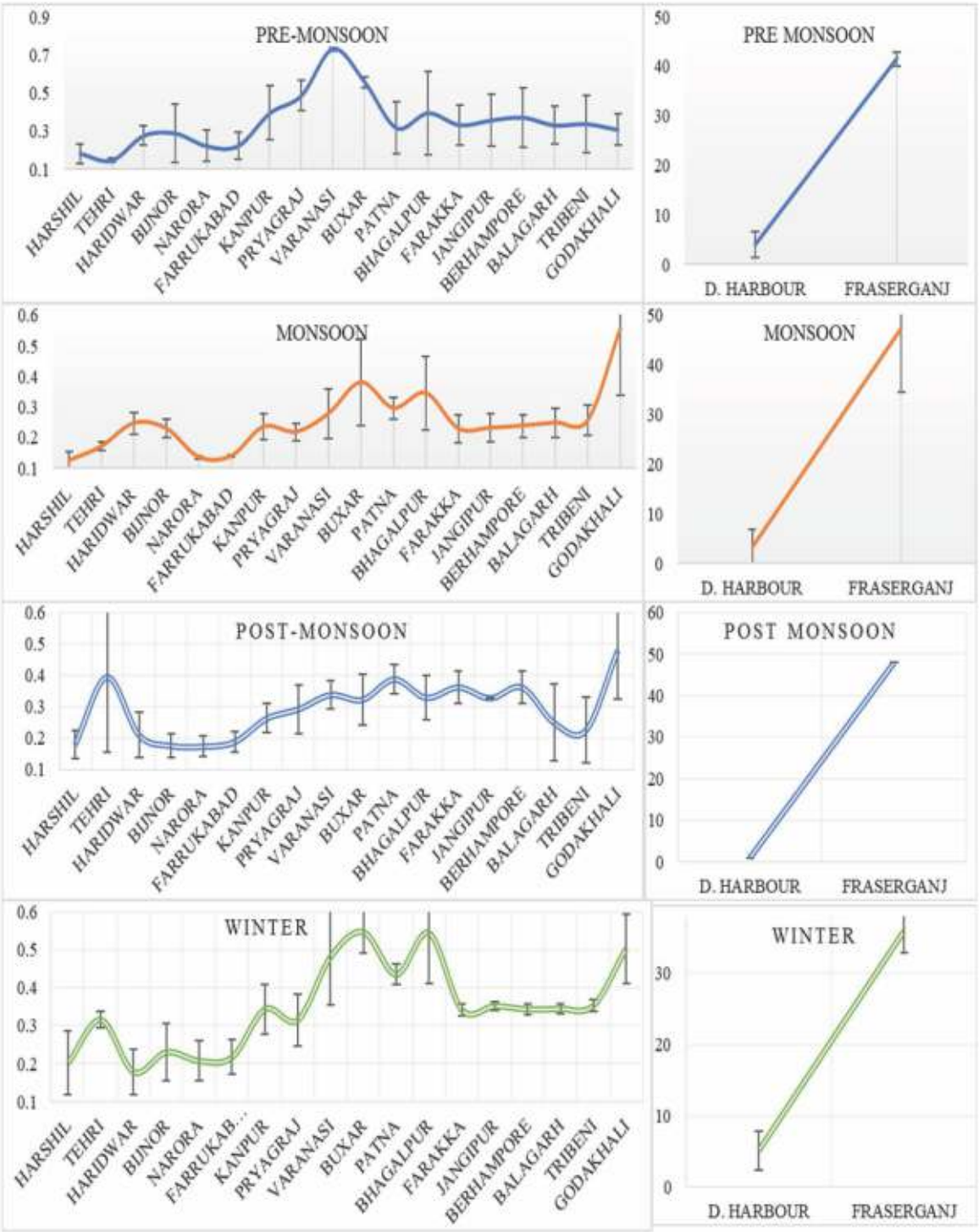


SALIENT TIMESCALE OBSERVATIONS

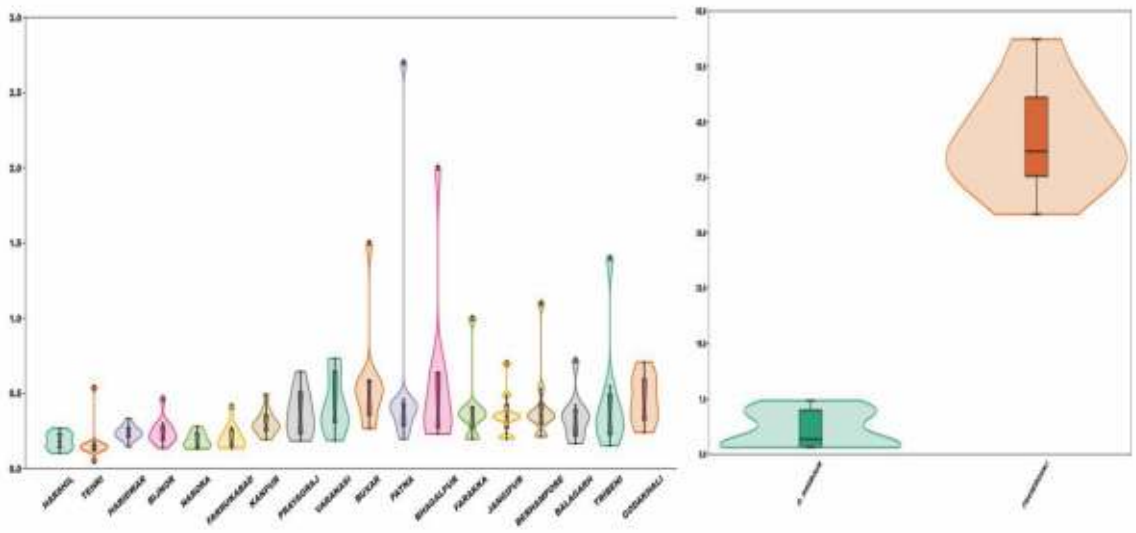
- In the upper stretch an increase in FCO_2 has been recorded at all the stretches except at Narora and Farrukhabad from 2017 to 2020.
- In the middle stretch decrease in the in FCO_2 has been observed at all the sampling sites except at Bhagalpur from 2017 to 2020.
- Among the sampling stations of lower stretch decrease in FCO_2 has been recorded at all the stations except at Berhampore from 2017 to 2020.
- In the estuarine stretch an increase in FCO_2 was recorded at D. Harbour and relative decrease have been observe at Fraserganj from 2017 to 2020.

Specific conductance (mS/cm)

Specific conductance is the ability of the water to conduct electricity, with the help of dissolved salts and inorganic contaminants. The parameter is the important pollution indicating parameter. The rise in the specific conductivity in the river water signifies amplification in the pollution. The parameter is affected by several contaminants and water temperature as well.


PRE-MONSOON
0.9
0.7
0.5
0.3
0.1
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
PRE MONSOON
50
40
30
20
10
0
D. HARBOUR
FRASERGANJ
MONSOON
0.6
0.5
0.4
0.3
0.2
0.1
MONSOON
POST-MONSOON
POST MONSOON
60
WINTER
FARRUKAB...

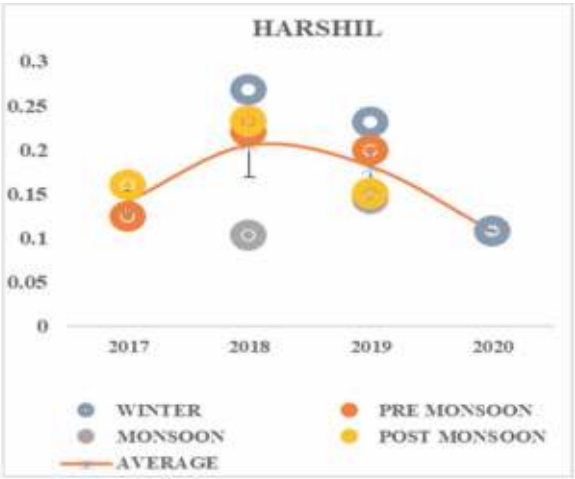
VIOLIN BOX PLOT ILLUSTRATING VARIATIONS IN FREE SPECIFIC CONDUCTANCE (ppm) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

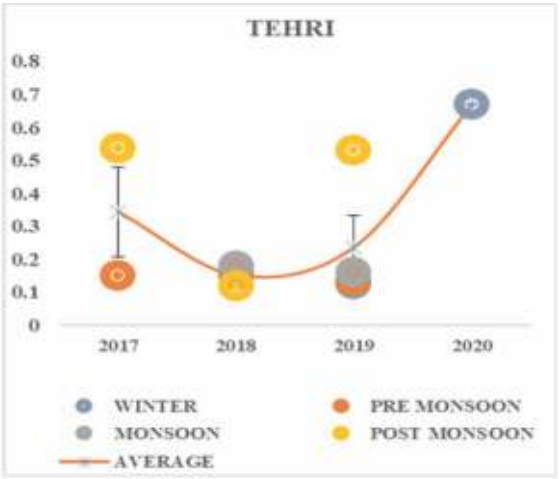


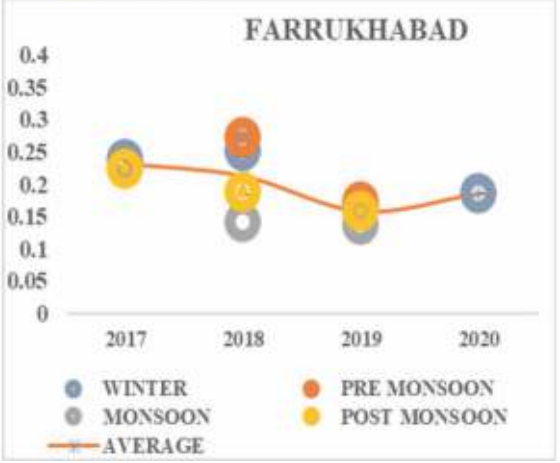
BRIEF DESCRIPTION

The mean specific conductivity in the entire stretch was 3.70 ± 1.39 mS/cm. The sp. conductivity varied from 0.17 mS/cm at Tehri to 42.74 ± 2.39 mS/cm at Fraserganj. Among the different stretches the highest mean conductivity was observed 23.06 ± 4.93 mS/cm in the estuarine stretch of the river, while the lowest conductivity was observed 0.20 ± 0.01 mS/cm. The mean conductivity in the middle and lower stretch of the river is 0.47 ± 0.05 mS/cm and 0.41 ± 0.03 mS/cm respectively. Among the different seasons, the highest mean conductivity was observed 2.85 ± 1.70 mS/cm, while the lowest conductivity was observed 2.15 ± 1.09 mS/cm during winter and during post-monsoon 2.15 ± 1.12 mS/cm. The mean conductivity during the pre-monsoon is 2.67 ± 1.26 mS/cm.

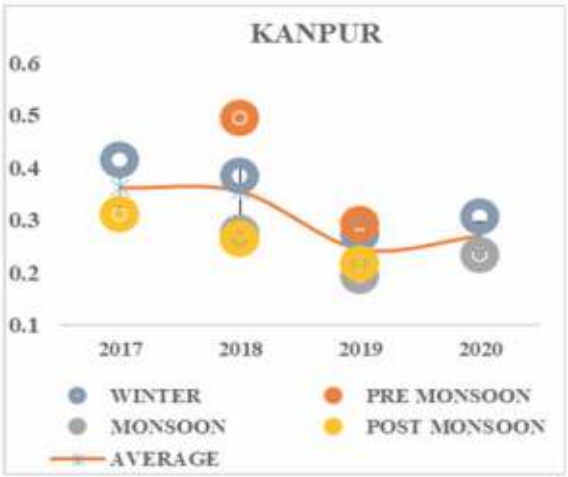
TIMESCALE CHANGES OF SPECIFIC CONDUCTIVITY (mS/cm) IN UPPER STRETCH OF RIVER GANGA (2016-20)

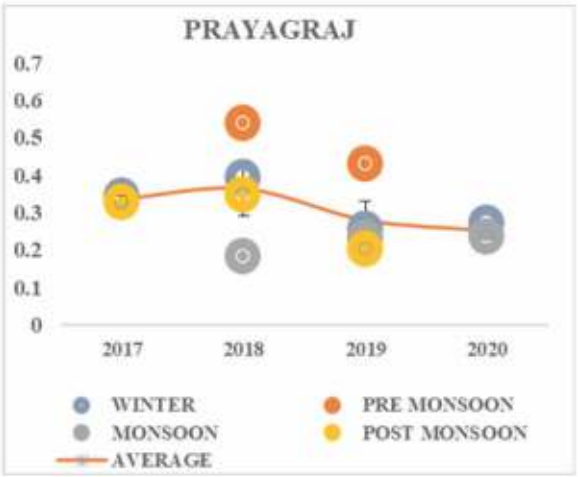


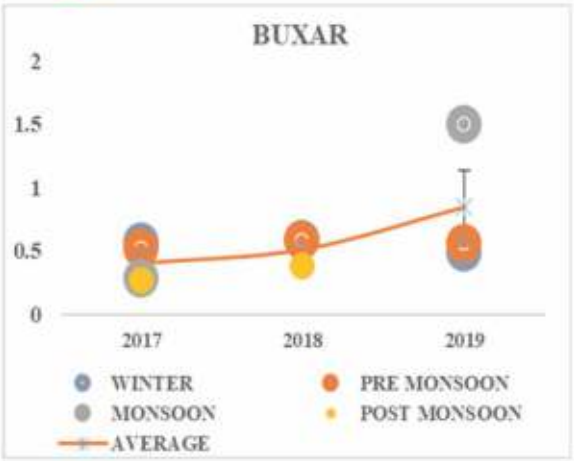


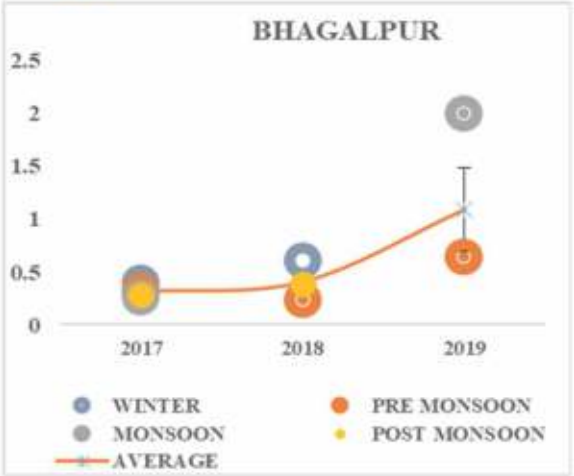


TIMESCALE CHANGES OF SPECIFIC CONDUCTIVITY (mS/cm) IN MIDDLE STRETCH OF RIVER GANGA (2016-20)

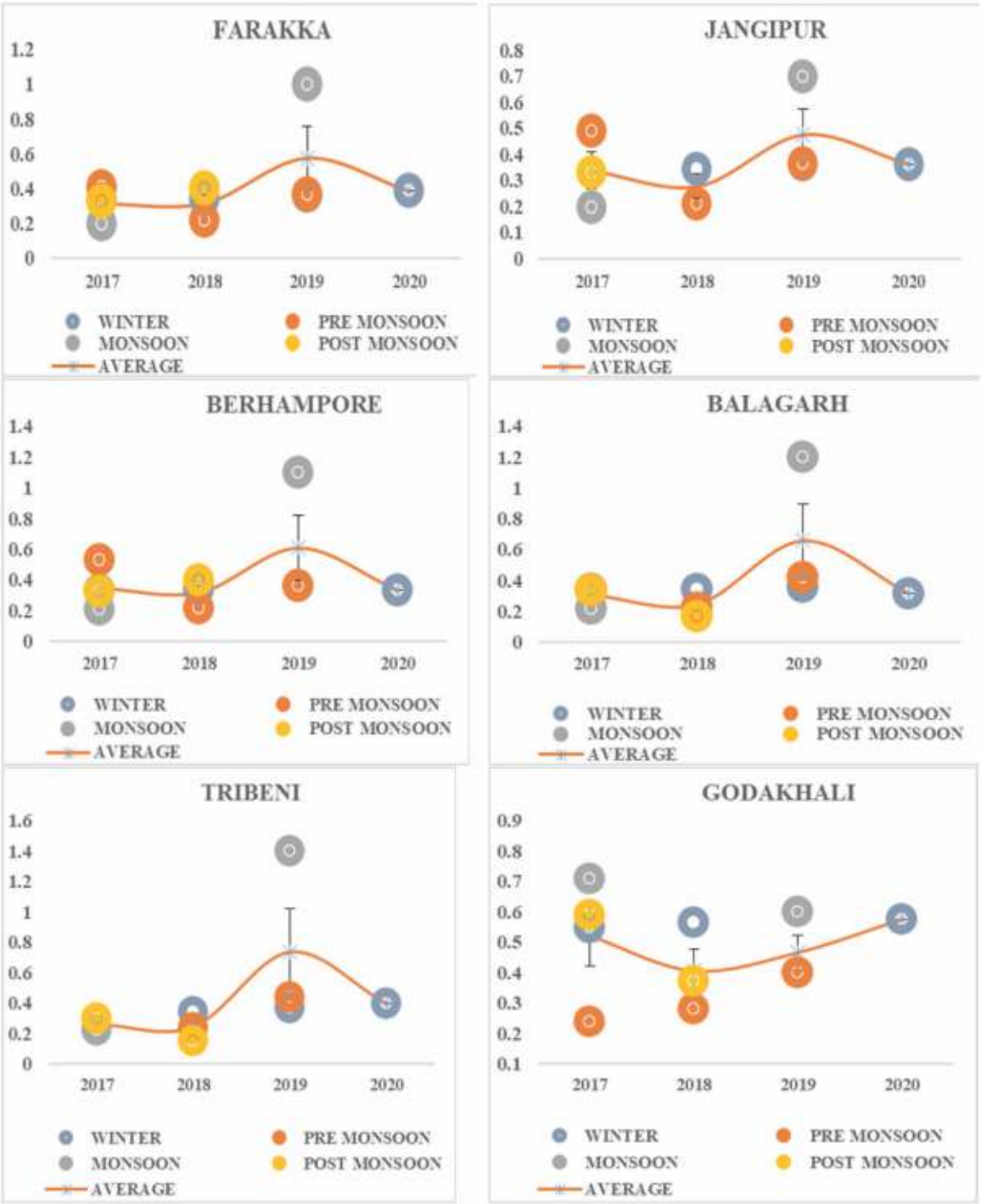




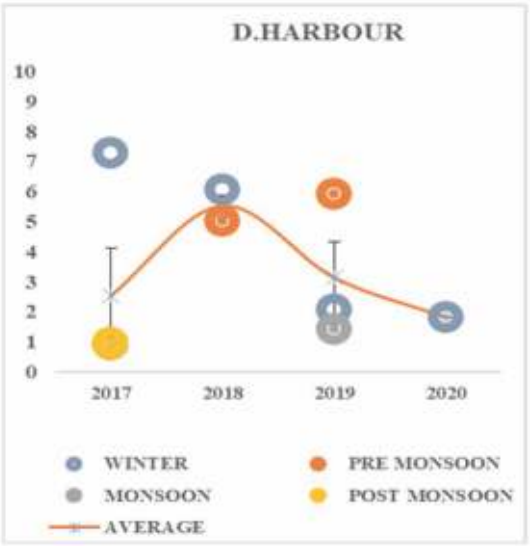


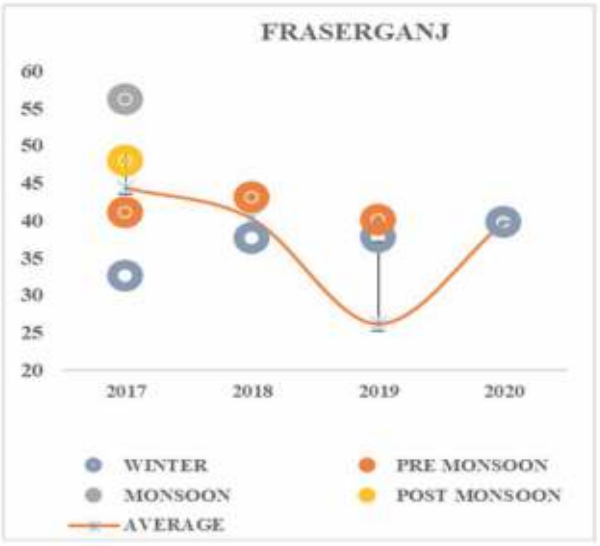


TIME-SCALE CHANGES OF SPECIFIC CONDUCTIVITY (mS/cm) IN LOWER STRETCH OF RIVER GANGA (2016-20)



TIMESCALE CHANGES OF SPECIFIC CONDUCTIVITY (mS/cm) IN ESTUARINE STRETCH OF RIVER GANGA (2016-20)





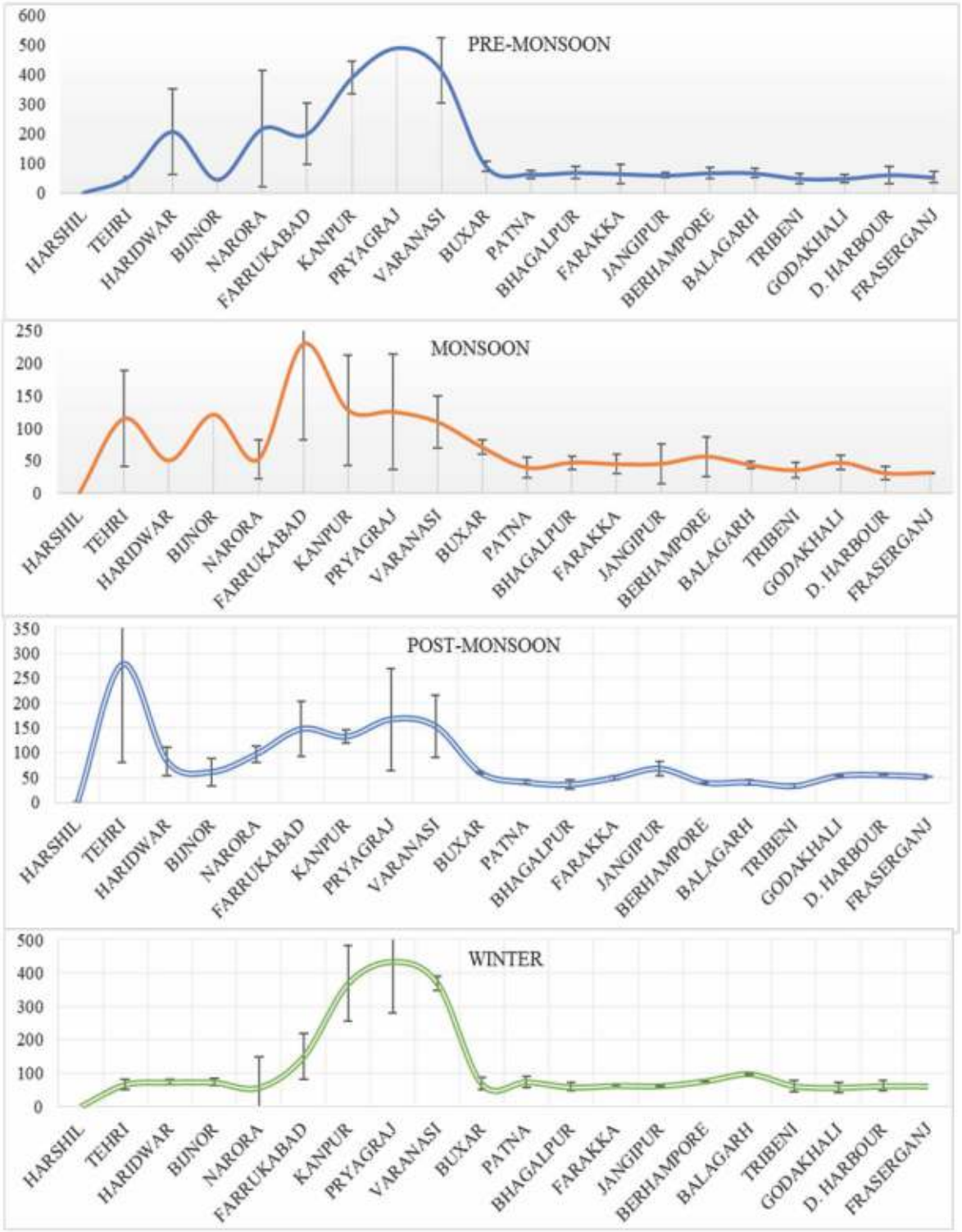
SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch a decrease in Specific conductivity has been recorded at all the sampling sites except at Tehri from 2017 to 2020.
- In the middle stretch an increase in specific conductivity was observed at Buxar, Patna, and Bhagalpur while a decrease has been recorded at Kanpur, Prayagraj and Varanasi from 2017 to 2020.
- Among the sampling stations of the lower stretch, an increase in specific conductivity has been observed at all the sampling sites except at Berhampore from 2017 to 2020.
- In the estuarine stretch, a decrease in sspecific conductivity has been recorded at all the sampling sites from 2017 to 2020.

PRODUCTIVITY PARAMETERS

Gross primary productivity (mg C/m^3 /h)

Gross primary productivity is the measurement of rate of capturing solar energy in per unit area in per unit time. The responsible organism for the productivity is chiefly the autotrophs. It is based on carbon dioxide intake and oxygen output in the aquatic ecosystem. GPP is the sum of net primary production and energy lost during the respiration.

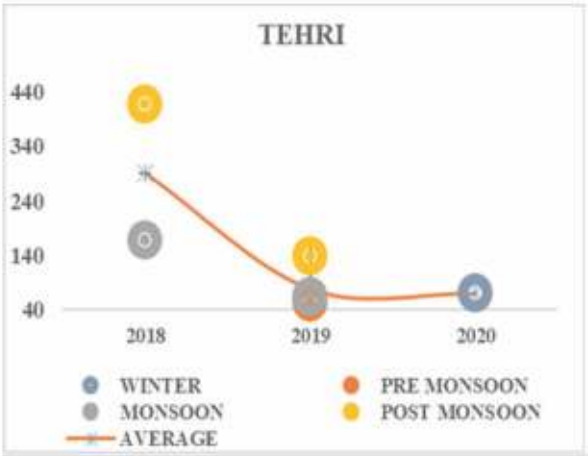

PRE-MONSOON
600
500
400
300
200
100
0
MONSOON
250
200
150
100
50
0
POST-MONSOON
350
300
250
200
150
100
50
0
WINTER
500
400
300
200
100
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

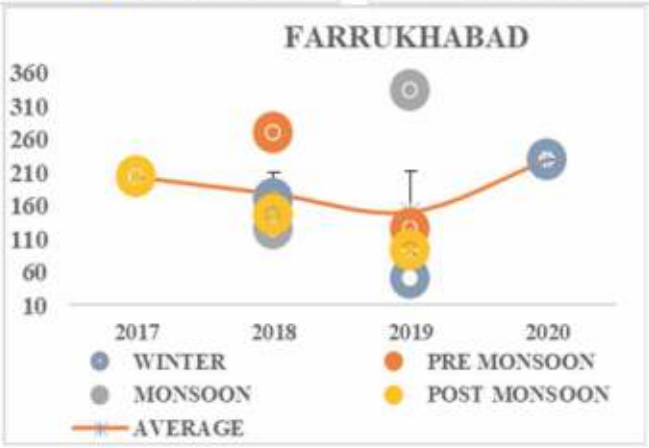
GRAPH ILLUSTRATING VARIATION IN GROSS PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

BRIEF DESCRIPTION

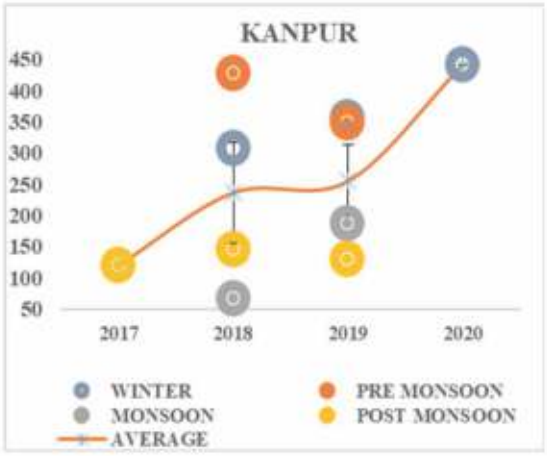
The mean GPP (mg C/m^3 /h) in the entire stretch was 103.63 ± 8.53. The GPP in the entire stretch ranged from 43.31 ± 4.75 at Tribeni to 266.51 ± 70.59 at Prayagraj. Among the different stretches the highest mean GPP was observed 147.71 ± 19.13 in the middle stretch of the river, while the lowest GPP was observed 51.90 ± 4.90. The mean GPP in the upper and lower stretches was 124.04 ± 16.15 mg C/m^3 /h and 54.31 ± 4.90. Among the different seasons the highest GPP was observed during winter seasons 123.18 ± 21.84, while the lowest GPP was observed 70.52 ± 10.17 during the monsoon season. The mean GPP during the pre-monsoon and post-monsoon were 119.44 ± 18.97 and 96.91 ± 12.35 respectively.

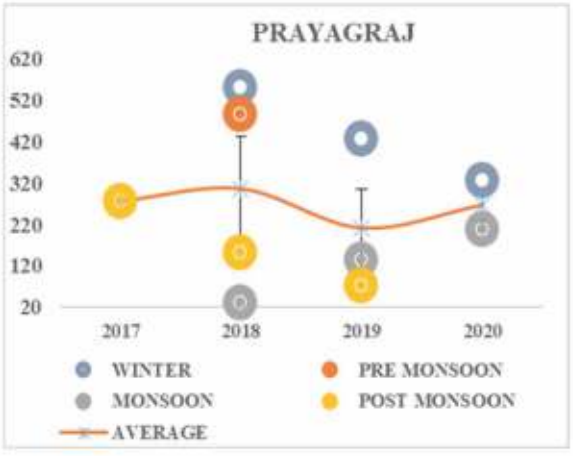
TIMESCALE CHANGES OF GROSS PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN UPPER STRETCH OF RIVER GANGA (2016-20)

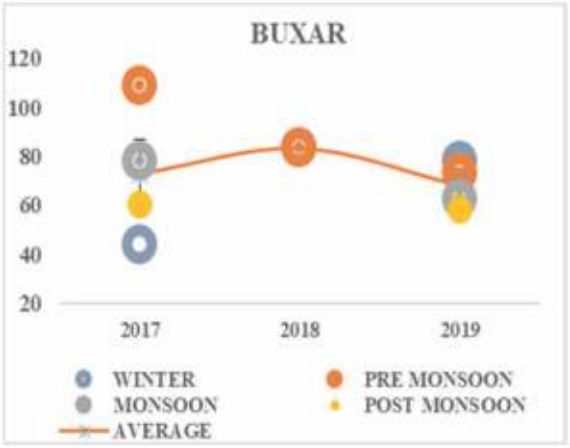


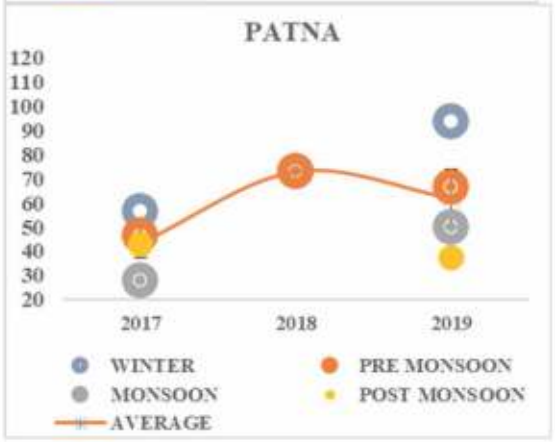


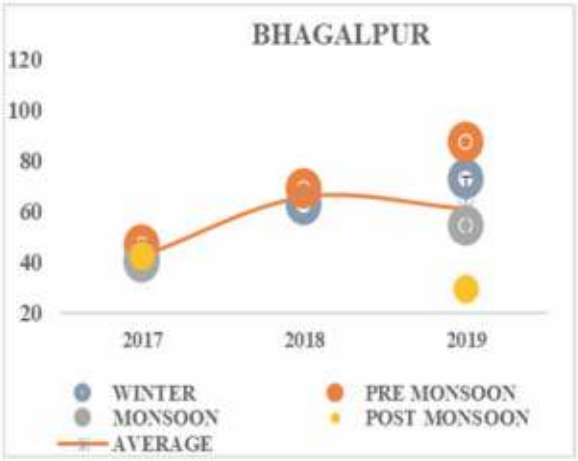
TIMESCALE CHANGES OF GROSS PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



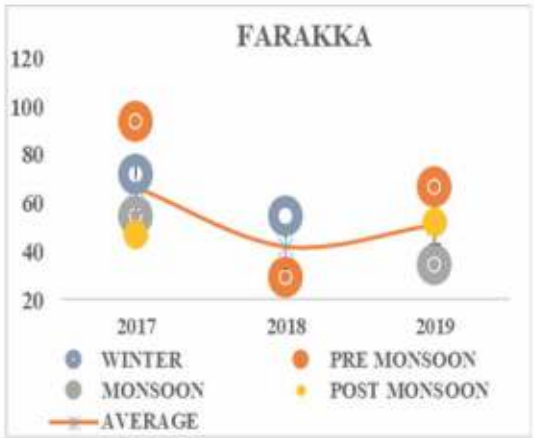


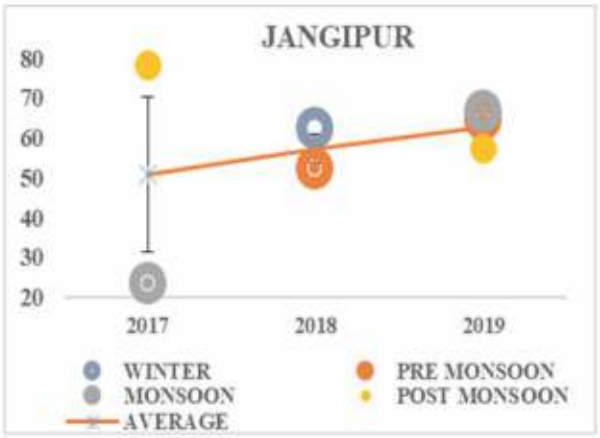


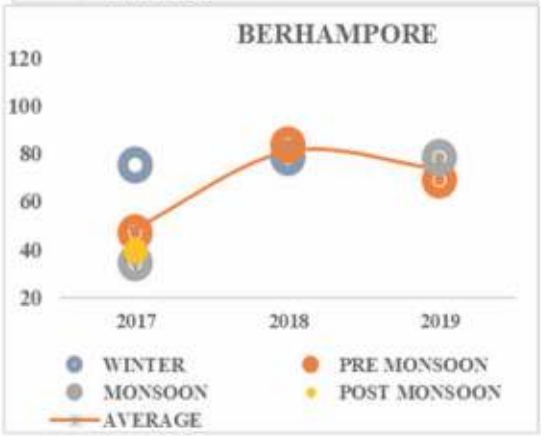


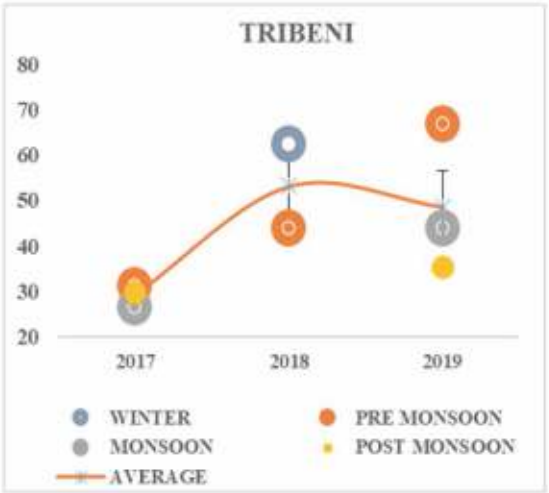


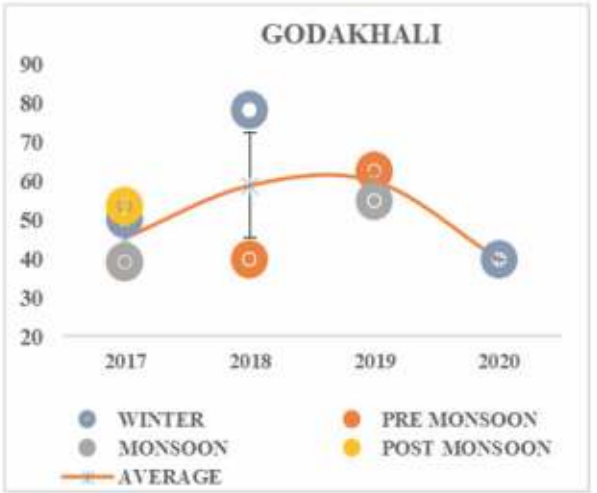
TIME-SCALE CHANGES OF GROSS PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN LOWER STRETCH OF RIVER GANGA (2016-20)



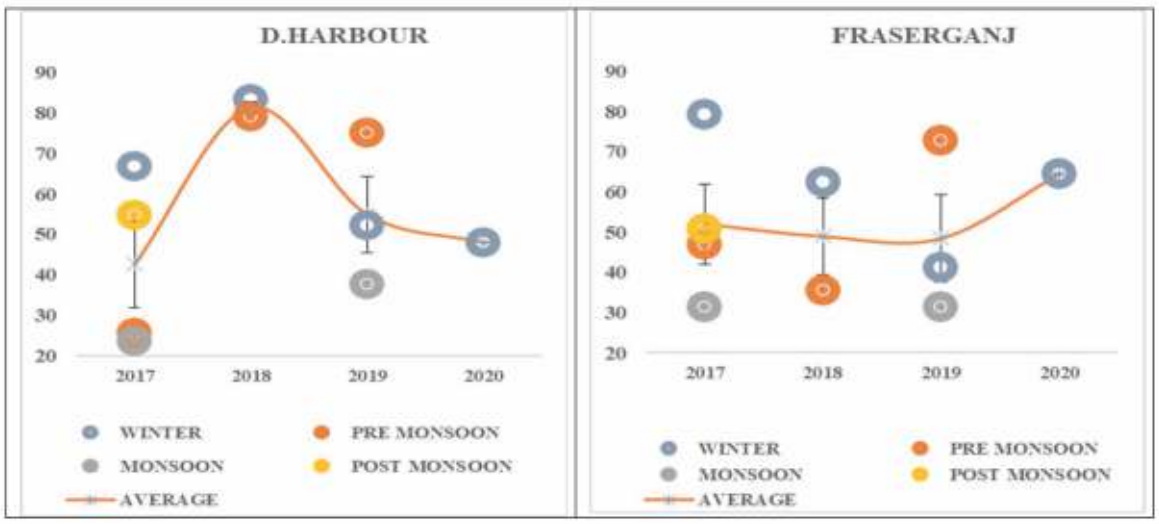








TIMESCALE CHANGES OF GROSS PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN ESTUARINE STRETCH OF RIVER GANGA (2016-20)

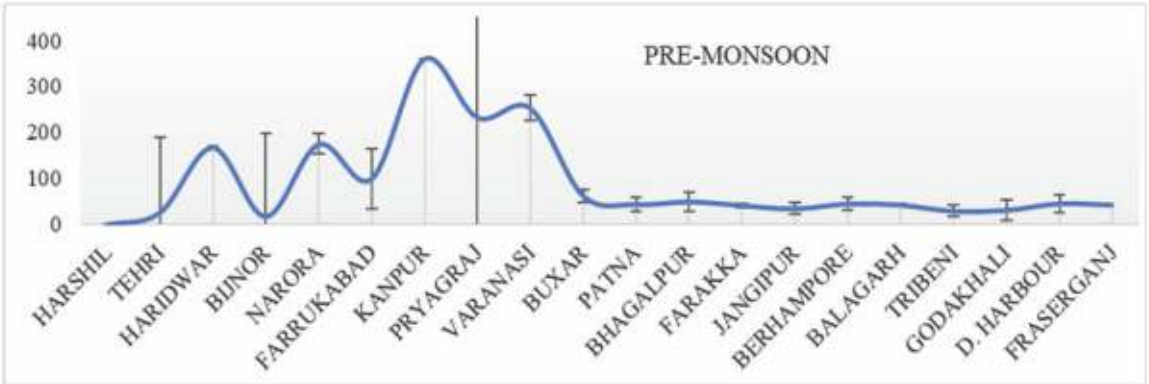


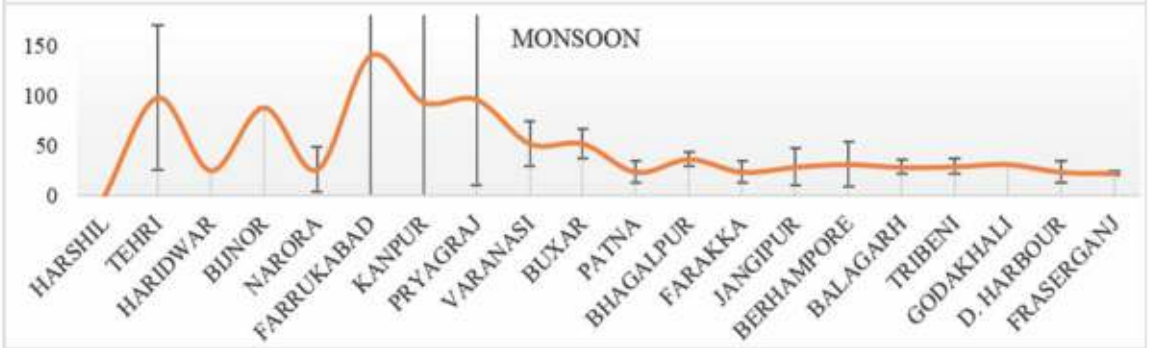
SALIENT TIMESCALE OBSERVATIONS

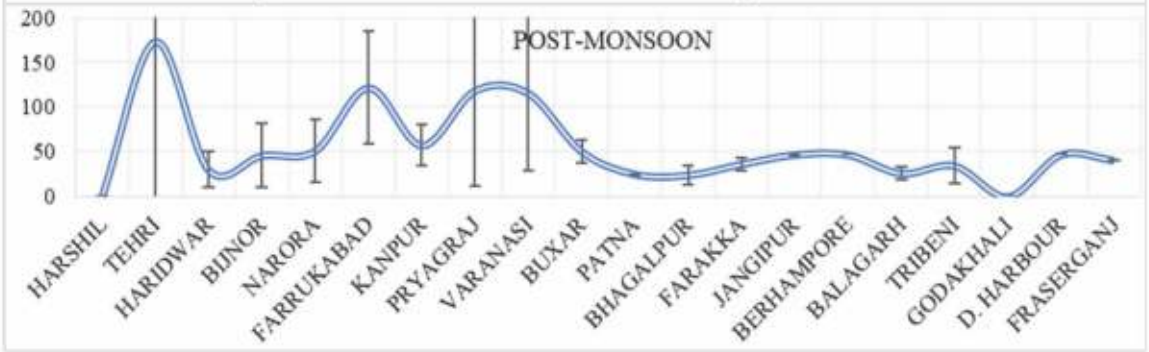
- In the upper stretch an increase in GPP has been recorded at Bijnor Farrukhabad and Haridwar while a decrease in GPP was observed at Tehri and Narora from 2017 to 2020.
- In the middle stretch increase in GPP has been observed at Kanpur, Patna, and Bhagalpur while a decrease was recorded at Buxar, Prayagraj, and Varanasi from 2017 to 2020.
- Among the sampling stations of lower stretch an increase in GPP has been recorded at all the stations while a decrease was observed at Farakka and Godakhali from 2017 to 2020.
- In the estuarine stretch a decrease in GPP was recorded at D. Harbour and increases at Fraserganj from 2017 to 2020.

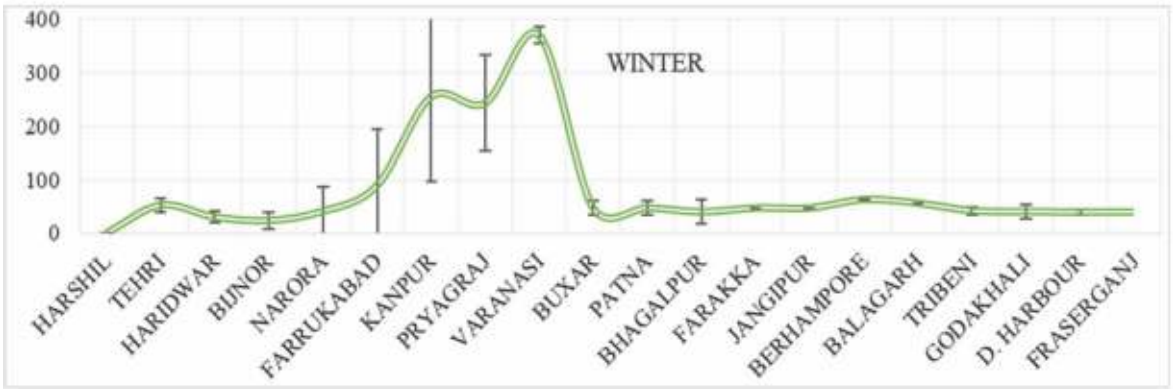
Net primary productivity (mg C/m^3 /h)

Net primary represents the quantity of energy left after the consumption of energy as the respiration. The NPP depends on many aquatic variables, chiefly macrophytes, plankton and periphyton.

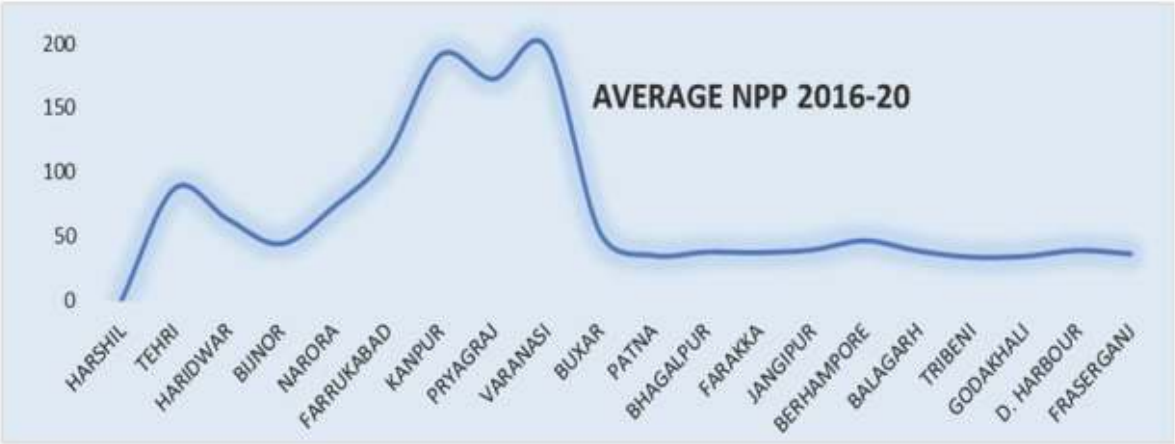

PRE-MONSOON
400
300
200
100
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


MONSOON
150
100
50
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


POST-MONSOON
200
150
100
50
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ


WINTER
400
300
200
100
0
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
D. HARBOUR
FRASERGANJ

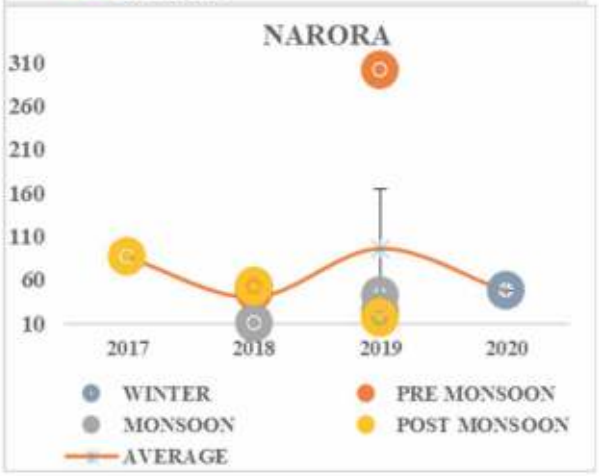
GRAPH ILLUSTRATING VARIATION IN NET PRIMARY PRODUCTIVITY (mg C/m^3 /h) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)

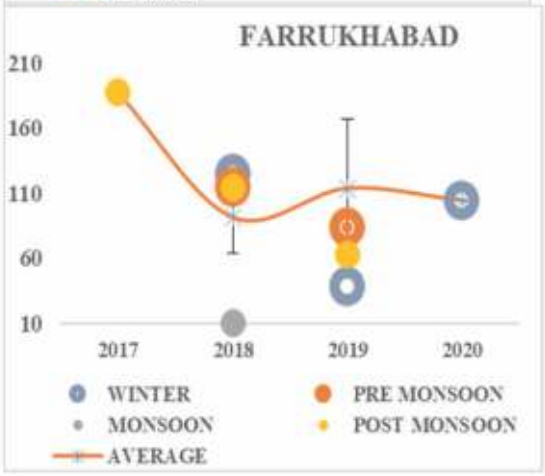


BRIEF DESCRIPTION

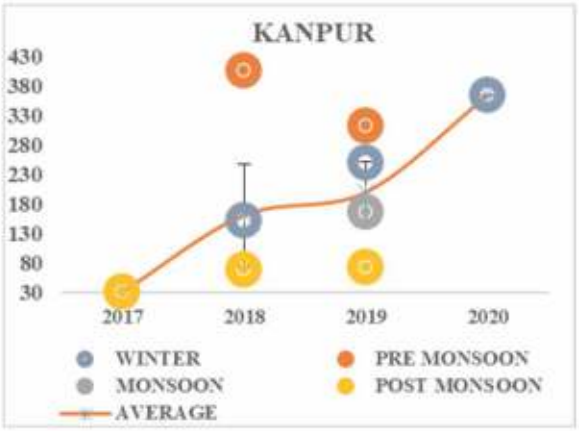
The mean net primary productivity (NPP) (mg C/m^3 /h) was recorded 71.99 ± 7.03. The NPP in the entire stretch ranged from 35.72 ± 4.79 to 179.58 ± 56.03 at Varanasi. Among the different stretches the highest NPP was observed 104.25 ± 15.74, while the lowest NPP was observed 37.05 ± 1.93. The NPP in the upper and estuarine stretch of the river is 81.62 ± 14.26 and 37.95 ± 3.54 respectively. Among the different seasons the highest mean NPP was observed at 88.24 ± 17.55 during winter, while the lowest NPP was observed 46.32 ± 8.65 during monsoon. The mean NPP during pre-monsoon and post monsoon season were 84.05 ± 15.78 and 66.07 ± 10.53 respectively.

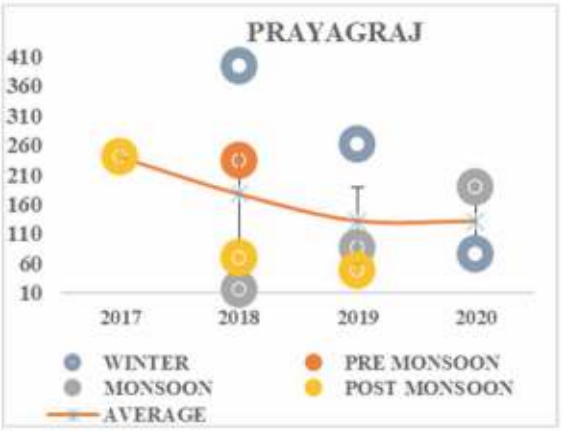
TIMESCALE CHANGES OF NET PRIMARY PRODUCTIVITY IN UPPER STRETCH OF RIVER GANGA (2016-20)

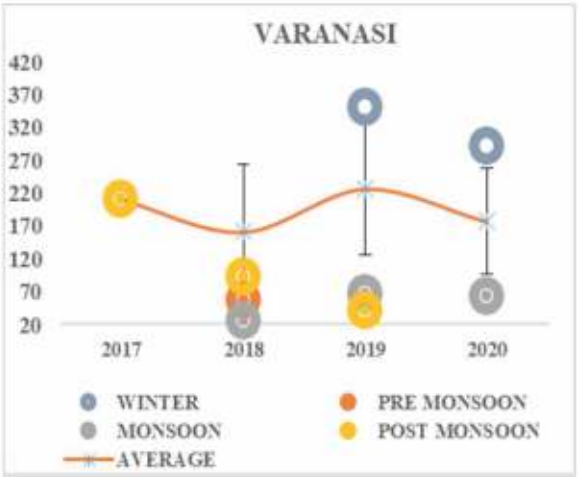


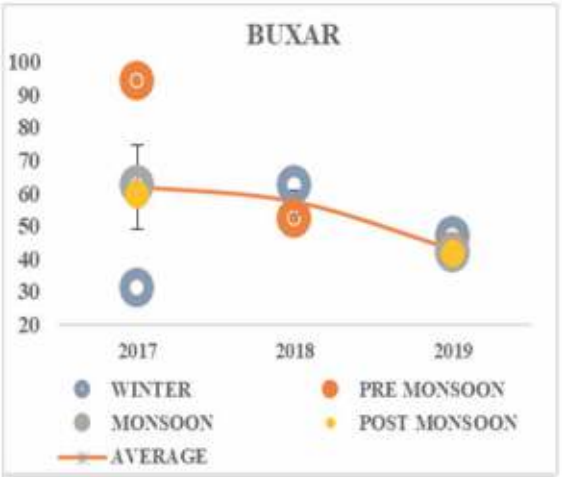


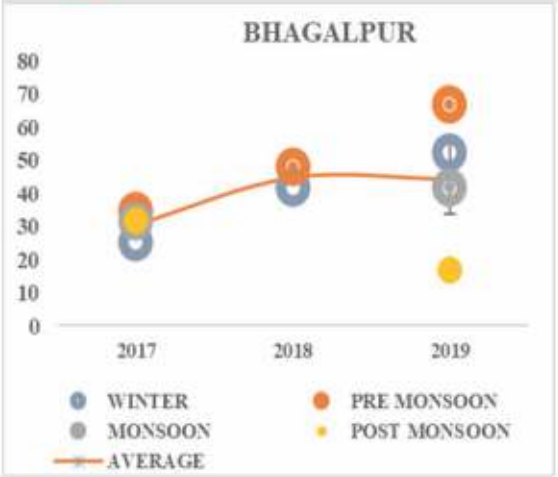
TIMESCALE CHANGES OF NET PRIMARY PRODUCTIVITY IN MIDDLE STRETCH OF RIVER GANGA (2016-20)



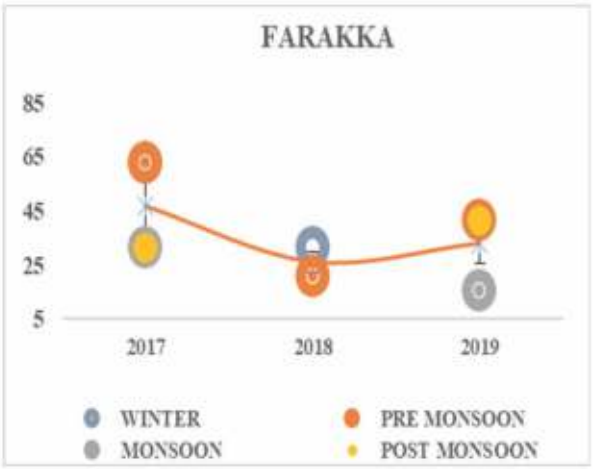


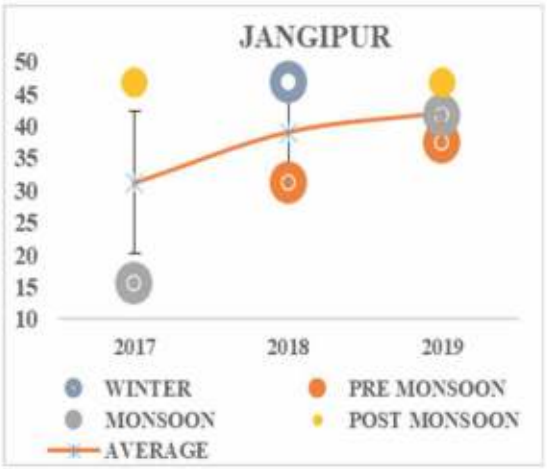


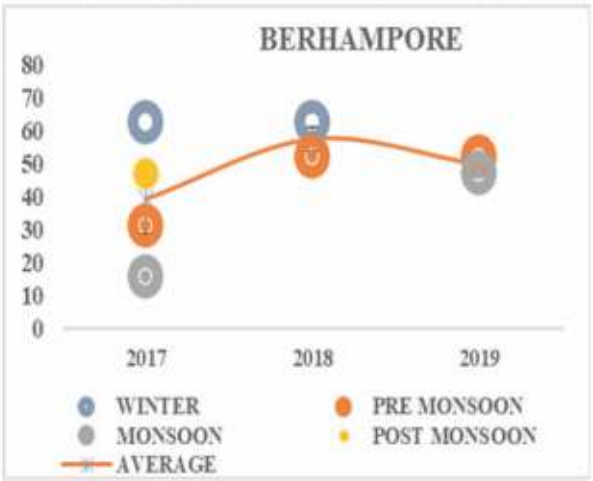


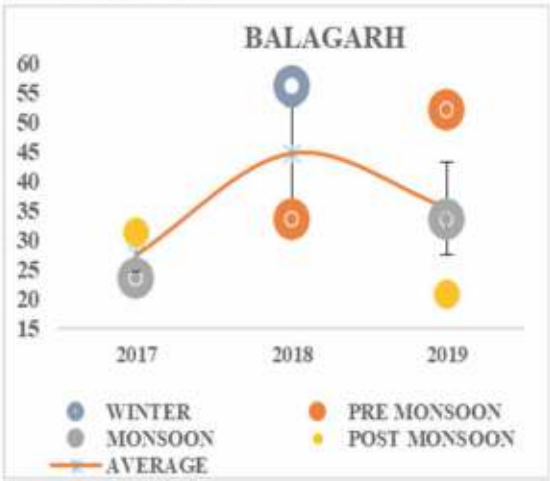


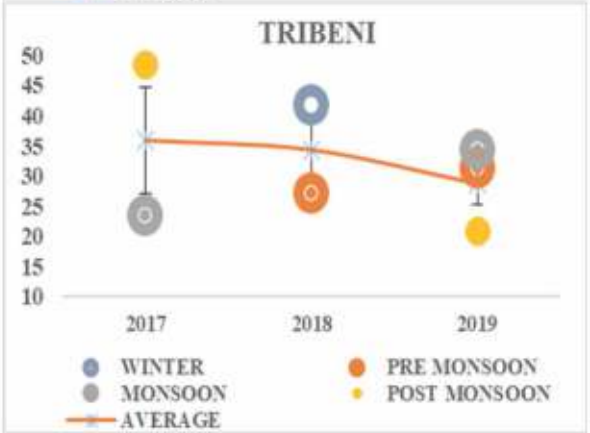
TIME-SCALE CHANGES OF NET PRIMARY PRODUCTIVITY IN LOWER STRETCH OF RIVER GANGA (2016-20)



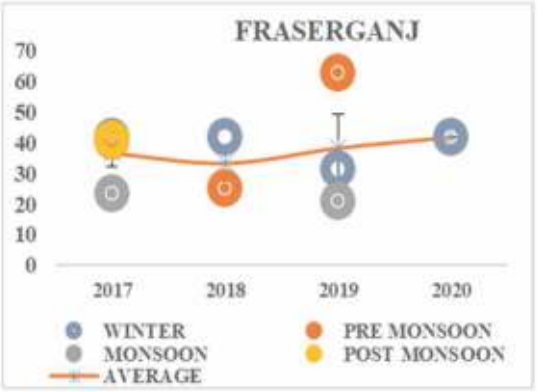








TIMESCALE CHANGES OF NET PRIMARY PRODUCTIVITY IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)

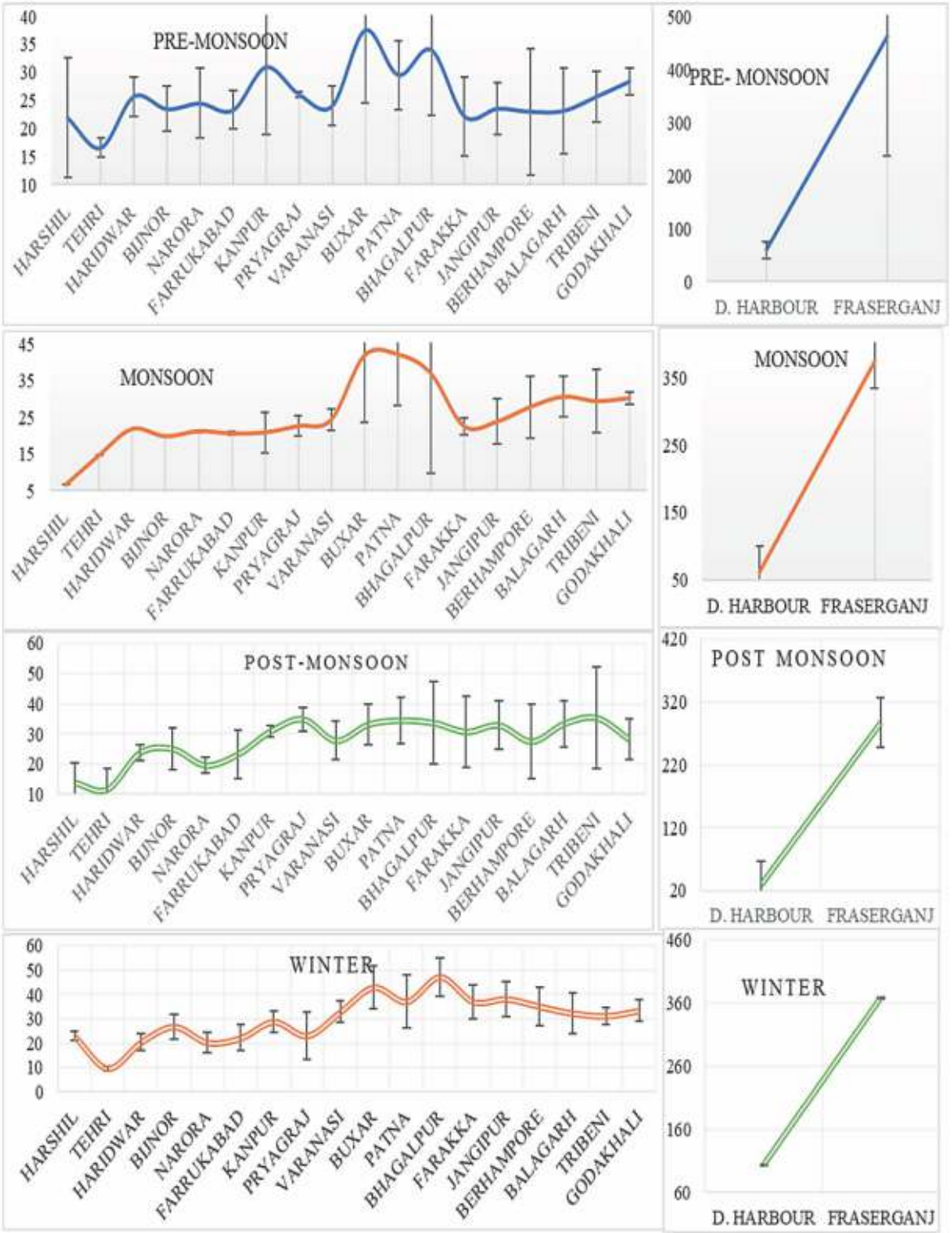


SALIENT TIMESCALE OBSERVATIONS

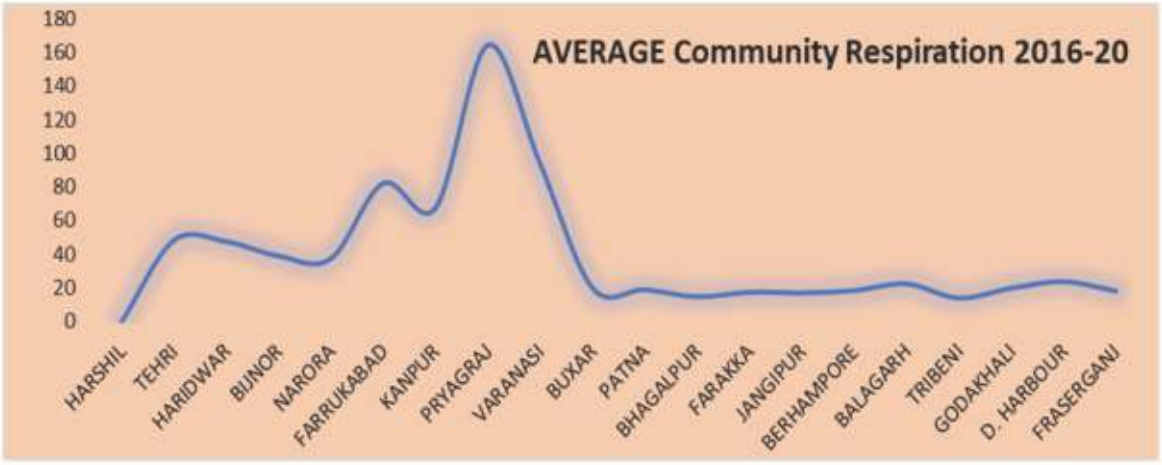
- In the upper stretch a decrease in NPP has been recorded at all the stretches except at Bijnor from 2017 to 2020.
- In the middle stretch an increase in NPP have been observed at Kanpur, Patna and Bhagalpur and a decrease at Prayagraj, Varanasi and Buxar from 2017 to 2020.
- Among the sampling stations of lower stretch there was an increase in NPP recorded at Jangipur, Berhampore and Balagarh while a decrease in NPP was recorded at Farakka, Tribeni and Godakhali from 2017 to 2020.
- In the estuarine stretch there is a decrease in NPP was recorded at D. Harbour and a increases at Fraserganj from 2017 to 2020.

Community respiration (mg C/m^3 /h)

Community respiration is the sum of carbon dioxide generated by individual aquatic organisms as a result of cellular respiration of organic matter.

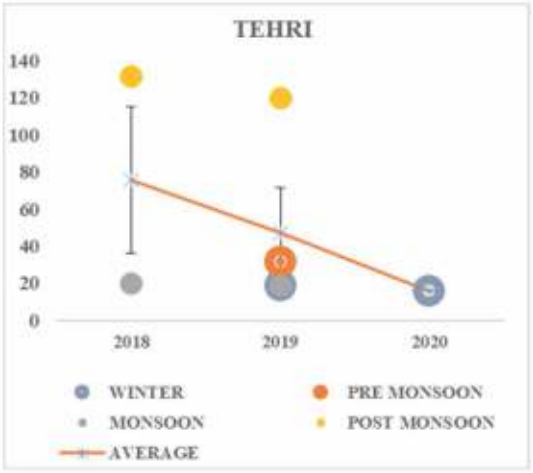

PRE-MONSOON
HARSHIL
TEHRI
HARIDWAR
BIJNOR
NARORA
FARRUKABAD
KANPUR
PRYAGRAJ
VARANASI
BUXAR
PATNA
BHAGALPUR
FARAKKA
JANGIPUR
BERHAMPORE
BALAGARH
TRIBENI
GODAKHALI
PRE- MONSOON
D. HARBOUR
FRASERGANJ
MONSOON
POST-MONSOON
POST MONSOON
WINTER

GRAPH ILLUSTRATING VARIATION IN COMMUNITY RESPIRATION (mg C/m^3 /h) IN VARIOUS STRETCHES OF RIVER GANGA (2016-20)



BRIEF DESCRIPTION

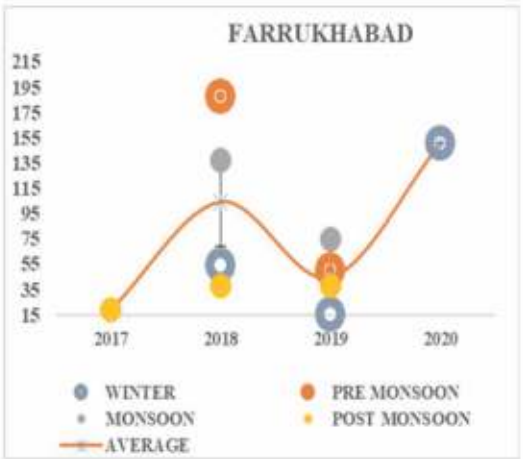
The Community Respiration (CR), (mg C/m^3/h) in the entire stretch ranges from 0.29 to 331.25. Average CR in the entire river was 38.84. Highest average CR value at 164.24 was recorded at Prayagraj. During the Pre-Monsoon the average CR value was 53.52. During Monsoon the average CR value was 29.52. The average CR during Post-Monsoon was 36.42. The average CR value during winter was 46.23.


TEHRI
140
120
100
80
60
40
20
0
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

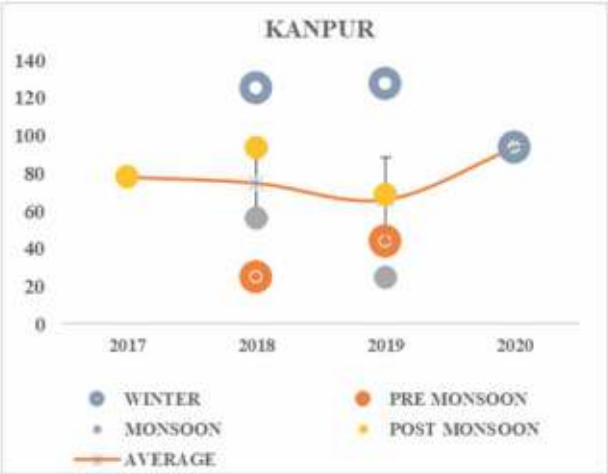

HARIDWAR
80
70
60
50
40
30
20
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

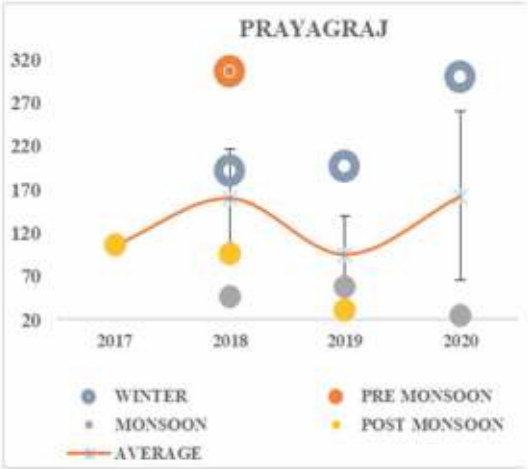

BIJNOR
80
70
60
50
40
30
20
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

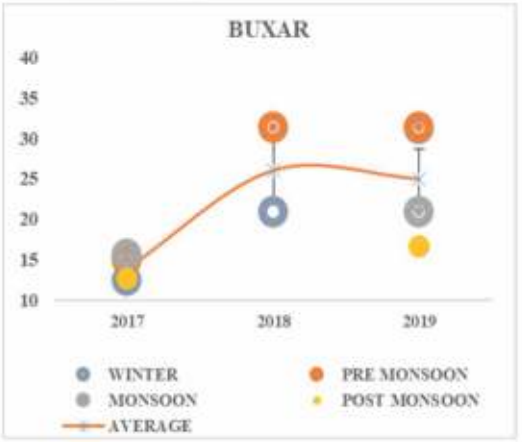

NARORA
80
70
60
50
40
30
20
10
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

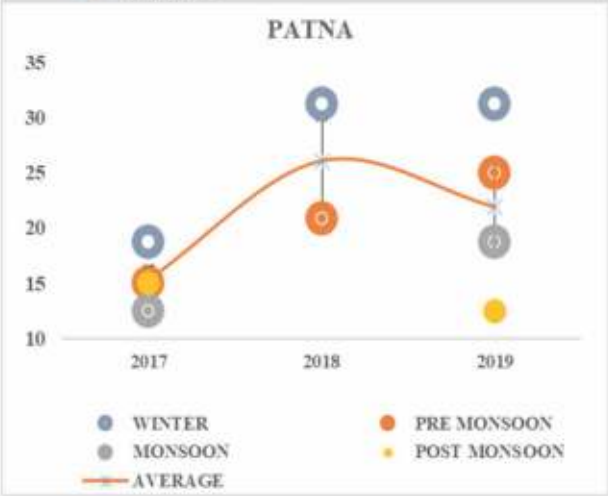

FARRUKHABAD
215
195
175
155
135
115
95
75
55
35
15
2017
2018
2019
2020
WINTER
PRE MONSOON
MONSOON
POST MONSOON
AVERAGE

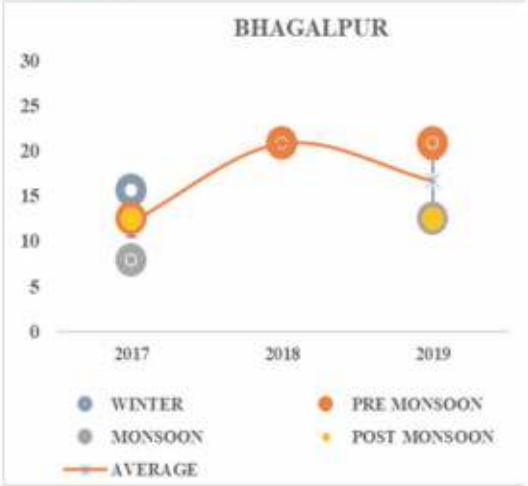
TIMESCALE CHANGES OF COMMUNITY RESPIRATION IN THE MIDDLE STRETCH OF RIVER GANGA (2016-20)



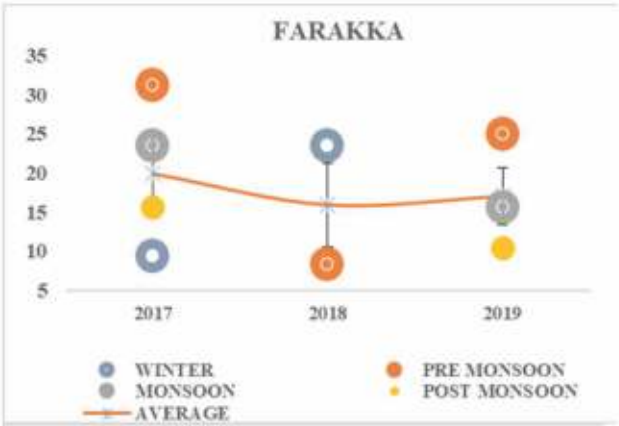


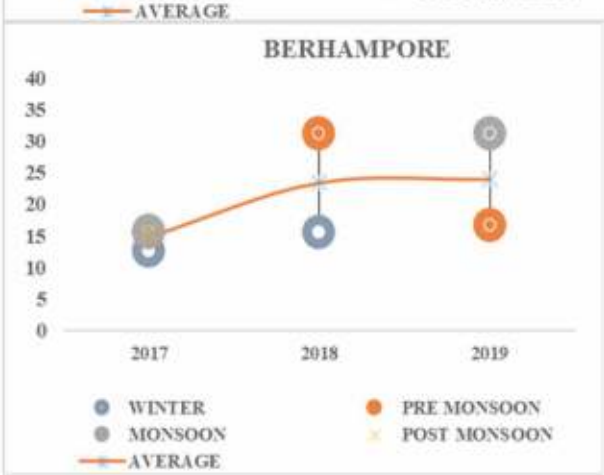


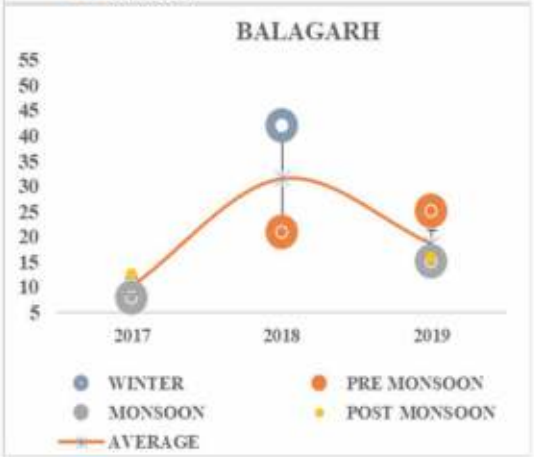


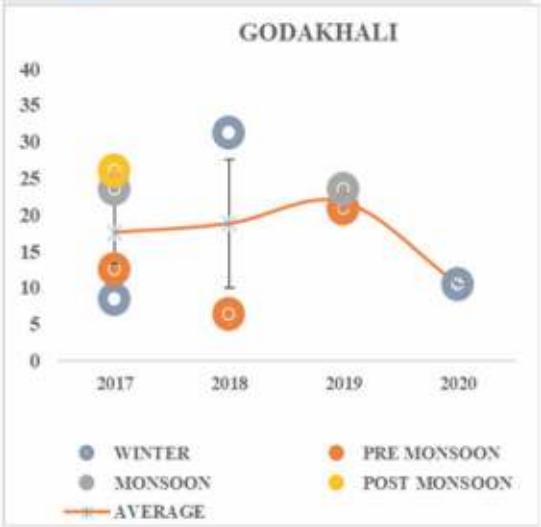


TIME-SCALE CHANGES OF COMMUNITY RESPIRATION IN LOWER STRETCH OF RIVER GANGA (2016-20)

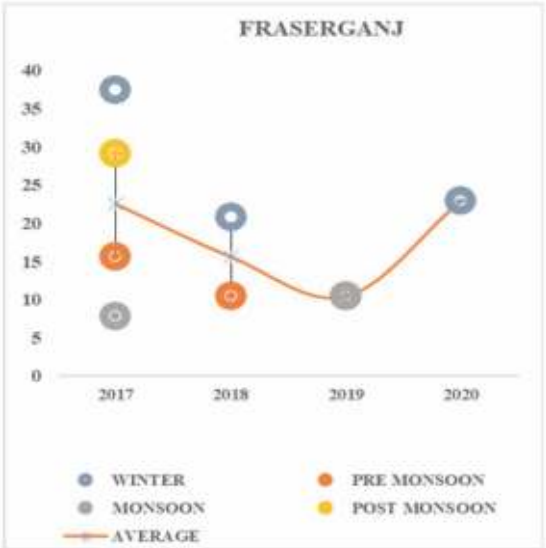








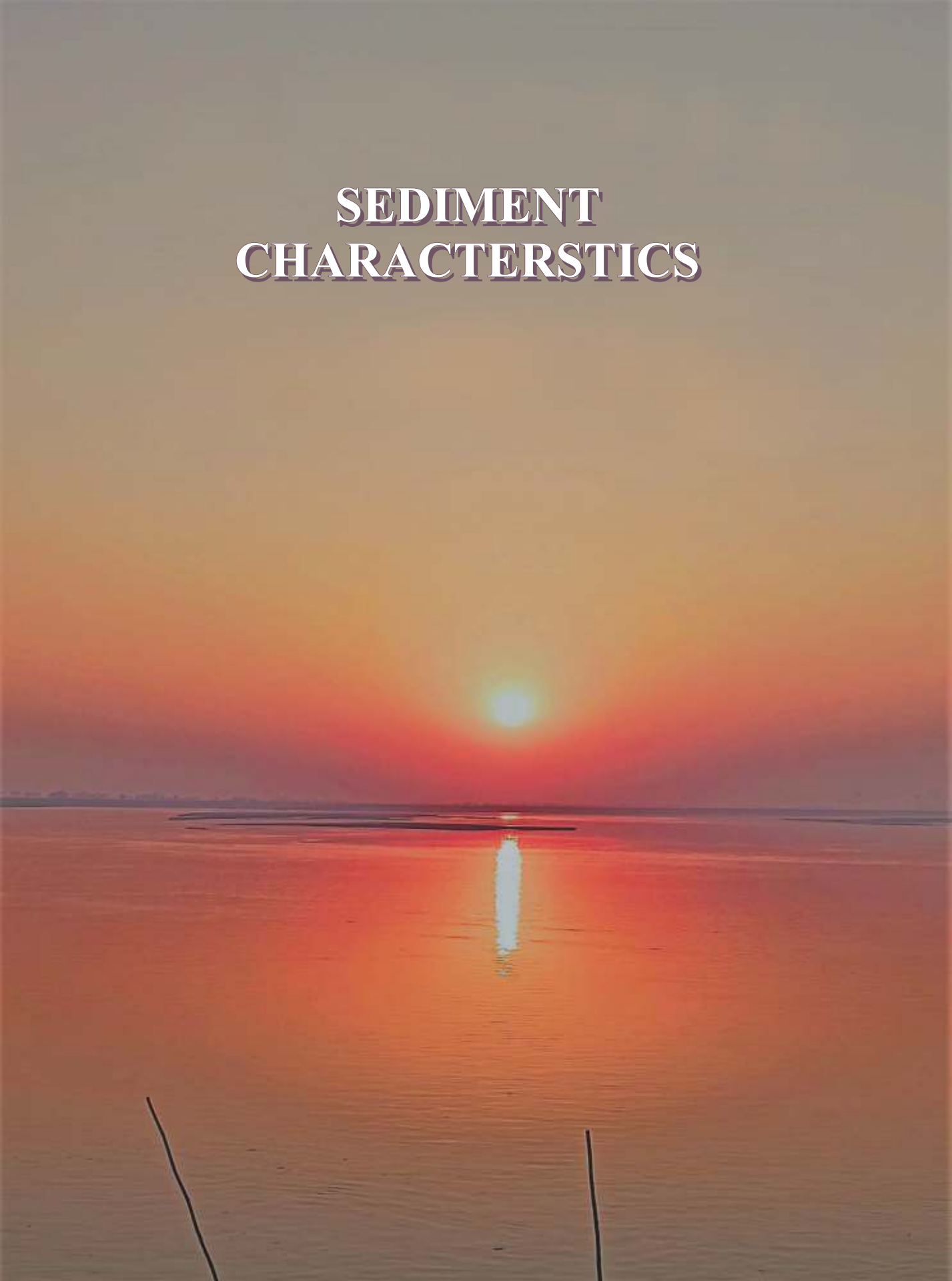
TIMESCALE CHANGES OF COMMUNITY RESPIRATION IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-20)



SALIENT TIMESCALE OBSERVATIONS

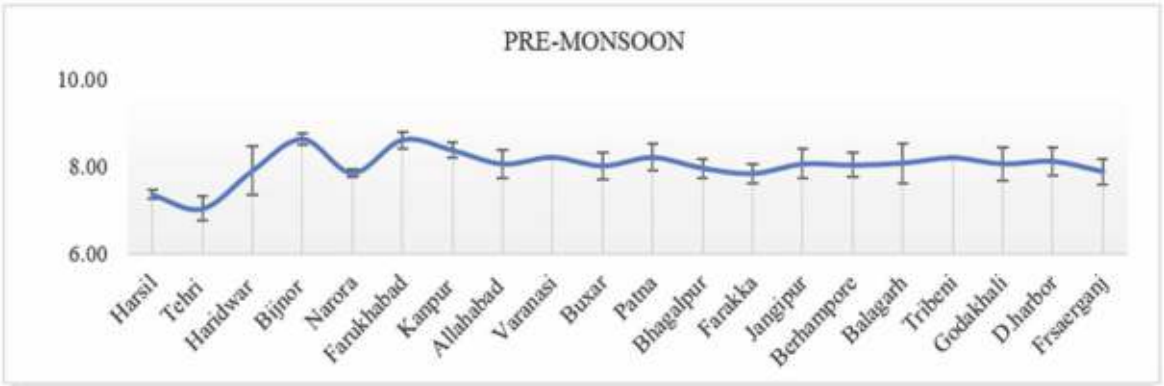
- In the upper stretch an increase in CR was recorded at Bijnor and Farrukhabad while a decrease was observed at Tehri, Haridwar and Narora from 2017 to 2020.
- In the middle stretch an increase in the in CR have been observed at all the stations from 2017 to 2020.
- In the estuarine stretch there was an increase in CR recorded at all the stations from 2017 to 2020.

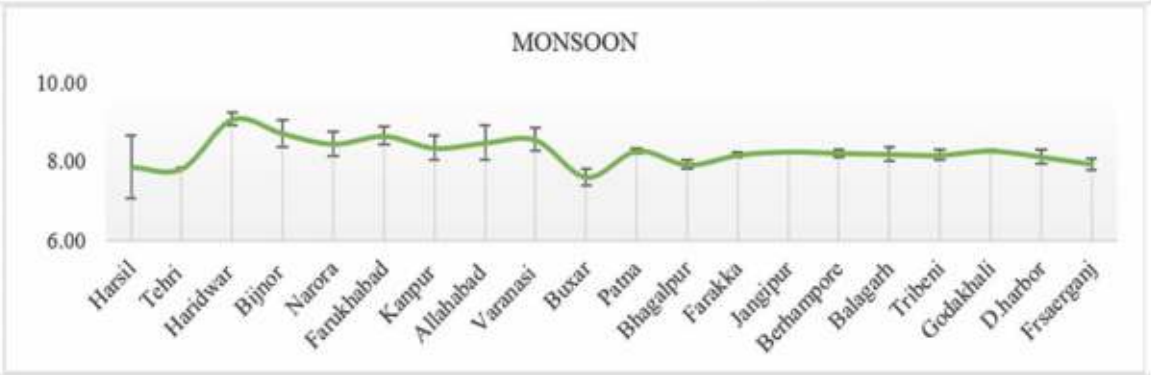
SEDIMENT CHARACTERSTICS

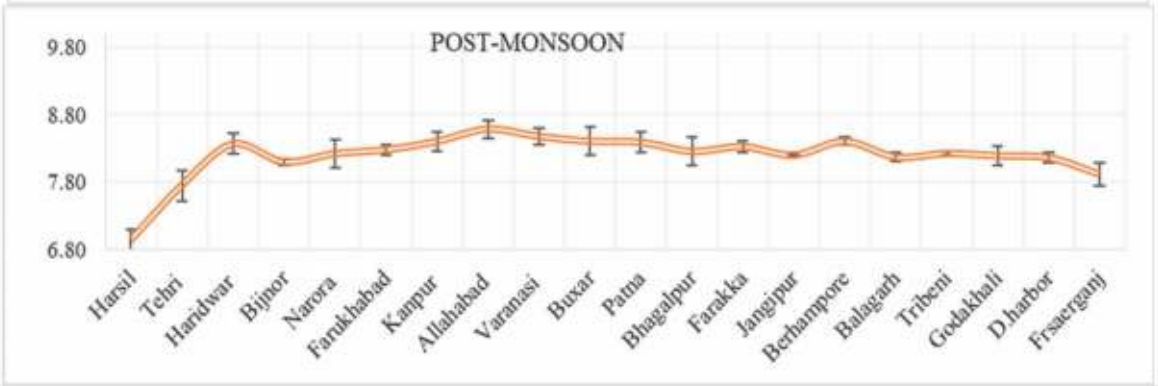


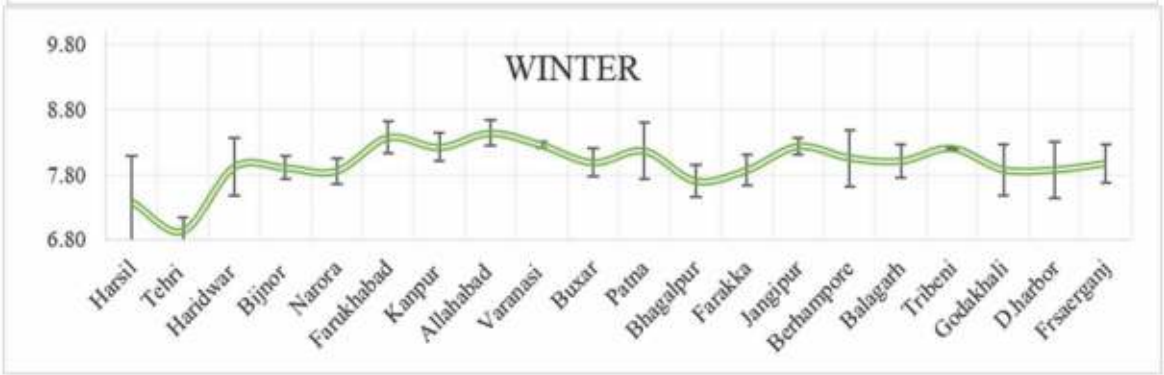
Sediment pH

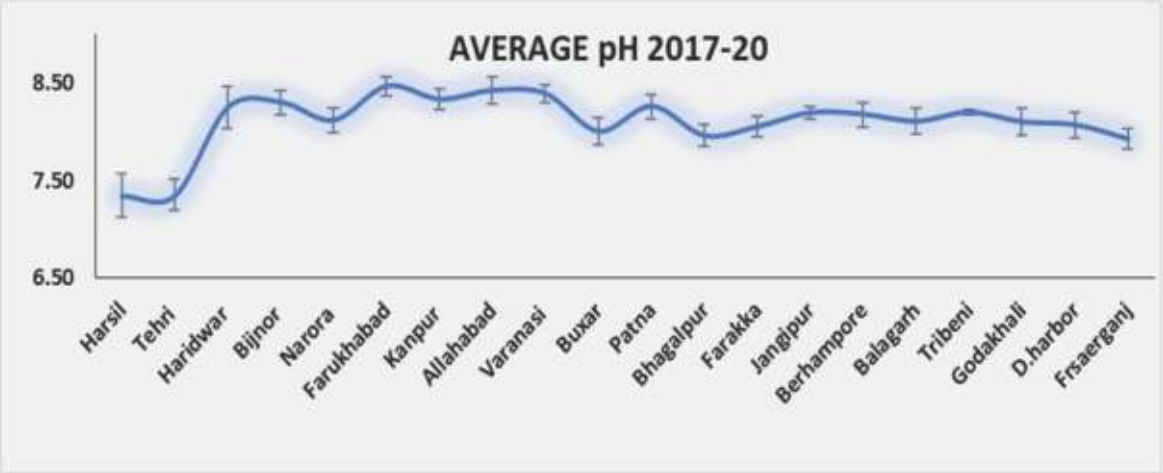
Sediment pH represents the acidity or basicity of the soil. The sediment pH affects the metabolism of many sedentary organisms such as benthic organisms and sedimentary microbes, which ultimately affects the aquatic habit and habitat of the riverine ecosystem.


PRE-MONSOON
10.00
8.00
6.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


MONSOON
10.00
8.00
6.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


POST-MONSOON
9.80
8.80
7.80
6.80
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


WINTER
9.80
8.80
7.80
6.80
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj



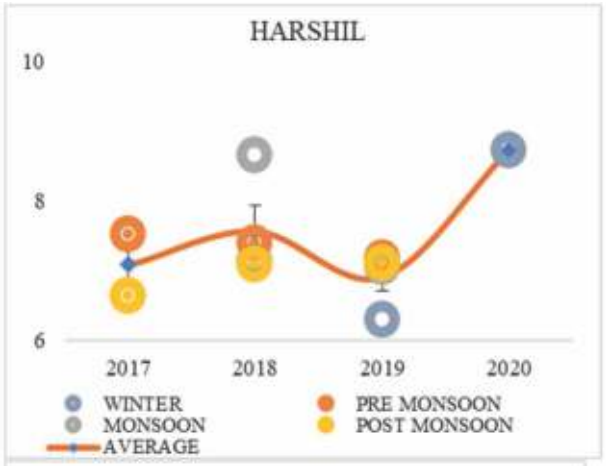
CHANGING PATTERN OF SEDIMENT pH OVER THE YEARS

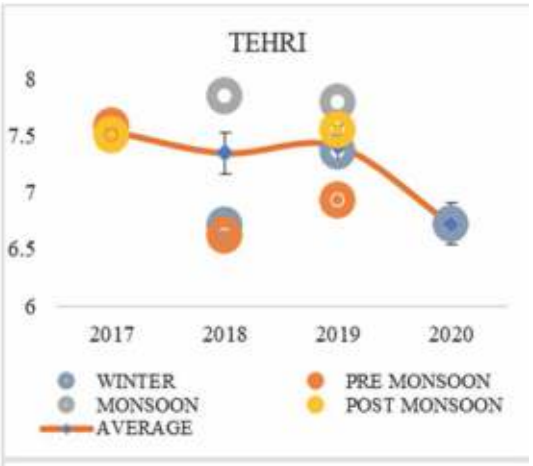
Stretches	Period	pH
Haridwar	2001-2006	7.35
Kanpur	1999	6.7-7.3
Prayagraj	2017-2018	7.24
Varanasi	2014	8.38
Barrackpore	2019	8.1
Diamond Harbor	2019	8.6
Fresarganj	2001-2006	7.85
Gangasagar	2019	7.9

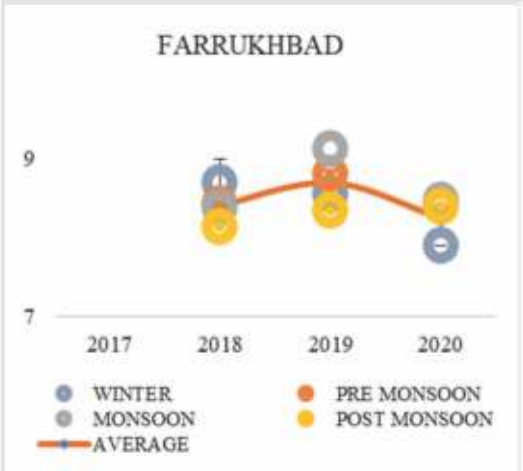
BRIEF DESCRIPTION

The sediment pH in the entire stretch ranges from 7. 30 to 8.46. Highest average pH value of 8.46 was recorded at Farukhabad. During pre-monsoon the average pH value was 8.03. In monsoon, average pH value was 8.25. The average pH value in post monsoon was 8.19. Whereas during Winter average pH value was 7.96. Soil of hilly stretch (Harsil to Tehri) of river Ganga was observed slightly acidic in nature; however, the rest of the stretch from Haridwar to Fraserganj was observed to be alkaline in nature during the study period.

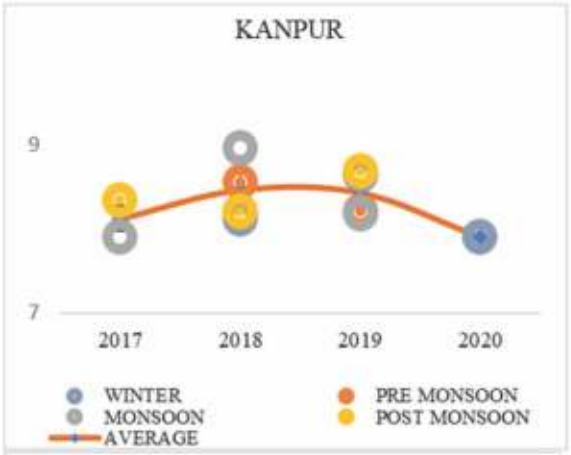
TIMESCALE CHANGES OF SEDIMENT pH IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)

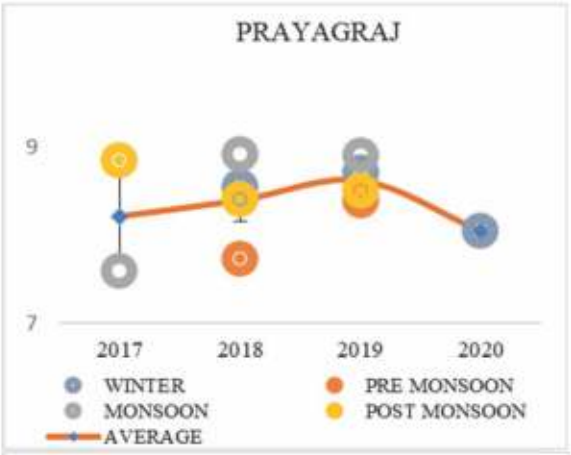


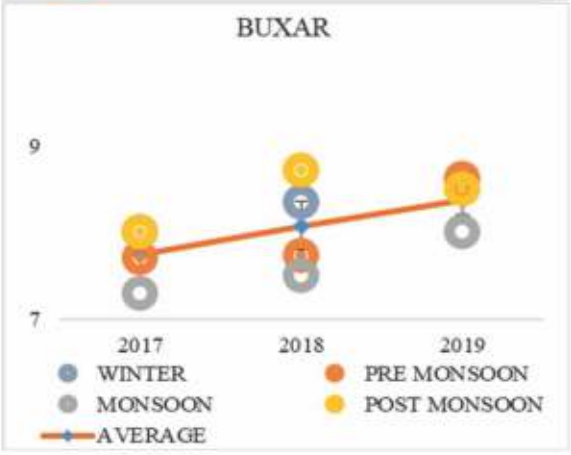


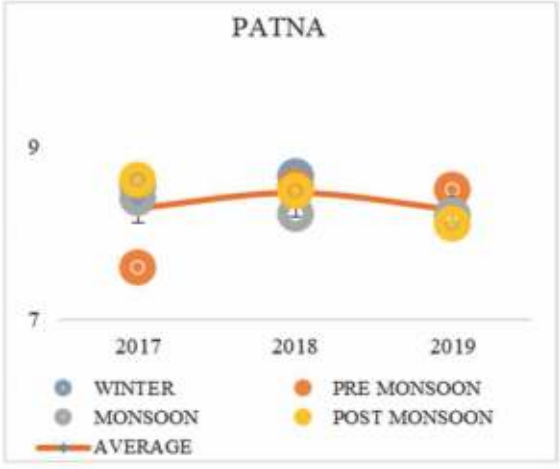


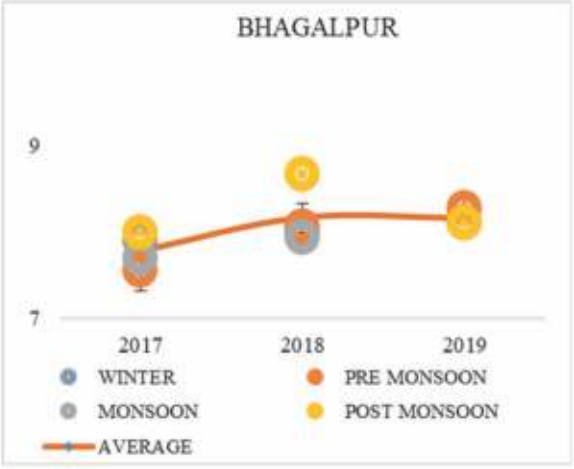
TIMESCALE CHANGES OF SEDIMENT pH IN MIDDLE STRETCH OF RIVER GANGA (2017-2020)



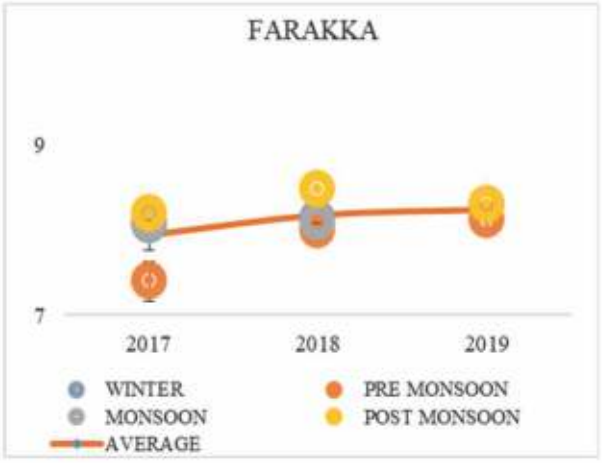


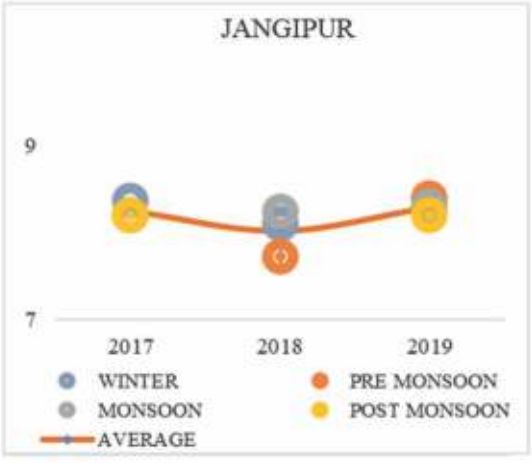


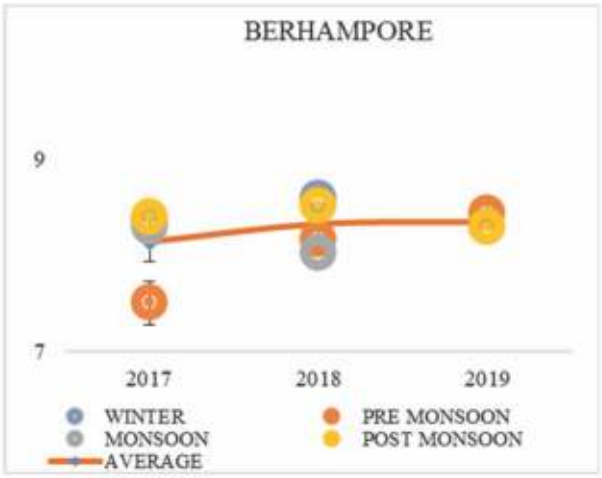


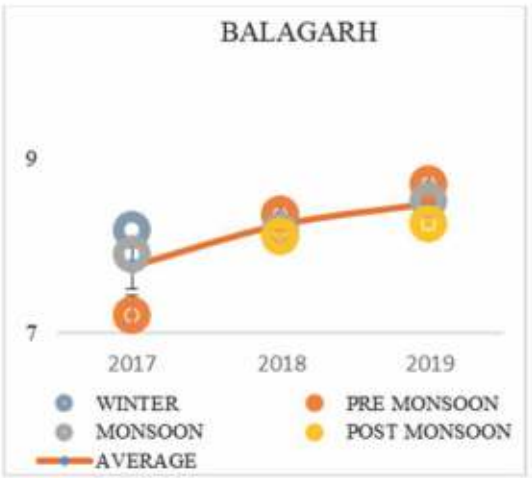


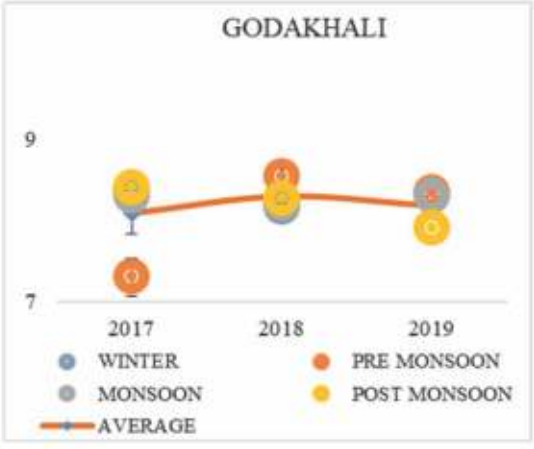
TIME-SCALE CHANGES OF SEDIMENT pH IN LOWER STRETCH OF RIVER GANGA (2017-2019)



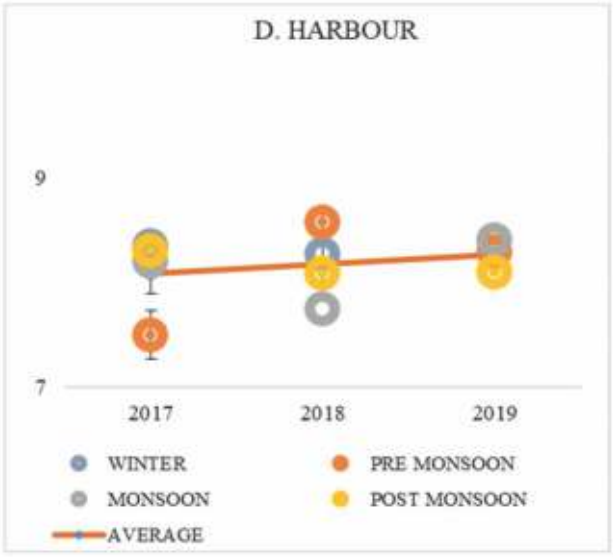


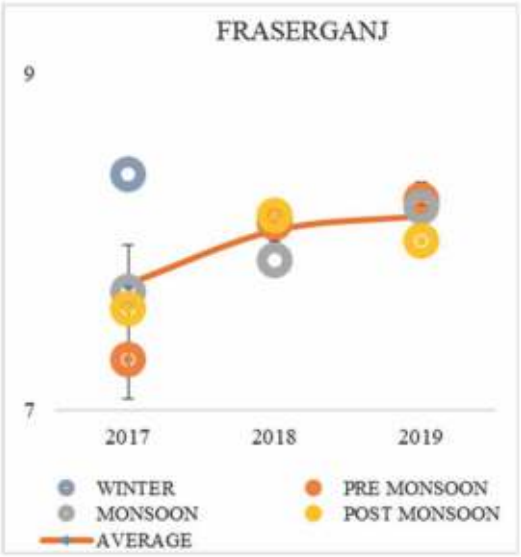






TIMESCALE CHANGES OF SEDIMENT pH IN THE ESTUARINE STRETCH OF RIVER GANGA (2016-2019)



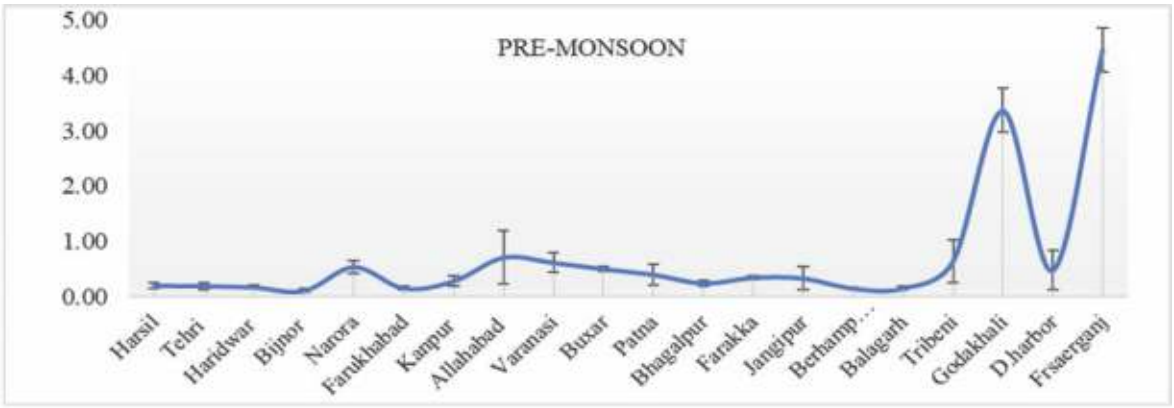


SALIENT TIMESCALE OBSERVATIONS

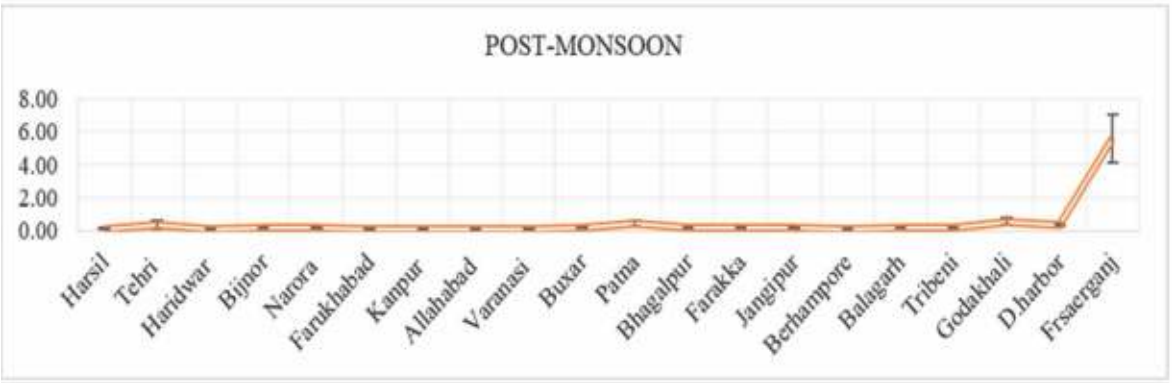
- In the upper stretch, a decrease in sediment pH was recorded at all the sampling stations except at Harshil from 2017 to 2019.
- In the middle stretch, an increase in sediment pH was observed at all the sampling stations except Buxar and Bhagalpur from 2017 to 2019.
- Among the sampling stations of lower stretch an increase in sediment pH was recorded at all the stations except at Godakhali from 2017 to 2019.
- In the estuarine stretch an increase in sediment pH was recorded at all the stations from 2017 to 2019.

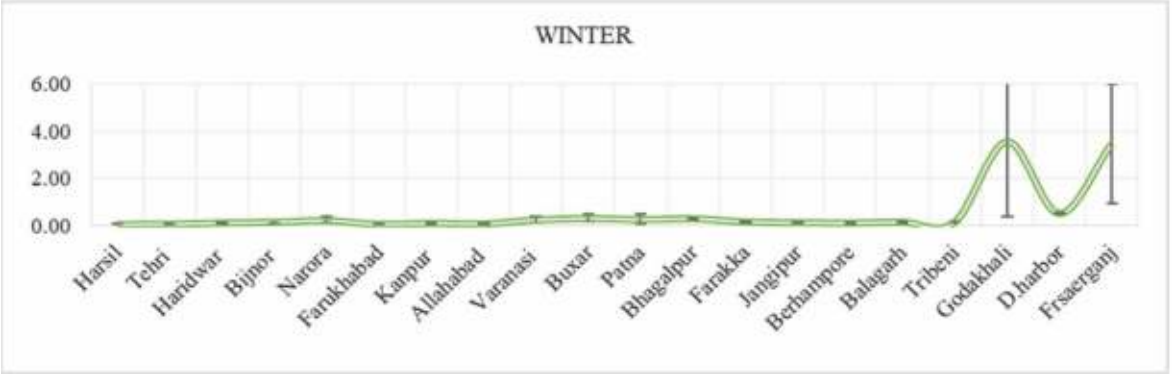
SPECIFIC CONDUCTIVITY (mS/cm)

Specific conductivity of the sediment represents the ability of the soil to conduct electricity via charge transfer. It is important pollution indicating characteristics. The value of specific conductivity depends on many of the abiotic as well as biotic components, such as temperature, deposition of organic wastes etc.


PRE-MONSOON
5.00
4.00
3.00
2.00
1.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhamp…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


MONSOON
8.00
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


POST-MONSOON
8.00
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


WINTER
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
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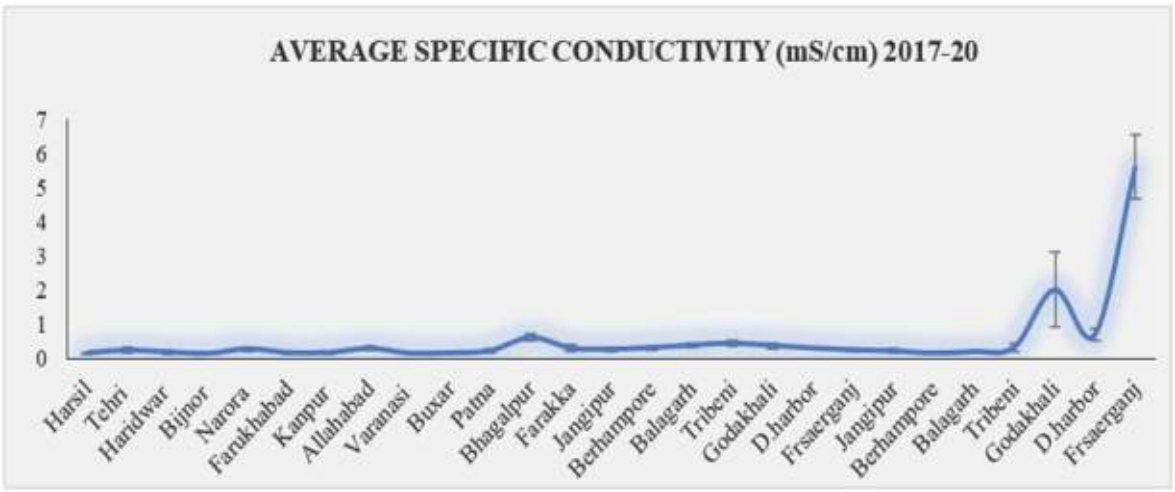
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

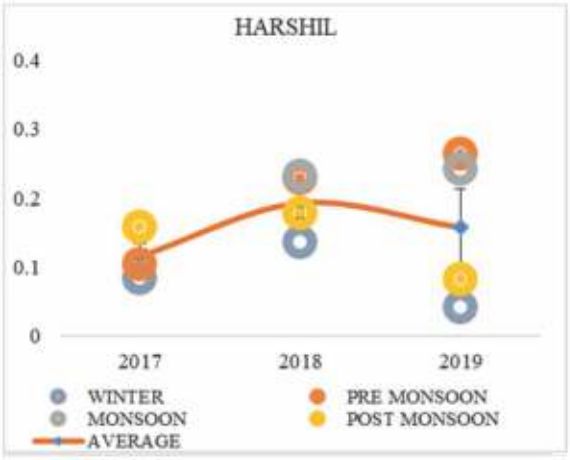


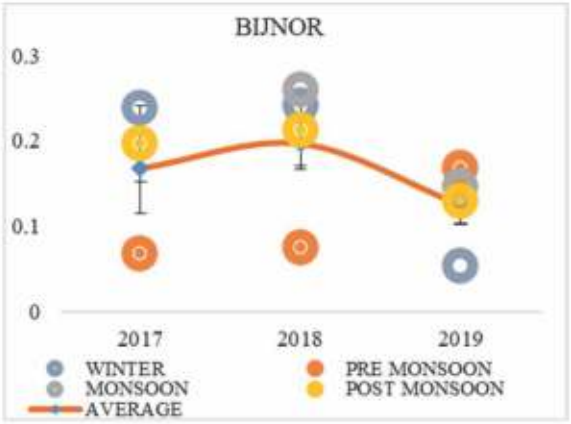
CHANGING PATTERN OF SPECIFIC CONDUCTIVITY (mS/cm) OVER THE YEARS		
Stretches	Period	EC
Haridwar	2001-2006	0.09
	2017-2018	0.40
	2014	0.07
Fraserganj	2001-2006	0.23

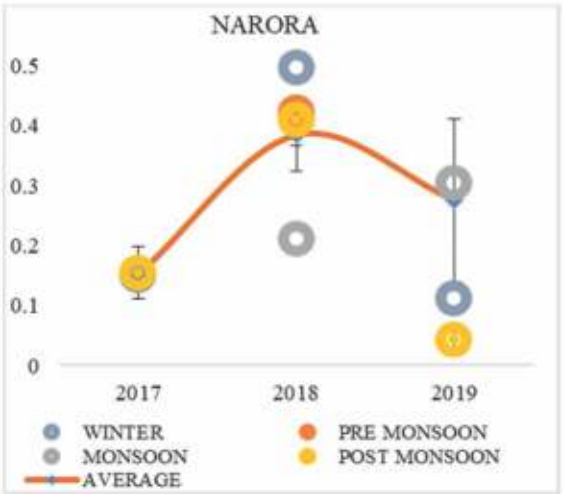
BRIEF DESCRIPTION

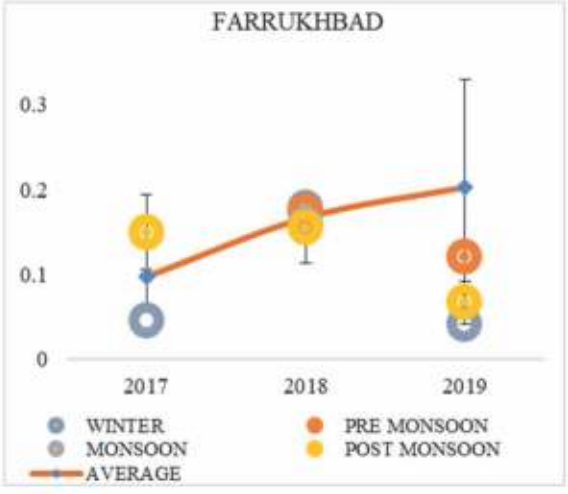
The specific conductivity in the entire stretch ranged from 0.14 to 5.59 mS/cm. The highest average sp. conductivity value was 5.59 mS/cm recorded at Fraserganj. During Pre-monsoon, the average specific conductivity value was 0.70 mS/cm. In monsoon the average specific conductivity value was 0.75 mS/cm. The average specific conductivity value during Post monsoon was 0.48 mS/cm. whereas, during Winter average specific conductivity value was 0.54 mS/cm. Higher values of specific conductivity were observed in estuarine zone due to the intrusion of seawater during high tide.

TIMESCALE CHANGES OF SEDIMENT SPECIFIC CONDUCTIVITY (mS/cm) IN THE UPPER STRETCH OF RIVER GANGA (2017-2019)

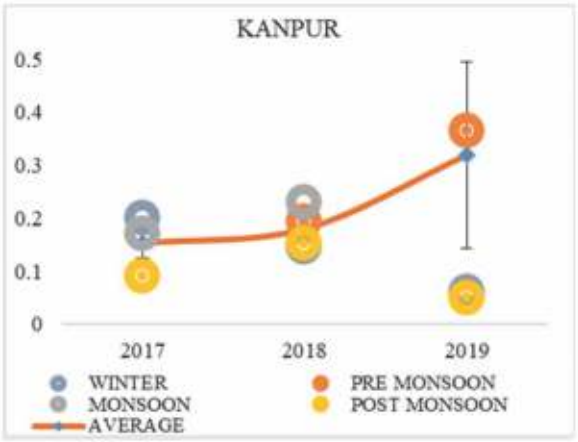


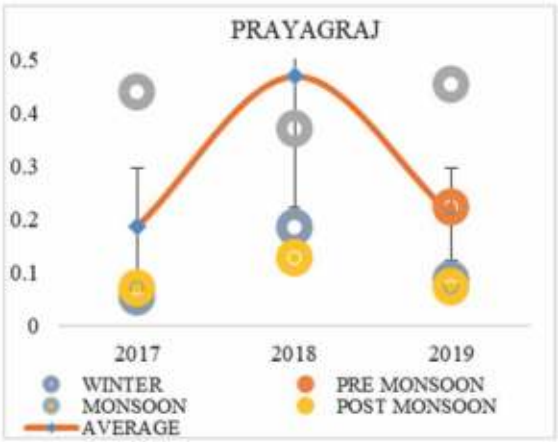


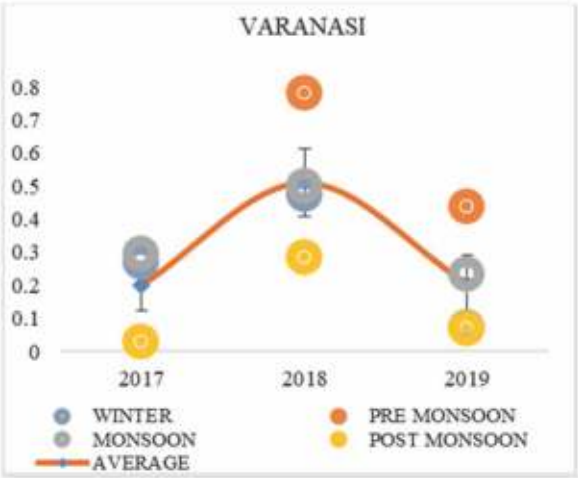


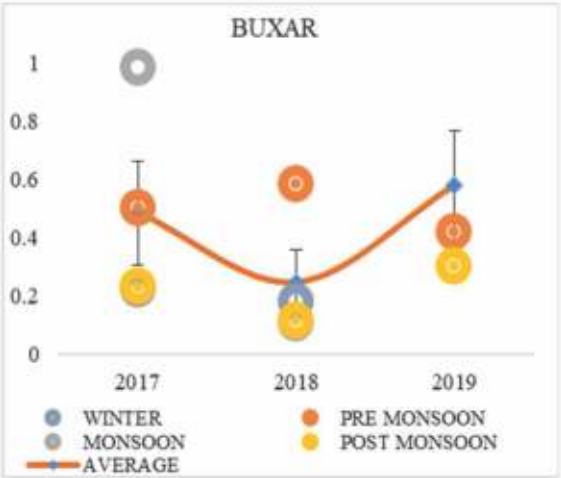


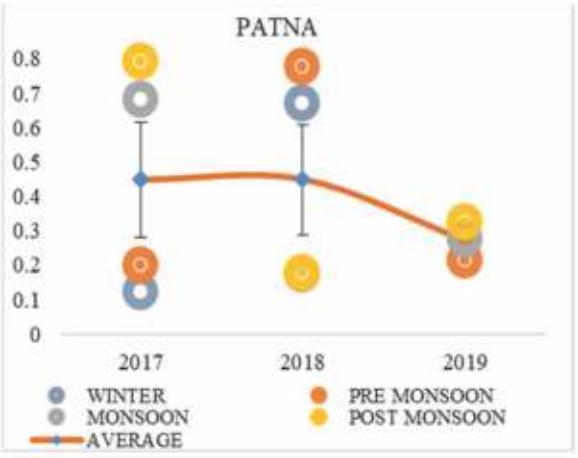
TIMESCALE CHANGES OF SEDIMENT SPECIFIC CONDUCTIVITY (mS/cm) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2019)

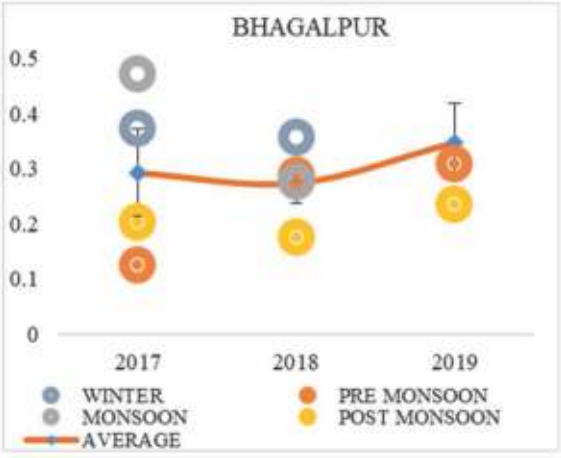




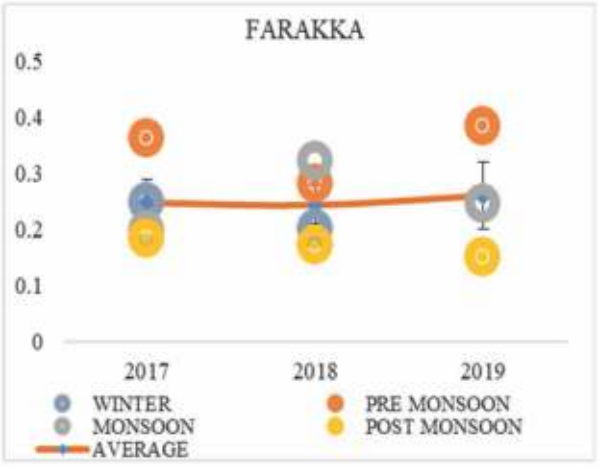


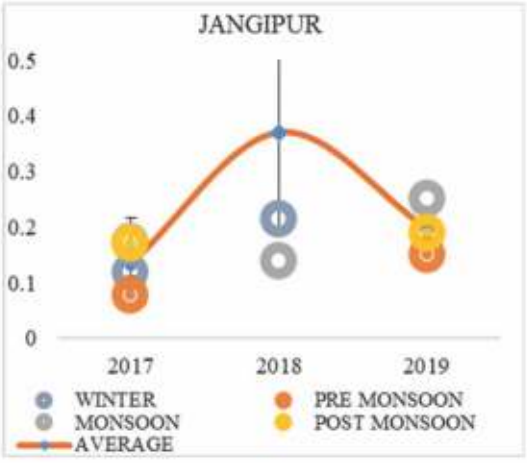


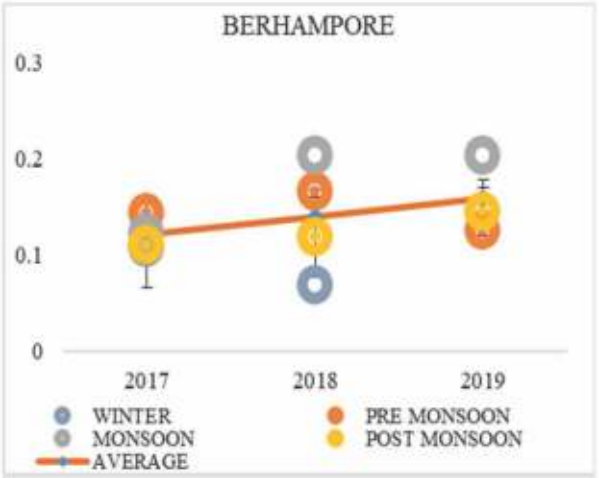


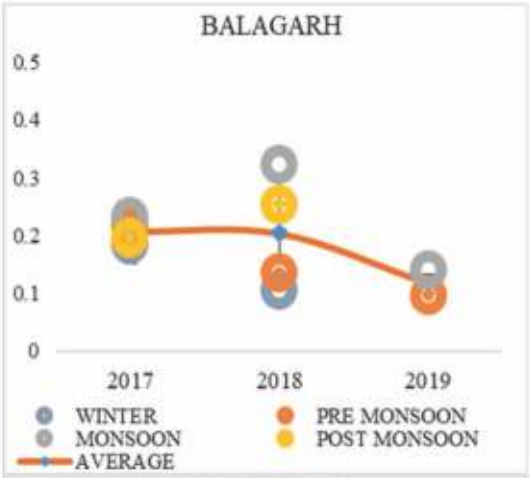


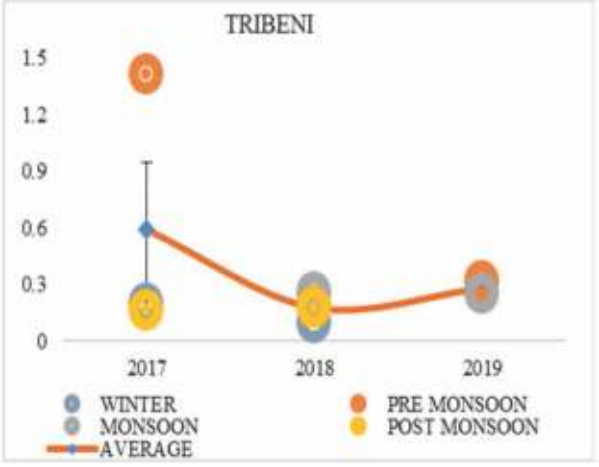
TIME-SCALE CHANGES OF SEDIMENT SPECIFIC CONDUCTIVITY (mS/cm) IN THE LOWER STRETCH OF RIVER GANGA (2017-2019)

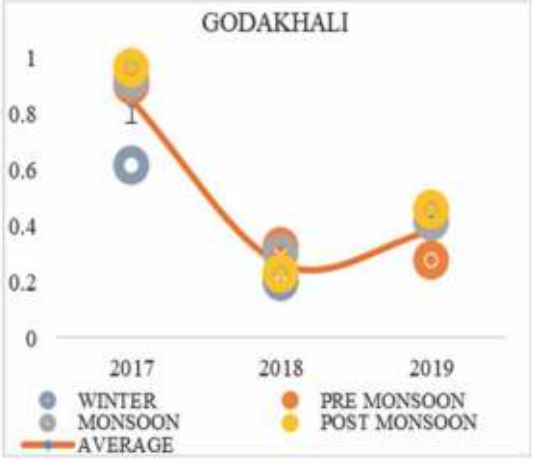




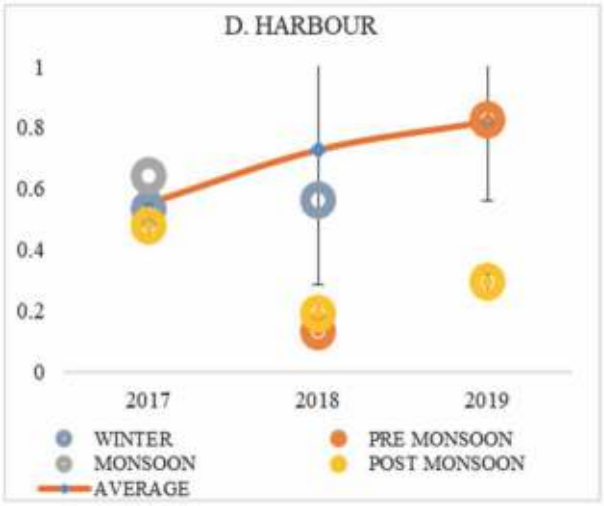


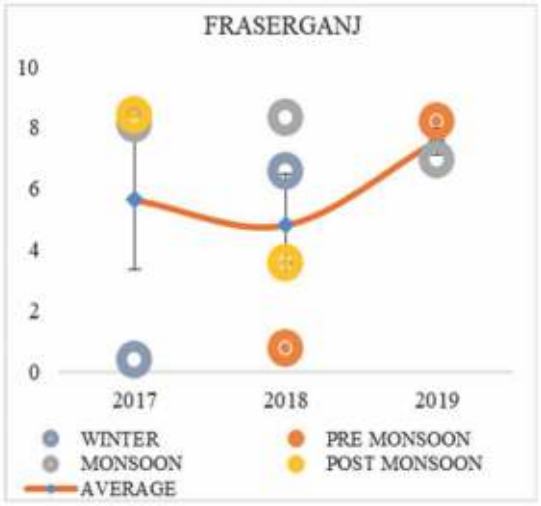






TIMESCALE CHANGES OF SPECIFIC CONDUCTIVITY (mS/cm) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)



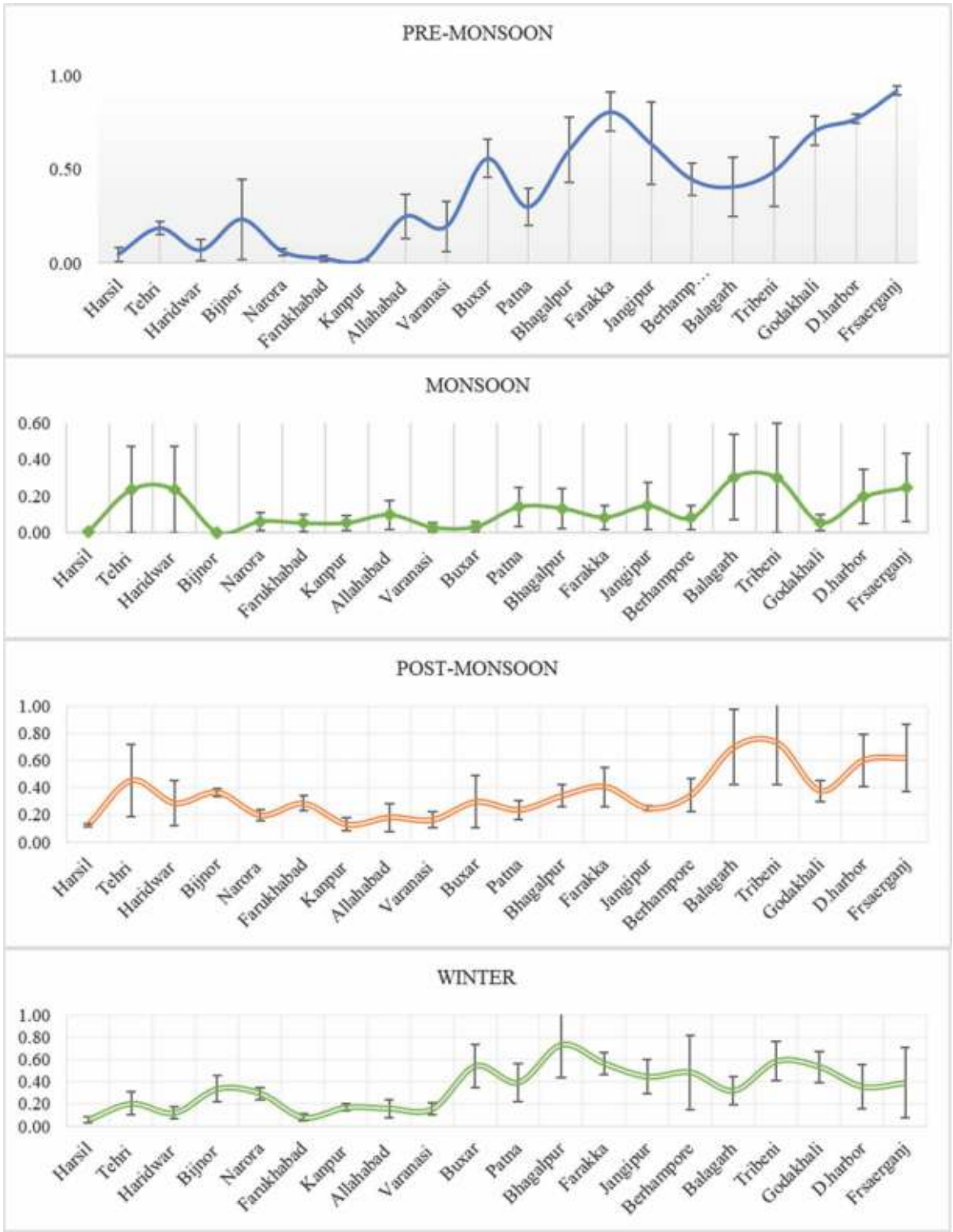


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch an increasing trend in specific conductivity was recorded at all the sampling sites except at Tehri and Bijnor from 2017 to 2019.
- In the middle stretch, also an increasing trend of specific conductivity has been observed at Kanpur, Buxar and Bhagalpur while decreasing trend was observed at Patna from 2017 to 2019.
- Among the sampling stations of lower stretch, an increase in specific conductivity was recorded at Farakka, Jangipur and Berhampore while a decrease was observed at Balagarh, Tribeni, and Godakhali from 2017 to 2019.
- In the estuarine stretch, an increase in sediment specific conductivity was recorded at all the stations from 2017 to 2019.

ORGANIC CARBON (%)

Sediment organic matter is percentage of organic matter in the form of organic carbon compound. The organic carbon in the river sediment is mainly due to aquatic macrophytes, microbes, phytoplankton and zooplankton, however along with all these organisms there are multiple factors such as sewage effluents and detritus also makes significant impact on increasing the sediment organic carbon. The parameter is the important pollution indicating parameter.


PRE-MONSOON
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0.50
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhamp…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
MONSOON
0.60
0.40
0.20
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
POST-MONSOON
1.00
0.80
0.60
0.40
0.20
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
WINTER
1.00
0.80
0.60
0.40
0.20
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
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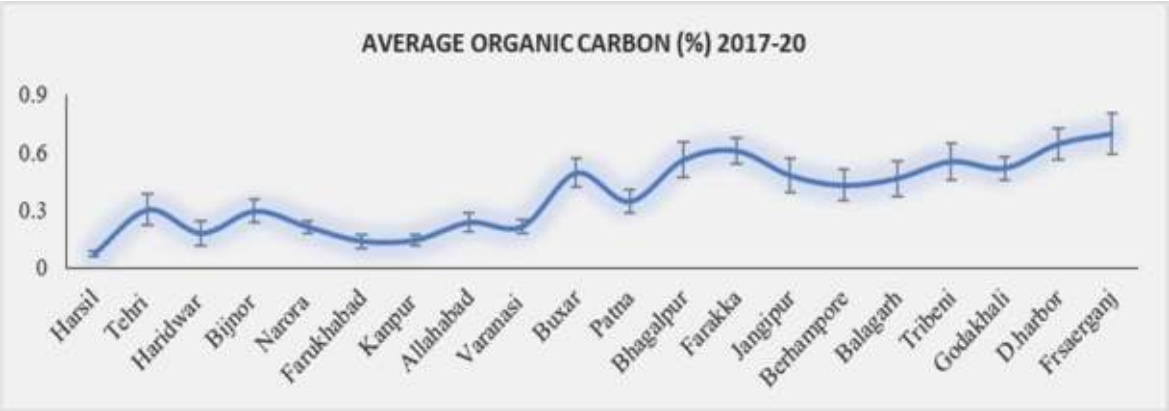
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

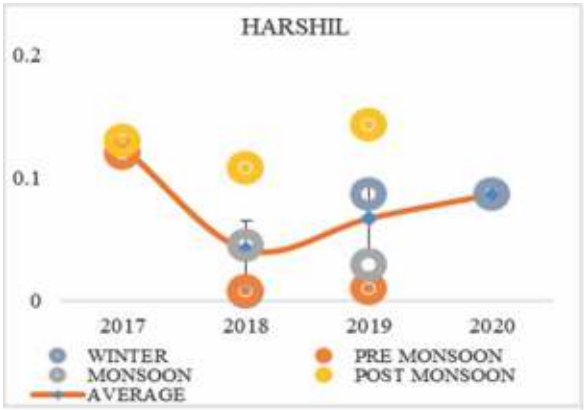


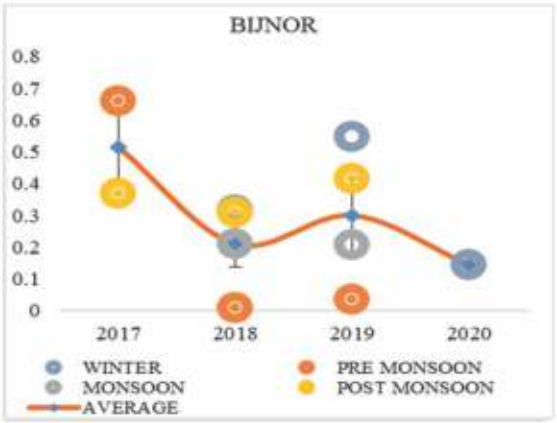
CHANGING PATTERN OF ORGANIC CARBON (%) OVER THE YEARS		
Haridwar	2001-2006	0.04
Prayagraj	2017-2018	0.36
Farakka	2001-2006	0.4
Barrackpore	2019	0.7
Diamond Harbour	2019	0.7
Gangasagar	2019	0.6

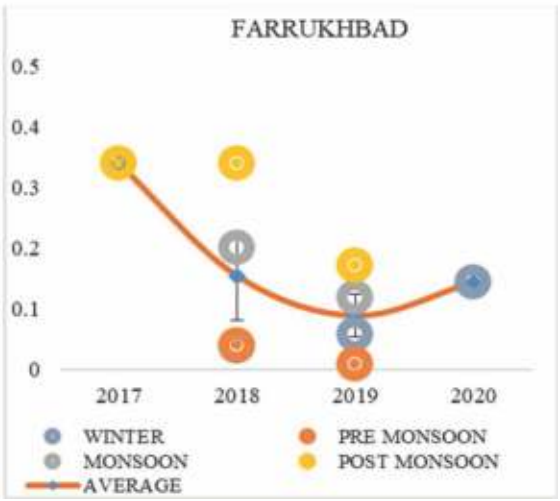
BRIEF DESCRIPTION

The organic carbon of sediment in the entire stretch ranged from 0.07 to 0.69 %. The highest average organic carbon was found 0.69% at Fraserganj stretch of river Ganga. In the pre-monsoon, the average organic carbon value was 0.39%. In monsoon the average organic carbon value was 0.13%. The average organic carbon value in post monsoon was 0.35%. Whereas, during winter average organic carbon value was 0.35%. Organic carbon accumulation in sediment was noted in few locations like Fraserganj due to higher primary productivity.

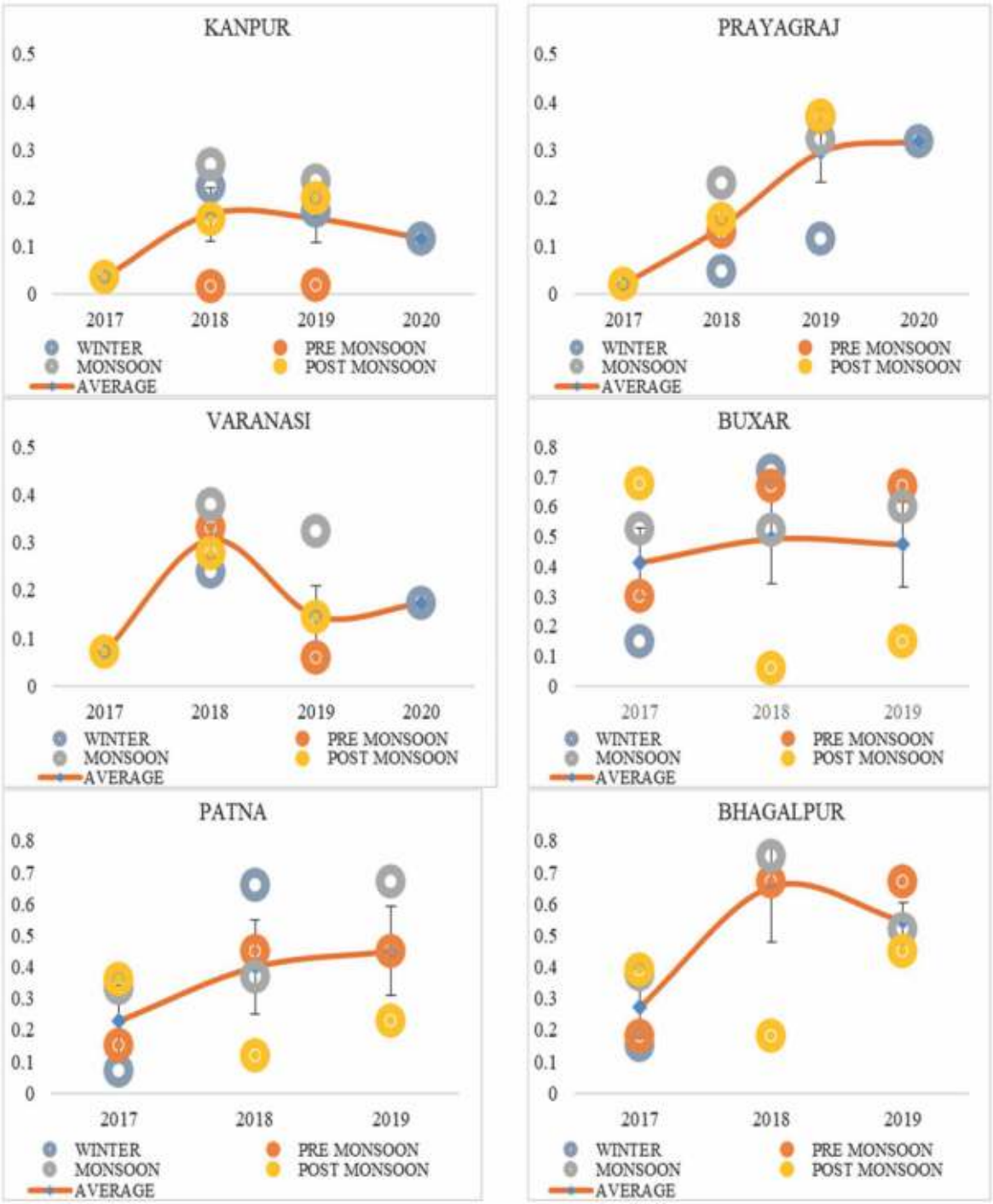
TIMESCALE CHANGES OF SEDIMENT ORGANIC CARBON (%) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)



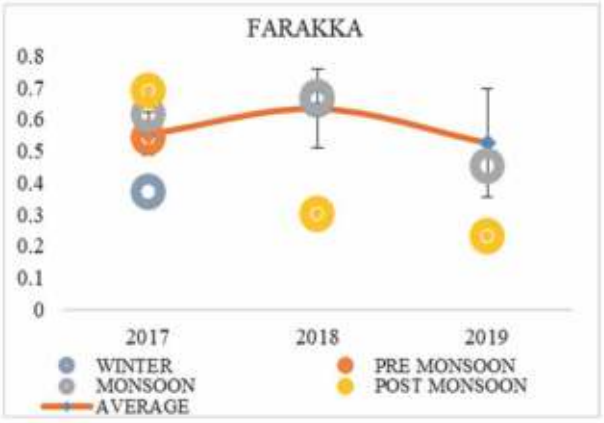


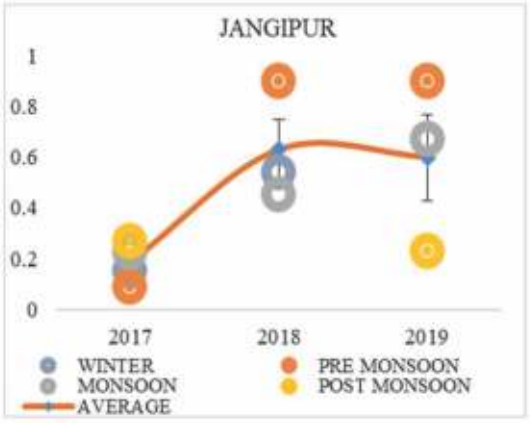


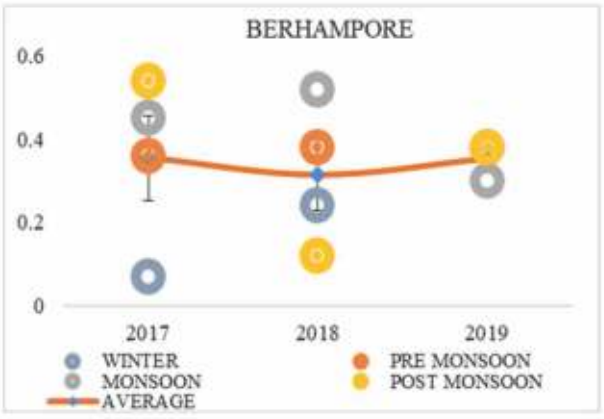
TIMESCALE CHANGES OF SEDIMENT ORGANIC CARBON (%) IN THE MIDDLE STRETCH RIVER GANGA (2017-2020)

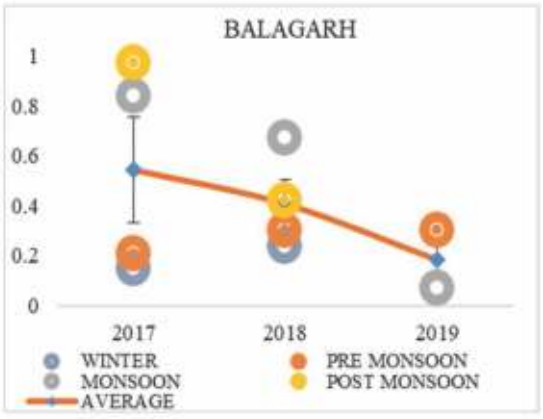


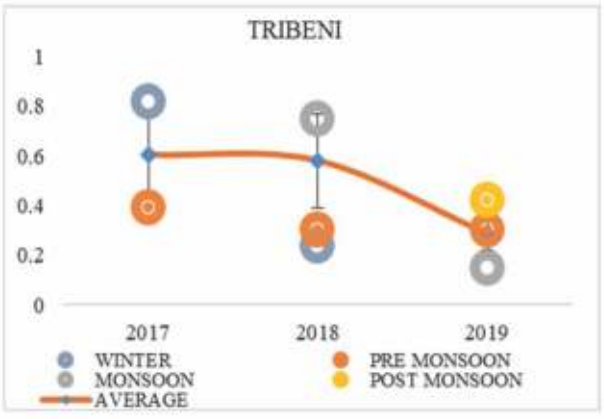
TIME-SCALE CHANGES OF SEDIMENT ORGANIC CARBON (%) IN THE LOWER STRETCH RIVER GANGA (2017-2019)

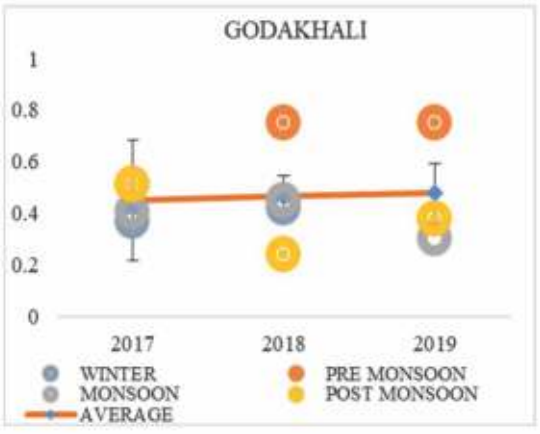




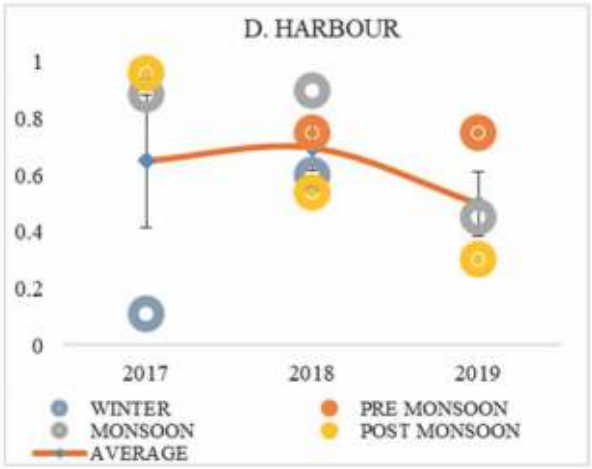


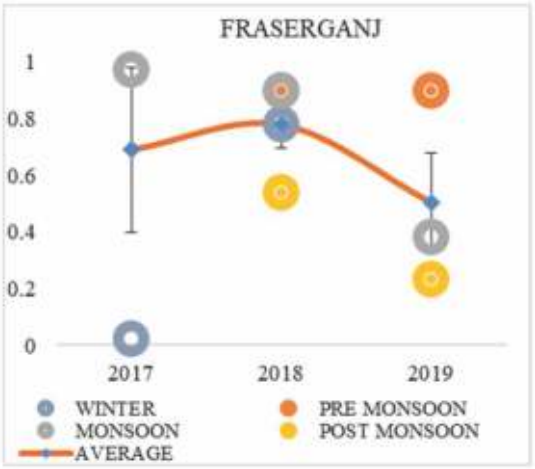






TIMESCALE CHANGES OF ORGANIC CARBON (%) IN THE ESTUARINE STRETCH RIVER GANGA (2017-2019)



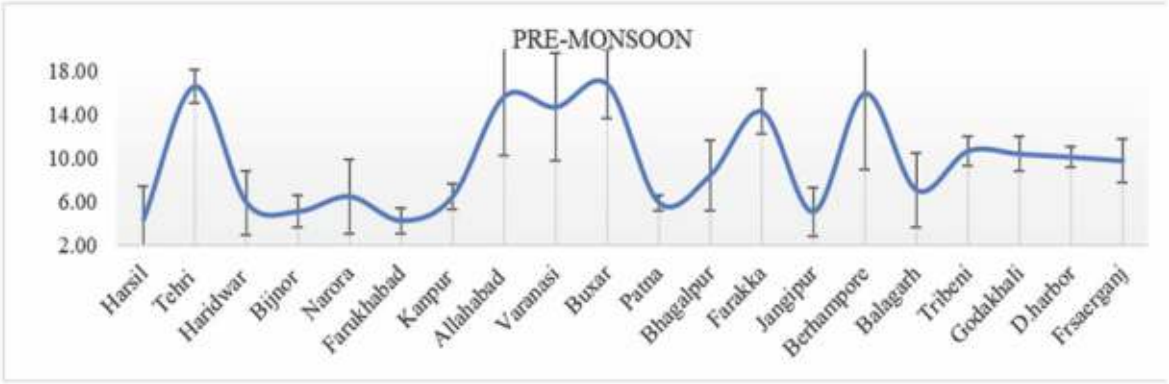


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch, a decrease in organic carbon percentage have been recorded at all the stations except at Narora from 2017 to 2019.
- In the middle stretch, an increase in organic carbon percentage was observed at all the stations from 2017 to 2019.
- Among the sampling stations of lower stretch, a decrease in organic carbon percentage has been recorded at Farakka, Balagarh and Tribeni while an increase was observed at Jangipur, Berhampore, and Godakhali from 2017 to 2019.
- In the estuarine stretch, a decrease in organic carbon percentage was recorded at all the stations from 2017 to 2019.

Available Nitrogen (mg/100g)

Sediment available nitrogen is the form of nitrogen available in the form mineral (nitrate and ammonium), The availability of available N in the sediment increases the productivity of the sediment by affecting the plankton and periphyton density in the river ecosystem.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10.00
6.00
2.00
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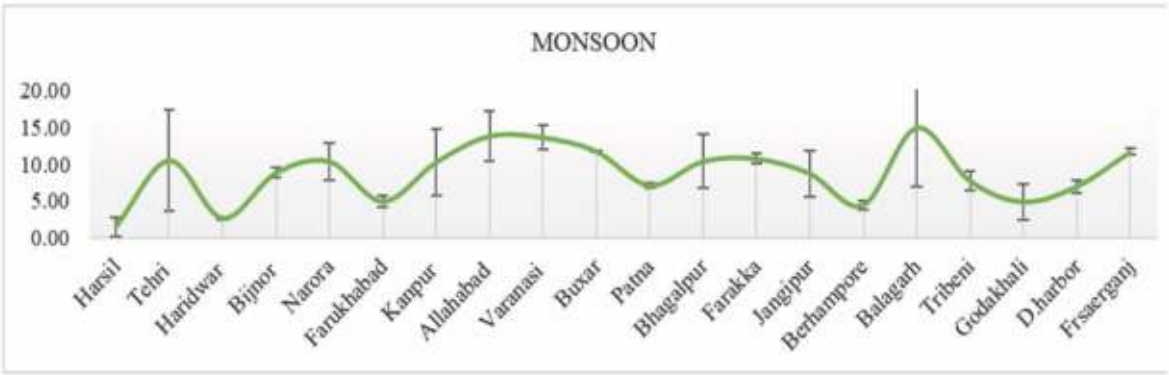
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj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15.00
10.00
5.00
0.00
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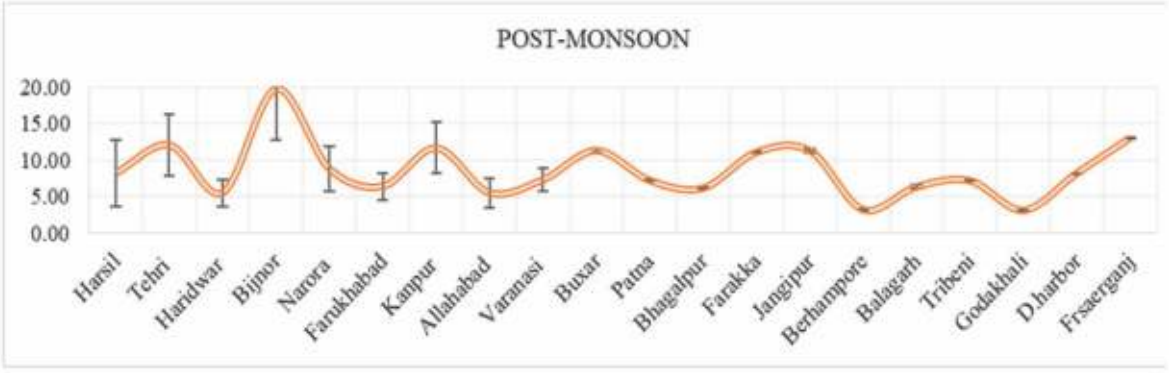
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj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10.00
5.00
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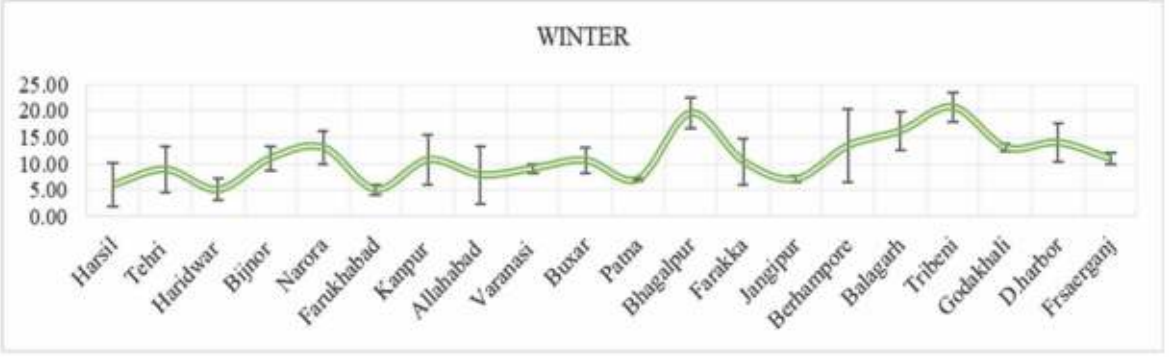
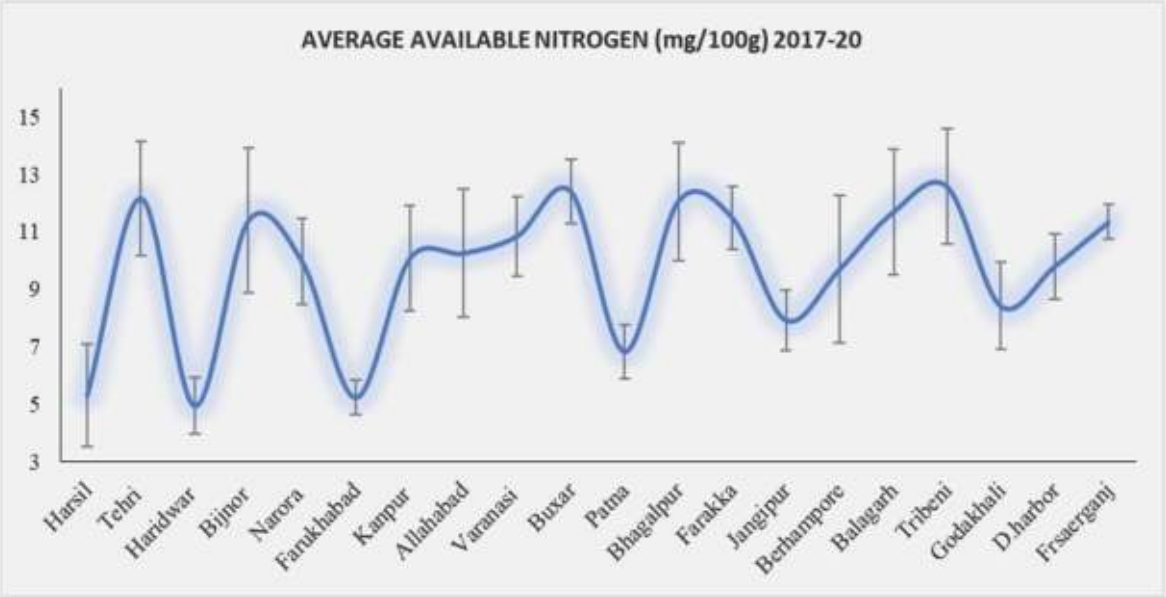
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

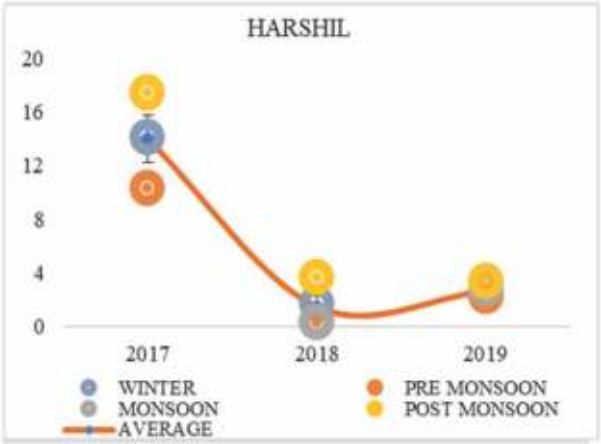

WINTER
25.00
20.00
15.00
10.00
5.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

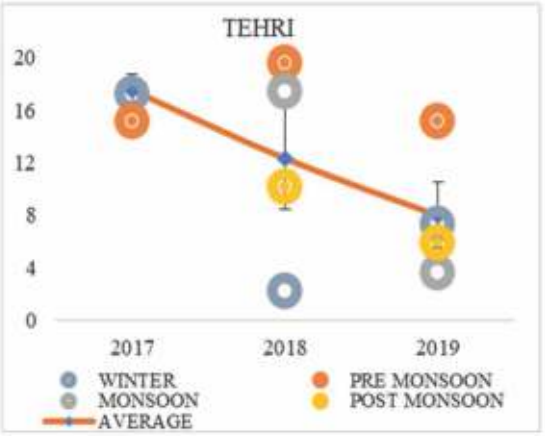


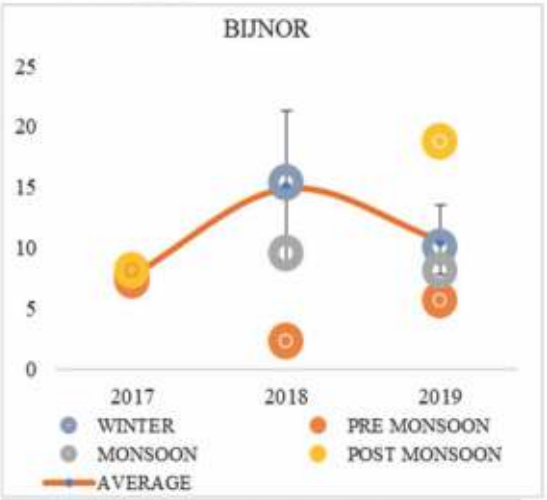
BRIEF DESCRIPTION

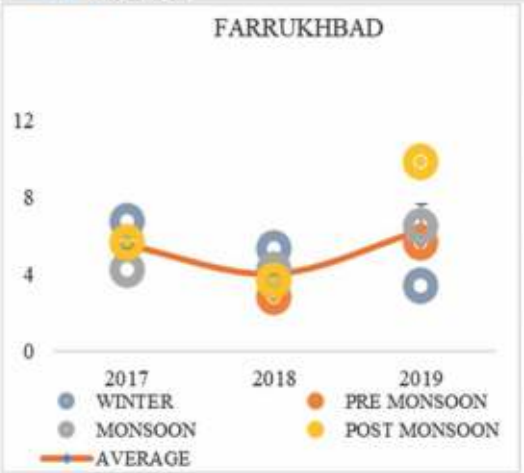
The sediment available nitrogen in the entire stretch ranged from 4.9 to 12.56 mg/100g. Highest average available N value at 12.56 mg/100g was recorded at Tribeni. In pre-monsoon the average available N value was 9.67 mg/100g. During monsoon the average available N value was 8.79 mg/100g. The average available N value during Post Monsoon was 8.62 mg/100g. While, in winter average available N value was 11.02 mg/100g. Low available N might be attributed to predominantly sandy character of river Ganga.

TIMESCALE CHANGES OF SEDIMENT AVAILABLE NITROGEN (mg/100g) IN THE UPPER STRETCH OF RIVER GANGA (2017-2019)

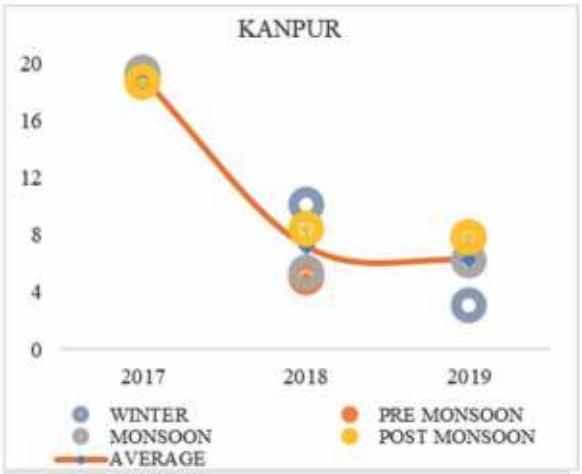


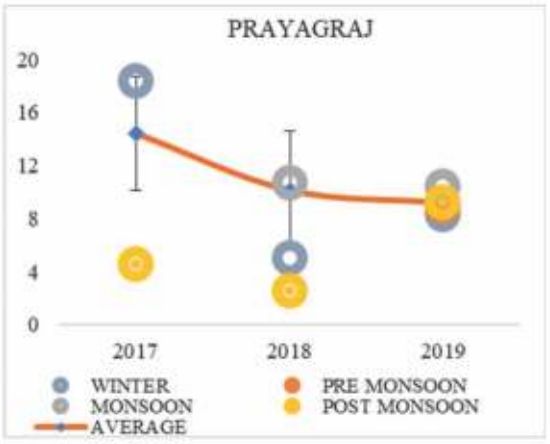


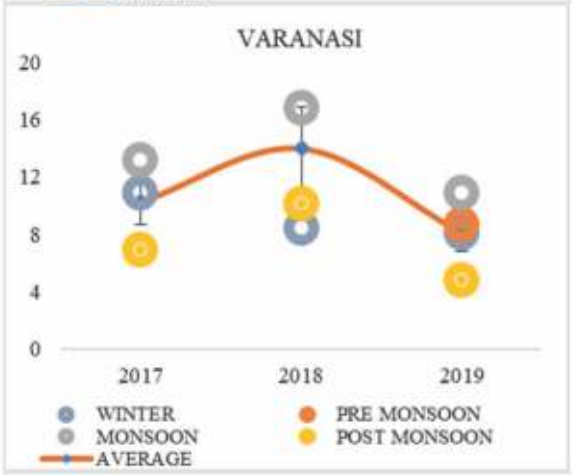


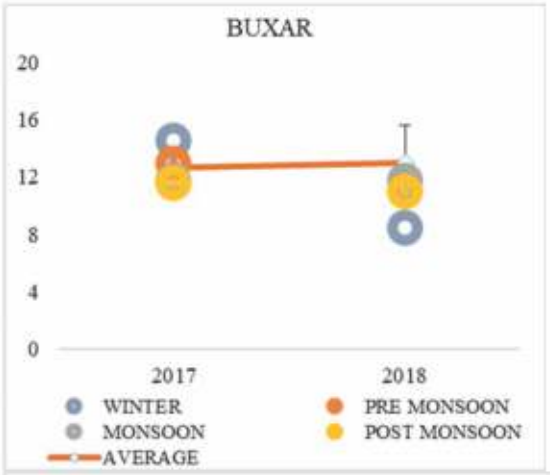


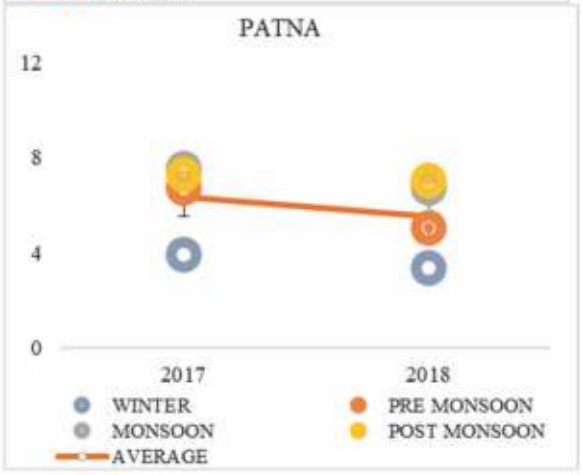
TIMESCALE CHANGES OF SEDIMENT AVAILABLE NITROGEN (mg/100g) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2019)

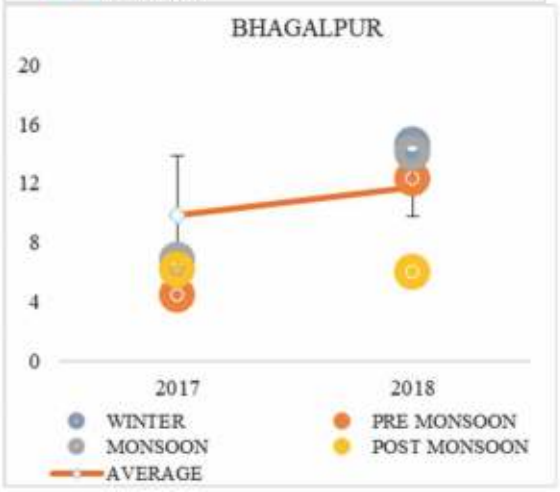




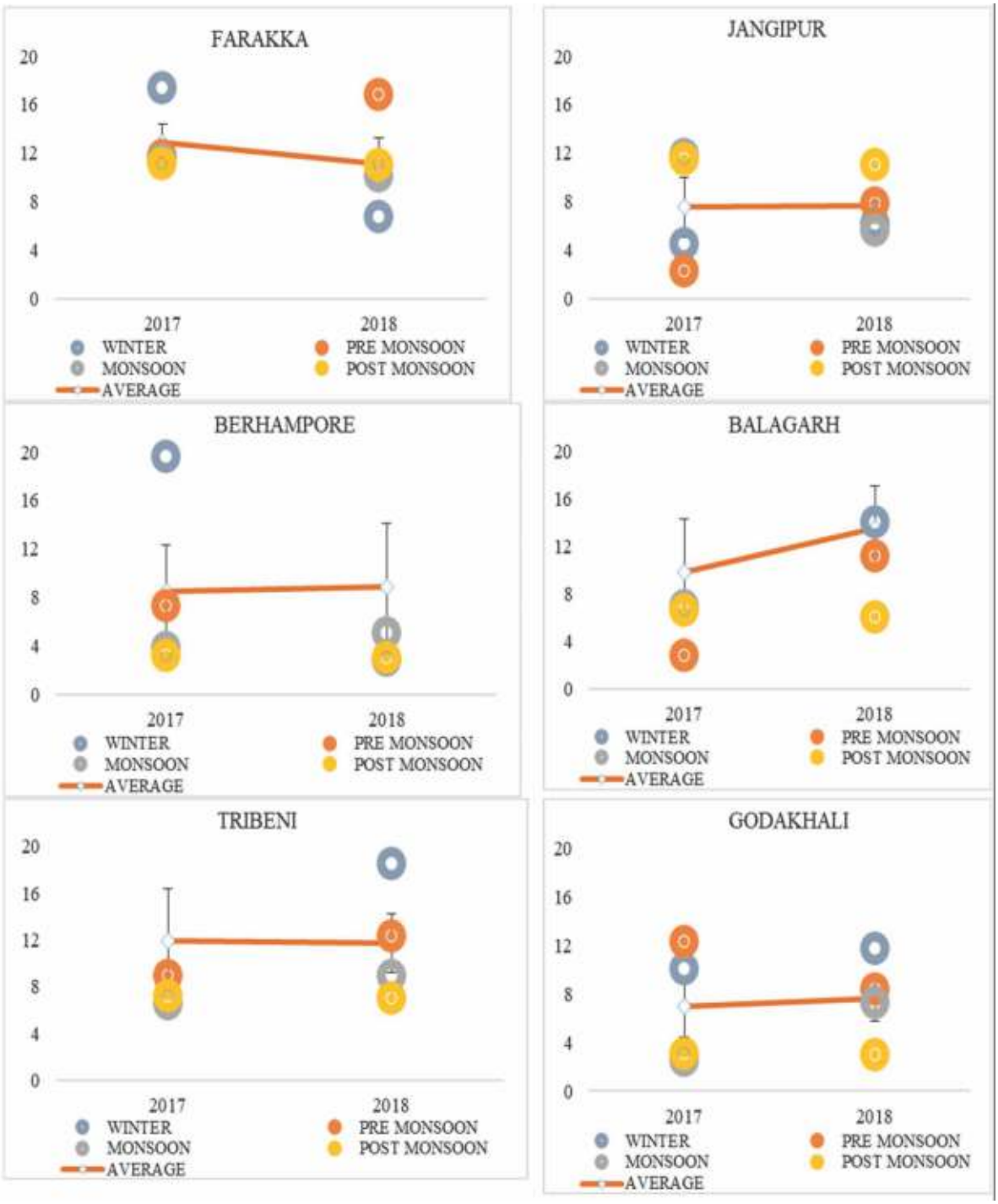




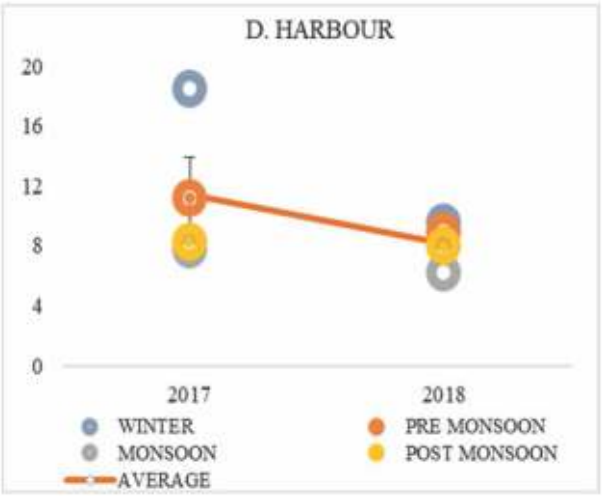


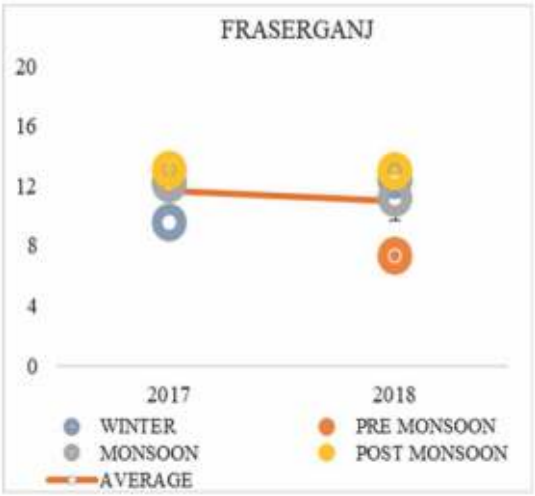


TIME-SCALE CHANGES OF SEDIMENT AVAILABLE NITROGEN (mg/100g) IN THE LOWER STRETCH OF RIVER GANGA (2017-2018)



TIMESCALE CHANGES OF AVAILABLE NITROGEN (mg/100g) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2018)



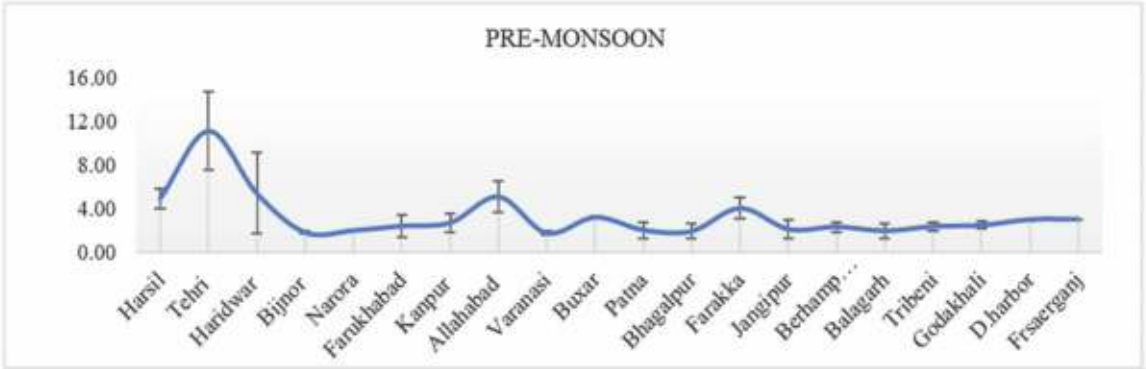


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch, a decrease in available N percentage was recorded at all the stations except at Bijnor and Farrukhabad from 2017 to 2018.
- In the middle stretch, a decrease in available N percentage was observed at all the stations except at Buxar and Bhagalpur from 2017 to 2018.
- Among the sampling stations of lower stretch decrease in available N percentage was recorded at Farakka, and Tribeni while increase was observed at Jangipur, Berhampore, Balagarh and Godakhali from 2017 to 2018.
- In the estuarine stretch a decrease in available N percentage have been recorded at all the stations from 2017 to 2018.

Available Phosphorus (mg/100g)

Sediment available phosphorus is the fraction of available P in the sediment. It is important nutrient help in increasing riverine productivity. The available P is available for the periphyton and phytoplankton which help in increasing river productivity.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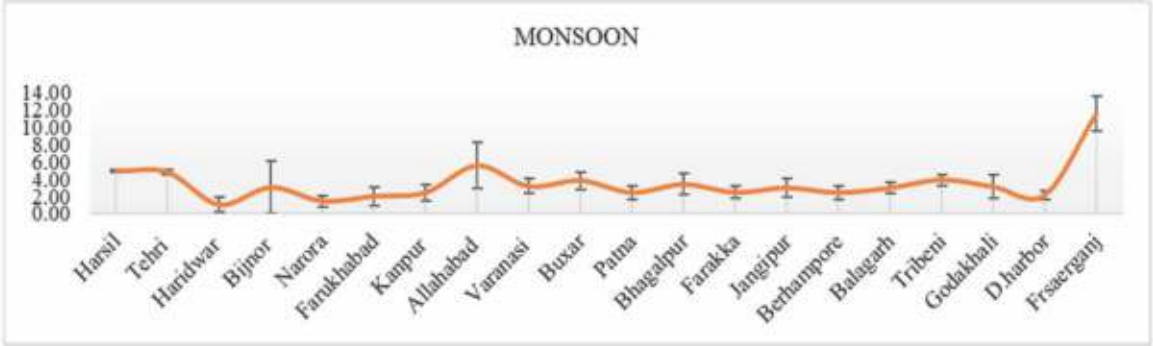
12.00
8.00
4.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhamp…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


MONSOON
14.00
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10.00
8.00
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
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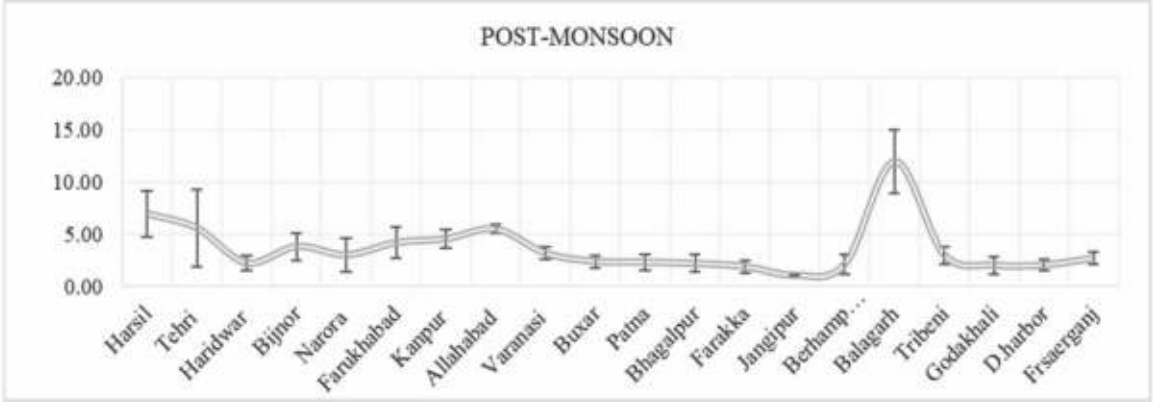
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


POST-MONSOON
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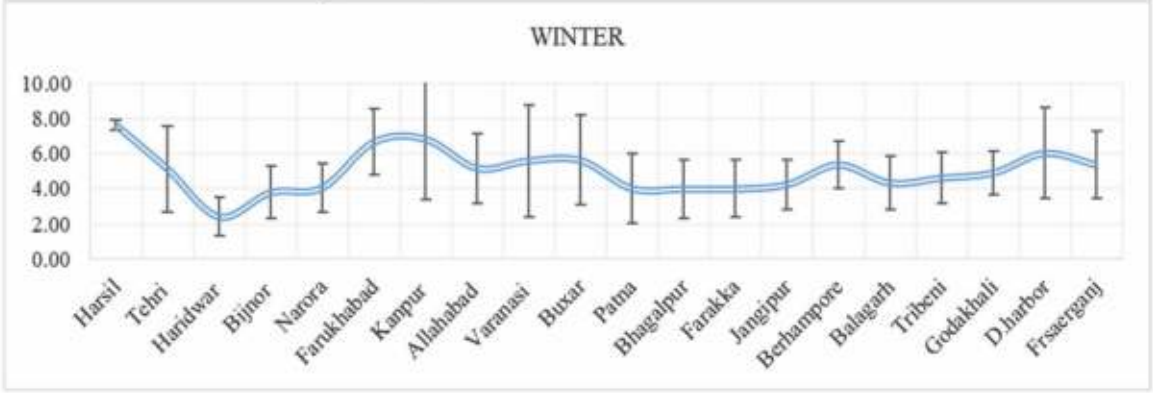
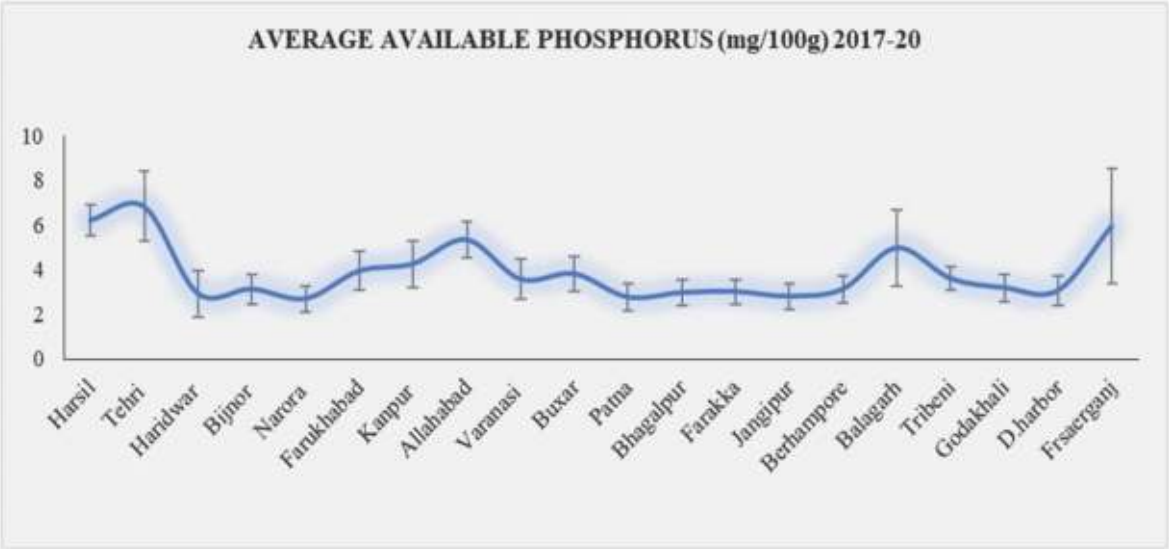
10.00
5.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhamp…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

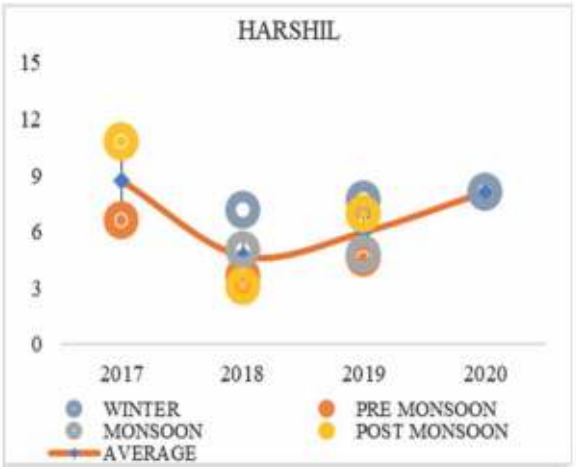

WINTER
10.00
8.00
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

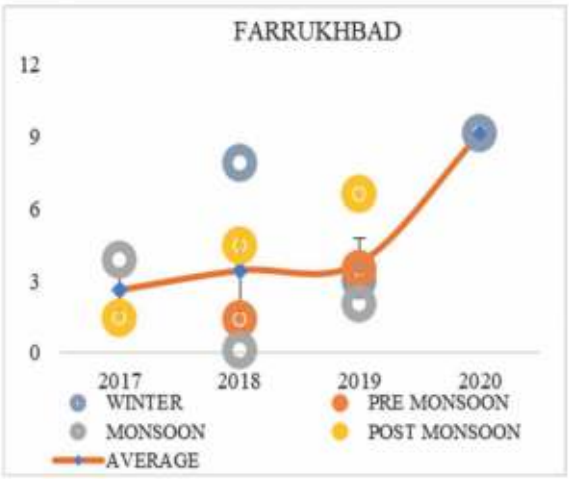


BRIEF DESCRIPTION

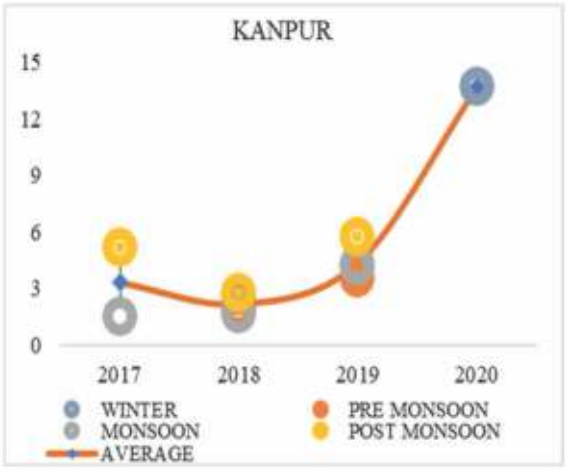
The Available phosphorus of sediment in the entire stretch ranged from 2.68 to 6.83 mg/100g. Highest average available P at 6.83 mg/100g was recorded at Tehri. In pre-monsoon, the average available phosphorus value was 3.30 mg/100g. In monsoon the average available P value was 3.47 mg/100g. The average available phosphorus value in post monsoon was 3.61 mg/100g. While, in winter, average available phosphorus value was 5 mg/100g. Low available P might be attributed to predominantly sandy character of river Ganga.

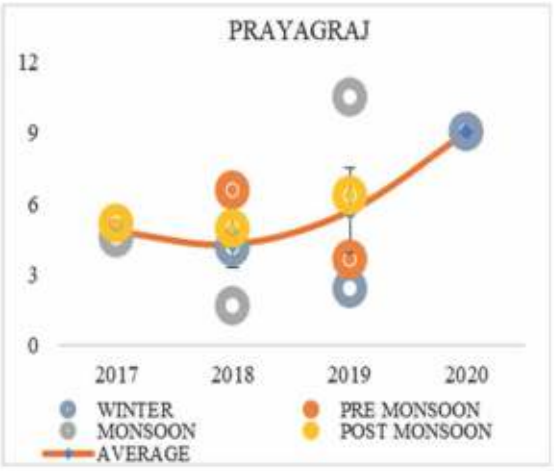
TIMESCALE CHANGES OF SEDIMENT AVAILABLE PHOSPHORUS (mg/100g) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)



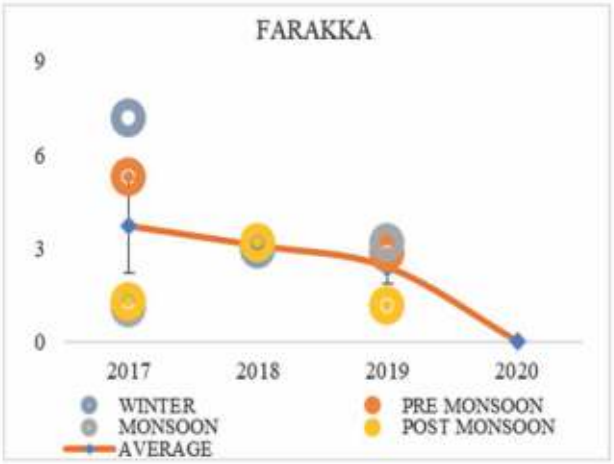


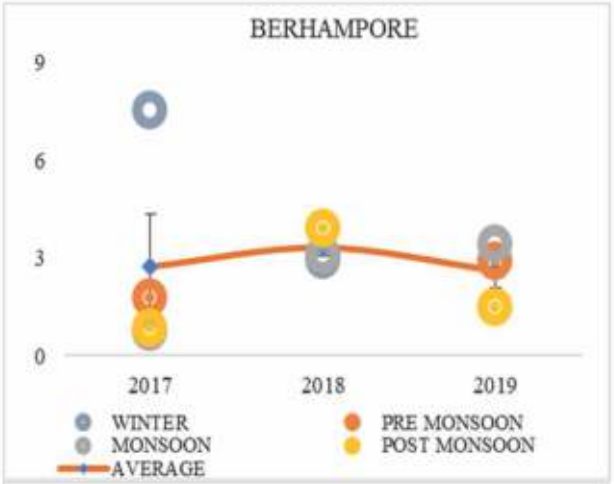
TIMESCALE CHANGES OF SEDIMENT AVAILABLE PHOSPHORUS (mg/100g) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2020)

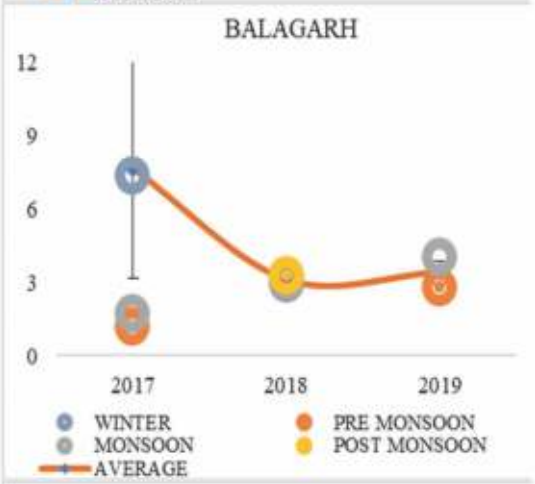


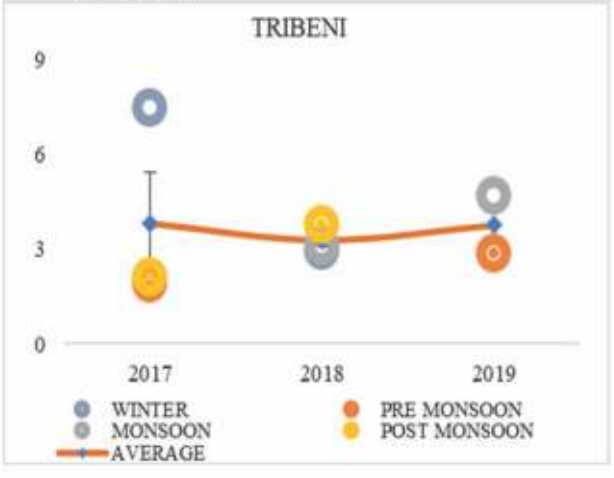


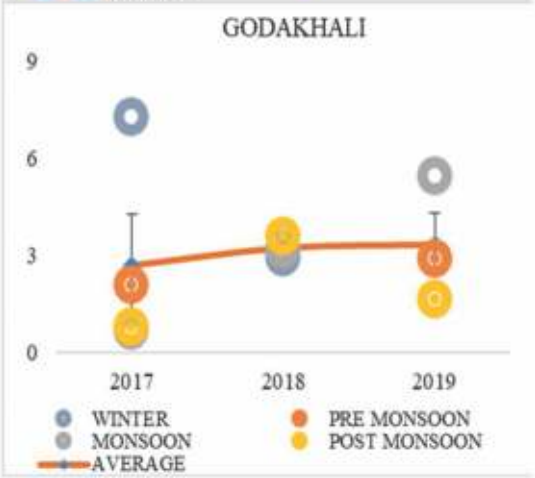
TIME-SCALE CHANGES OF SEDIMENT AVAILABLE PHOSPHORUS (mg/100g) IN THE LOWER STRETCH OF RIVER GANGA (2017-2020)



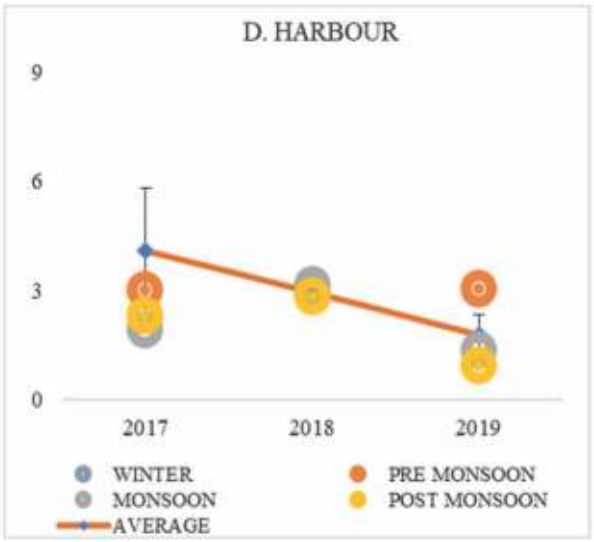


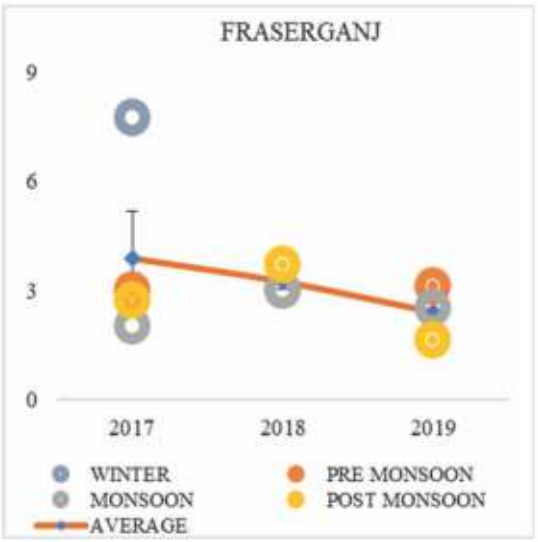






TIMESCALE CHANGES OF AVAILABLE PHOSPHORUS (mg/100g) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)



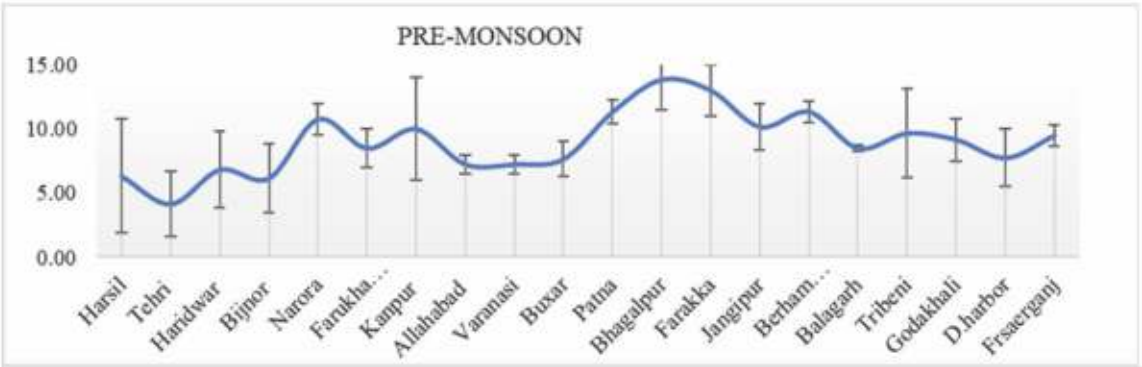


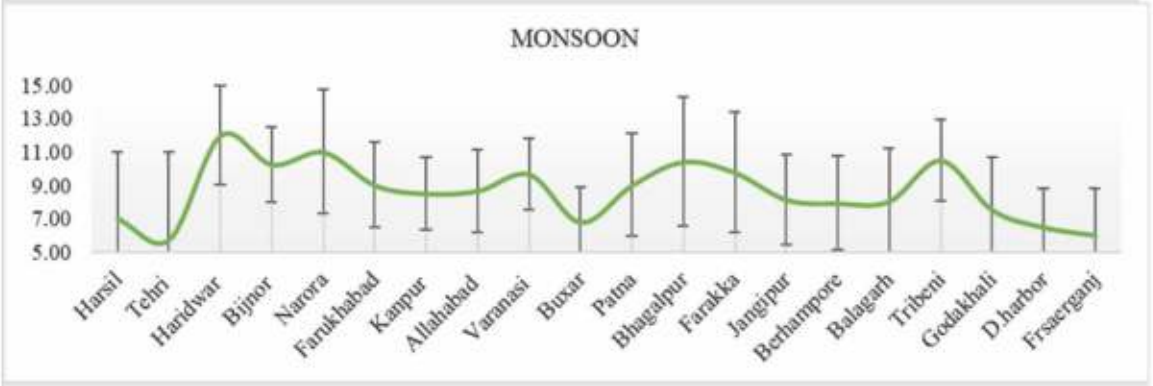
SALIENT TIMESCALE OBSERVATIONS

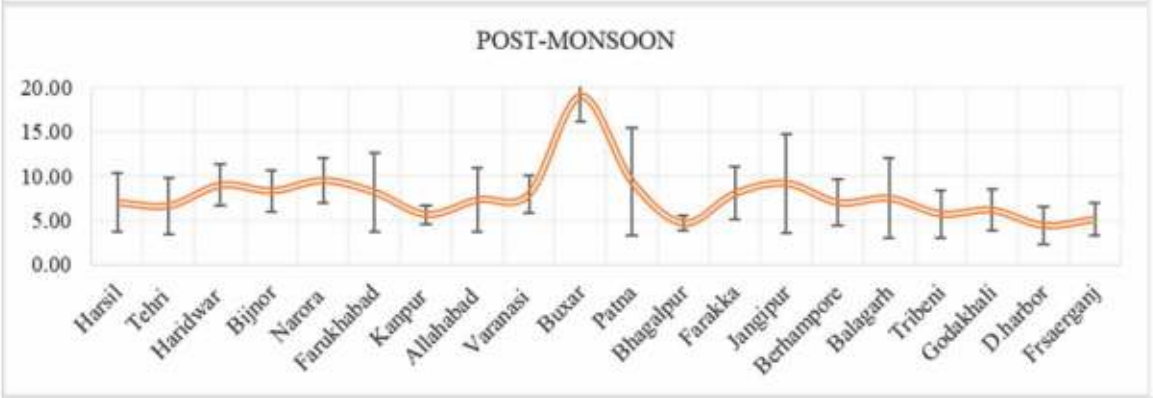
- In the upper stretch, a decrease in available P was recorded at Harshil, Tehri and Haridwar while increases at Bijnor, Narora and Farrukhabad from 2017 to 2020.
- In the middle stretch, an increase in available P was observed at Kanpur, Prayagraj and Varanasi while decrease at Buxar, Patna and Bhagalpur from 2017 to 2020.
- Among the sampling stations of lower stretch there is a decrease in available P was recorded at Farakka, Jangipur, Balagarh and Tribeni while an increase at Berhampore and Godakhali from 2017 to 2020.
- In the estuarine stretch, there is a decrease in available P was recorded at all the stations from 2017 to 2019.

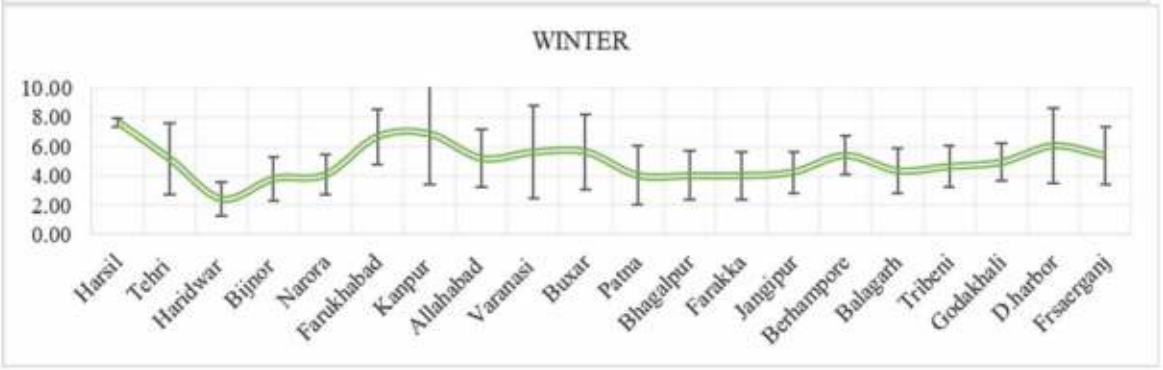
Free Calcium carbonate (%)

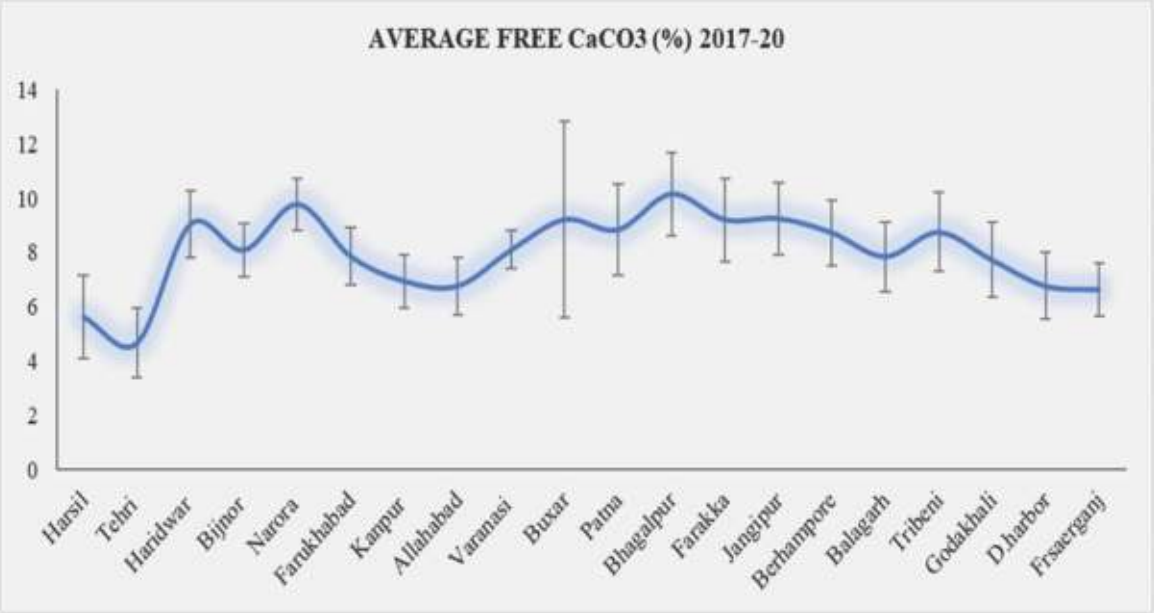
Calcium is the important nutrient present in the sediment in the form of Free $CaCo_3$. The nutrient helps in flourishment of many of the aquatic macro and microorganisms. The production of many of the plankton organism also depends on its concentration.


PRE-MONSOON
15.00
10.00
5.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukha…
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berham…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


MONSOON
15.00
13.00
11.00
9.00
7.00
5.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


POST-MONSOON
20.00
15.00
10.00
5.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

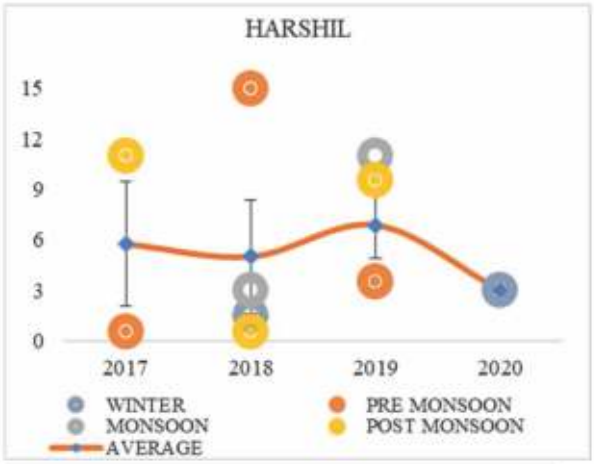

WINTER
10.00
8.00
6.00
4.00
2.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj

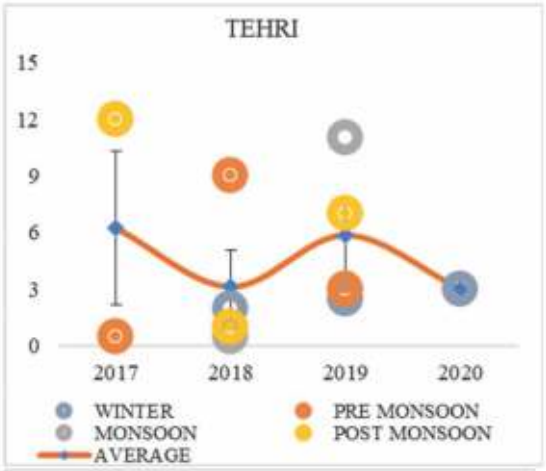


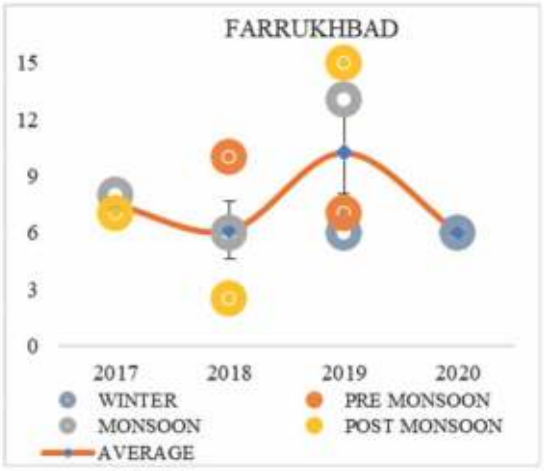
BRIEF DESCRIPTION

The Free $CaCO_3$ of sediment in the entire stretch ranged from to 4.68 to 10.15%. Highest average Free $CaCO_3$ value of 10.15% was recorded at Bhagalpur. During the pre-monsoon the average Free $CaCO_3$ value was at 8.96%. In monsoon the average Free $CaCO_3$ value was 8.62%. The average Free $CaCO_3$ value during post monsoon was 7.80%. while, in winter average Free $CaCO_3$ value was 6.92%.

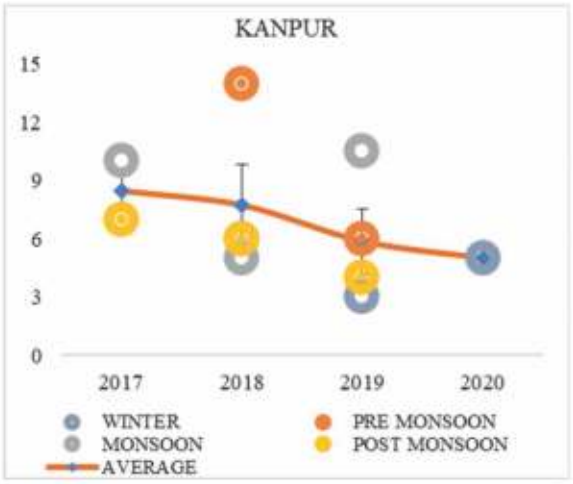
TIMESCALE CHANGES OF SEDIMENT FREE $CaCO_3$ (%) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)

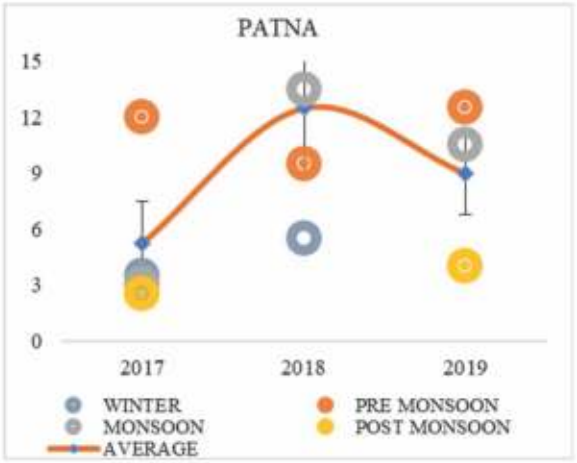




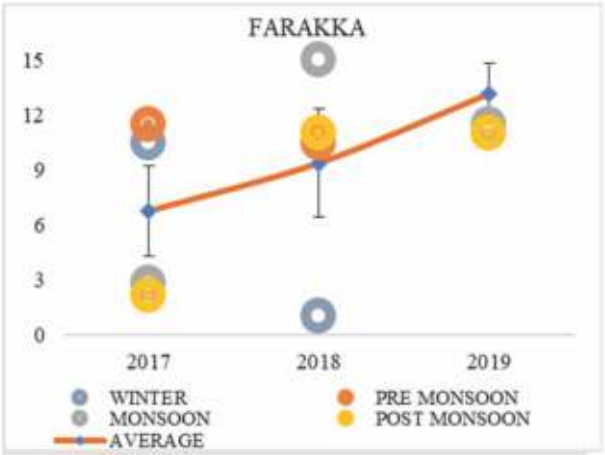


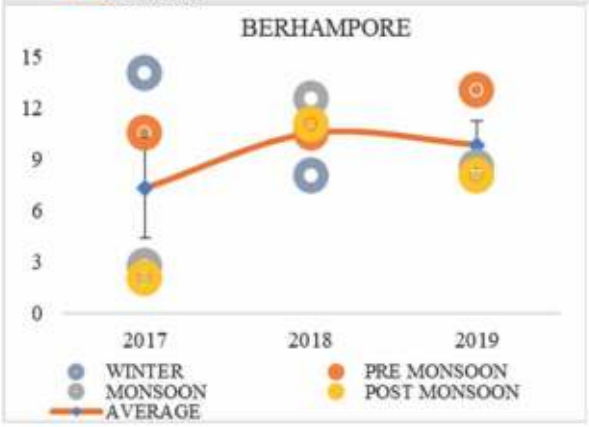
TIMESCALE CHANGES OF SEDIMENT FREE $CaCO_3$ (%) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2020)

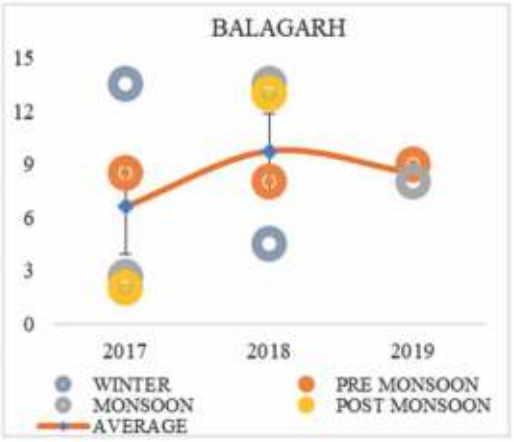


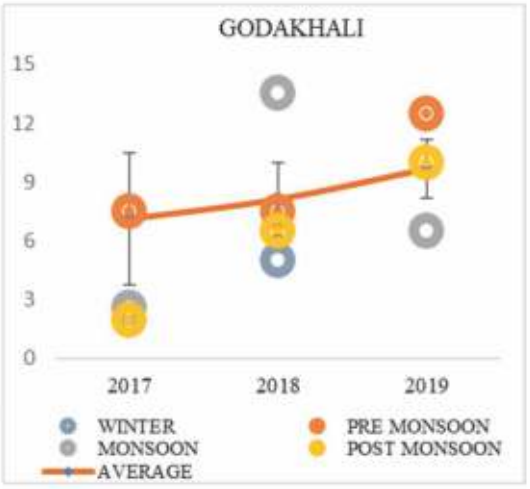


TIME-SCALE CHANGES OF SEDIMENT FREE $CaCO_3$ (%) IN THE LOWER STRETCH OF RIVER GANGA (2017-2019)

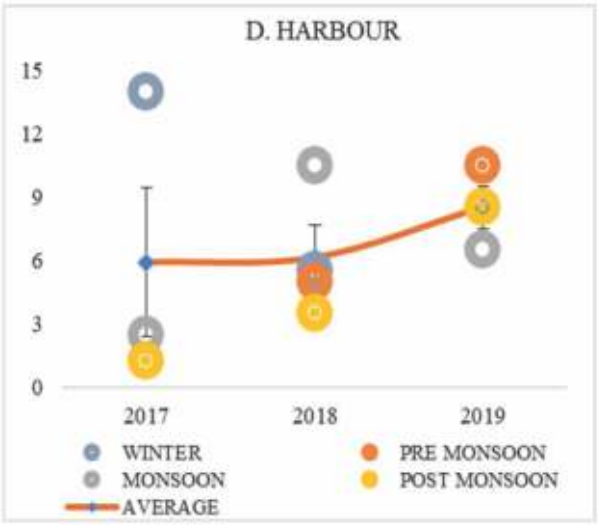


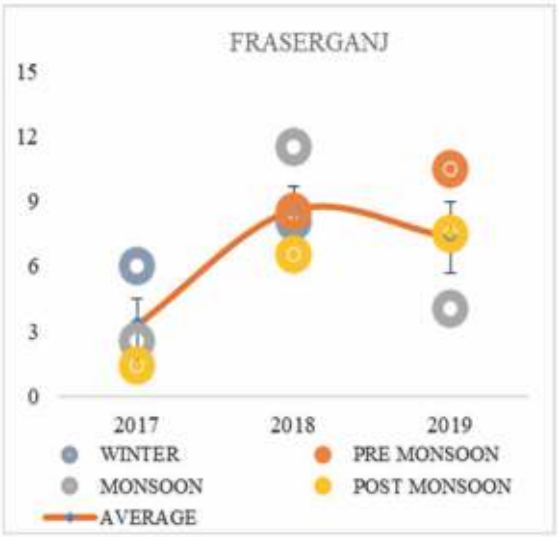






TIMESCALE CHANGES OF FREE $CaCO_3$ (%) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)





SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch, a decrease in free $CaCO_3$ was recorded at all the stations except Haridwar and Bijnor from 2017 to 2020.
- In the middle stretch, a decrease in free $CaCO_3$ was observed at all the stations except Patna and Bhagalpur from 2017 to 2019.
- Among the sampling stations of lower stretch, an increase in free $CaCO_3$ was recorded at all the stations from 2017 to 2019.
- In the estuarine stretch, an increase in free $CaCO_3$ was recorded at all the stations from 2017 to 2019.

Sand (%)

Sand % is the important component of the sediment characteristics. The sand is loose, individual visible grain having size range of 0.02 to 0.2 mm. The sand content in the river varies with altitude and flow dynamics.


PRE-MONSOON
100.00
80.00
60.00
40.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukha...
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berham...
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
MONSOON
100.00
90.00
80.00
70.00
60.00
50.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
POST-MONSOON
100.00
80.00
60.00
40.00
20.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
WINTER
100.00
90.00
80.00
70.00
60.00
50.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
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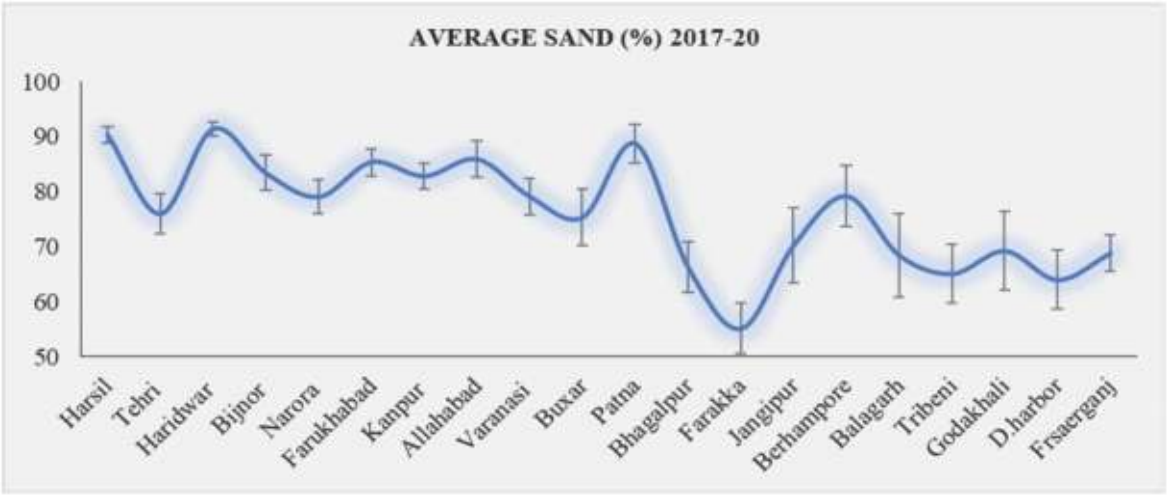
Godakhali
D.harbor
Frsaerganj



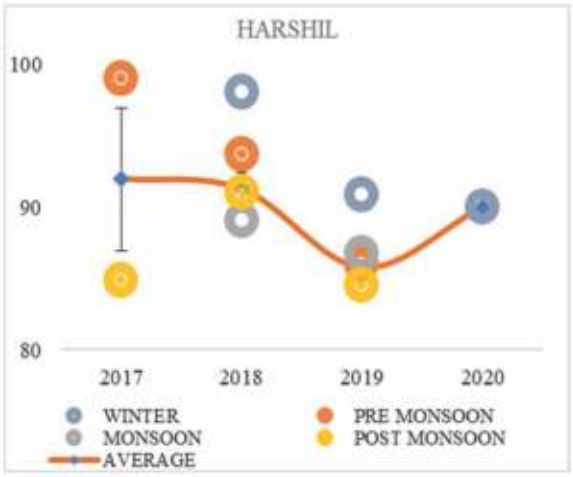
CHANGING PATTERN OF SAND (%) OVER THE YEARS

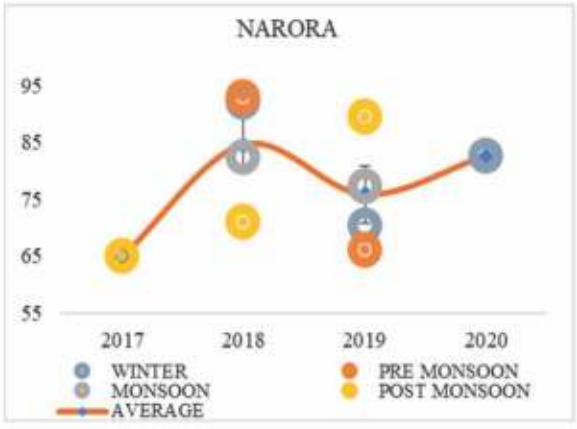
Stretches	Period	Sand (%)
Teheri-Patna	2010	79-100
Haridwar	2001-2006	99
Varanasi	2014	71
Farakka	2001-2006	65
Sultanpur-Katwa	2010	34-79
Barrackpore	2019	3
Dimond harbour	2019	28
Gangasagar	2019	20

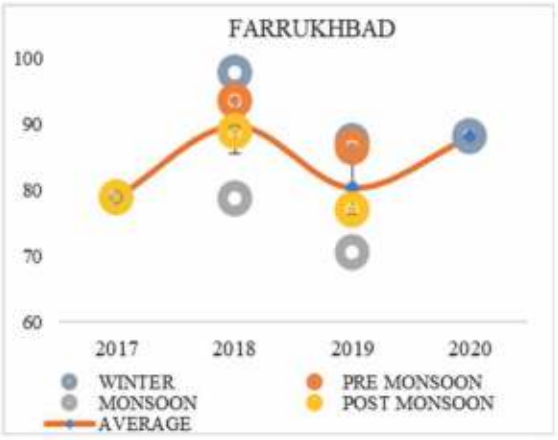
BRIEF DESCRIPTION

The percentage of sand in sediment in the entire stretch ranged from 55 to 91%. The highest average sand value was at 91% recorded at Haridwar. During the Pre-Monsoon, the average sand value was 81%. During monsoon, the average sand value was at 75%. The average sand value in post monsoon was 71%. whereas, in winter average sand value was at 78%. Sandification of river bed (>90% sand) is a matter of concern especially in the upper and middle stretch of river up to Prayagraj.

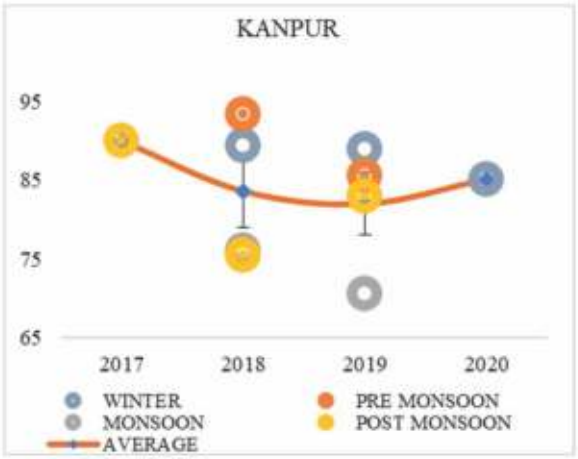
TIMESCALE CHANGES OF SAND (%) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)

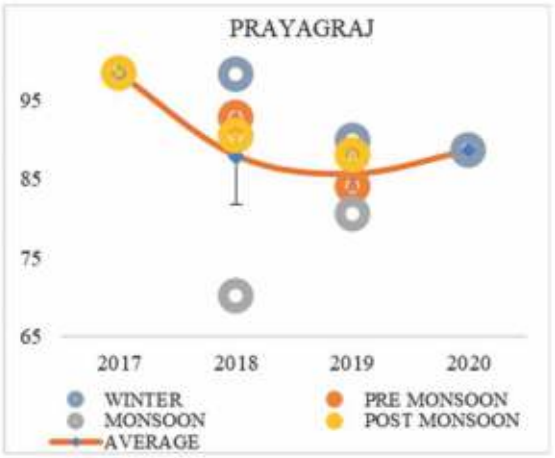


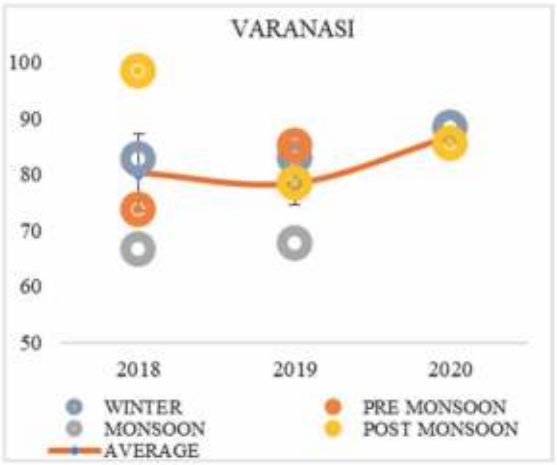


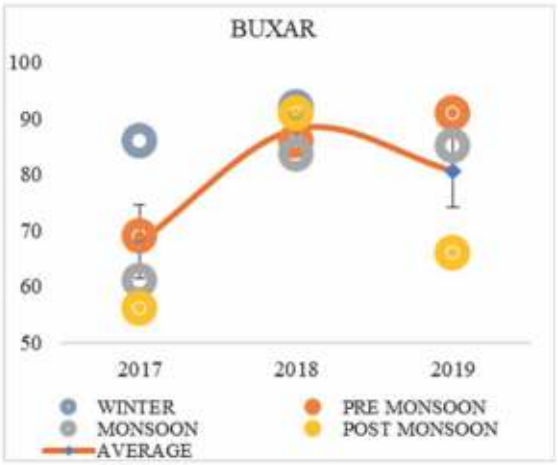


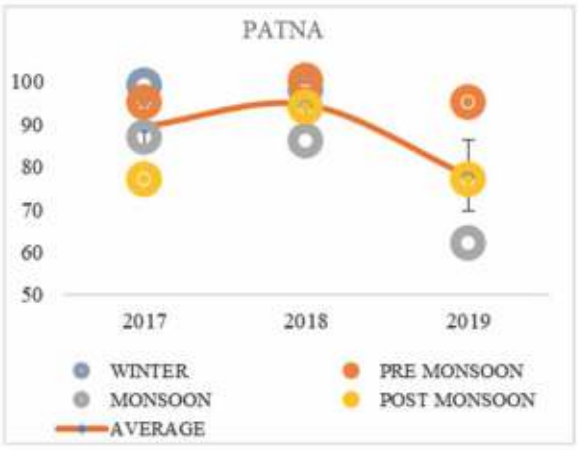
TIMESCALE CHANGES OF SAND (%) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2020)

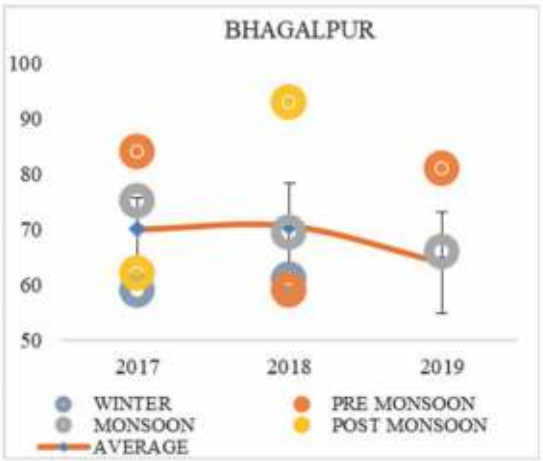




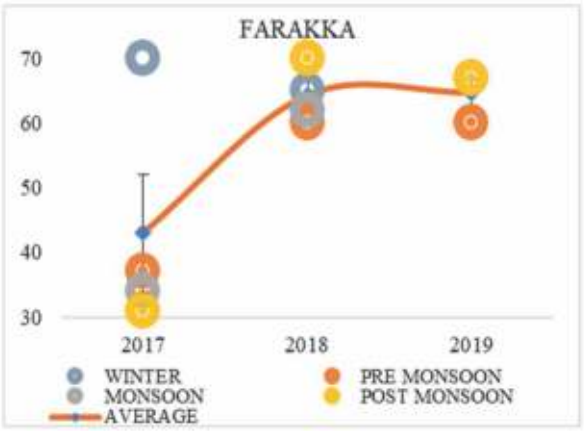


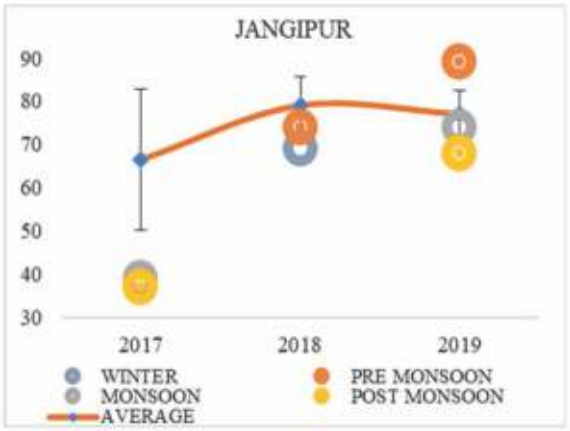


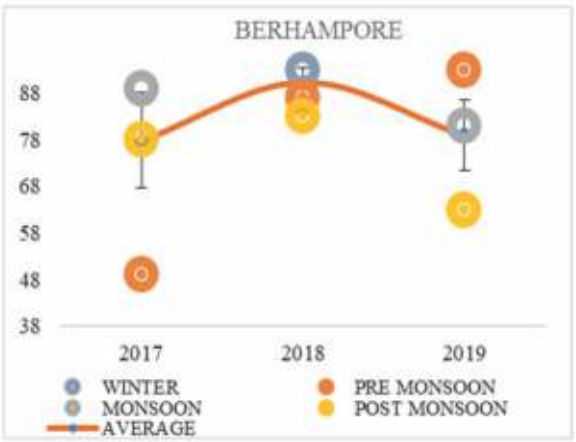


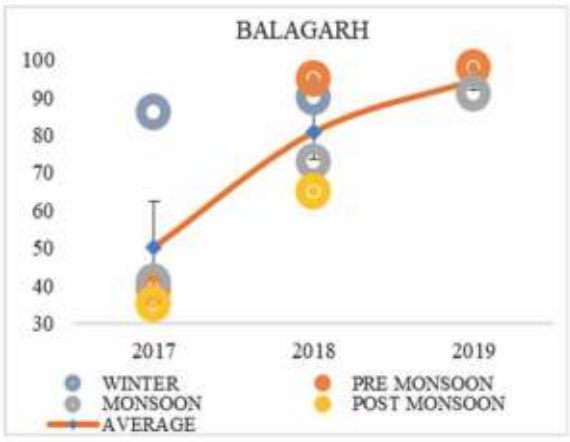


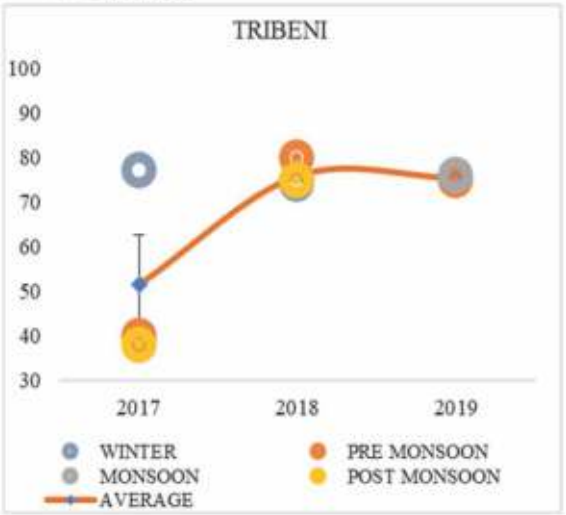
TIME-SCALE CHANGES OF SAND (%) IN THE LOWER STRETCH OF RIVER GANGA (2017-2019)

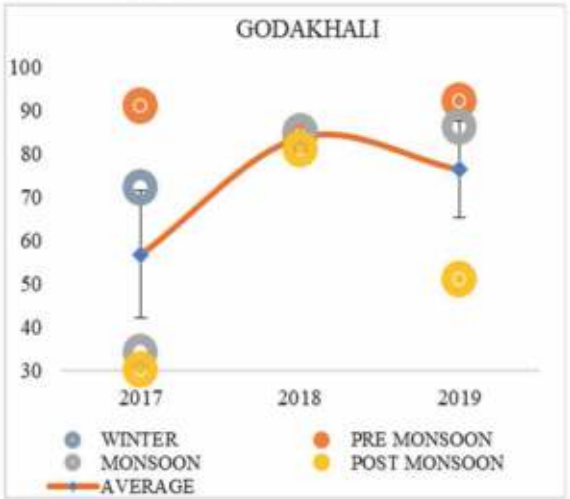




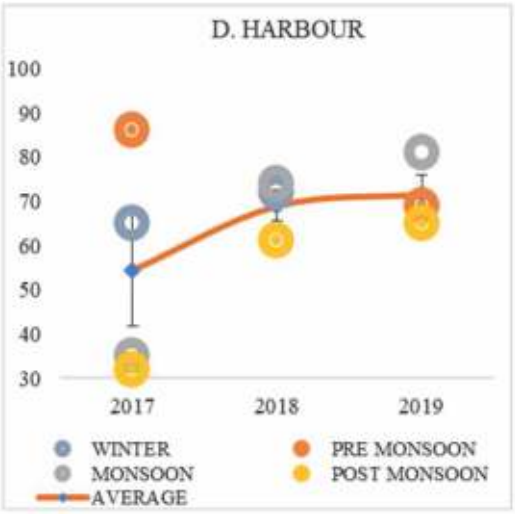


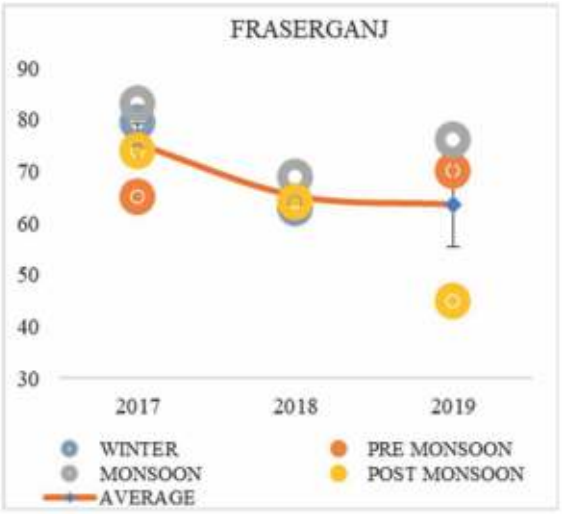






TIMESCALE CHANGES OF SAND (%) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)



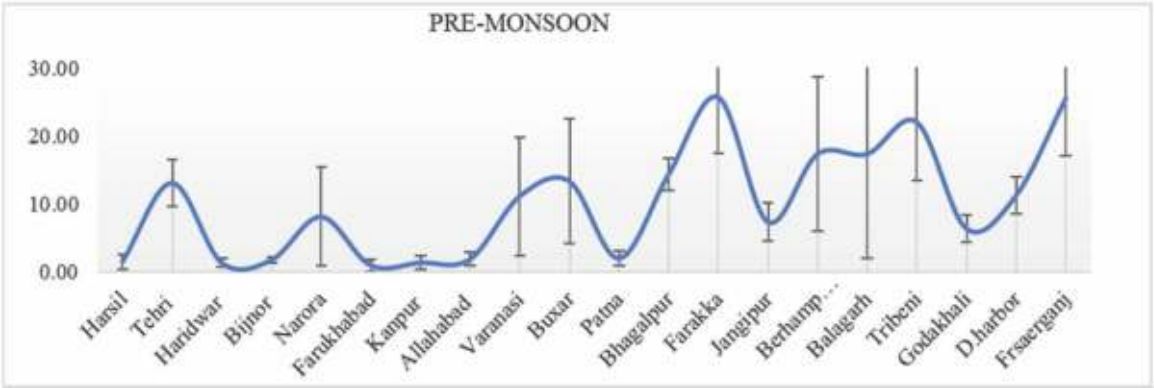


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch an increase in sand percentage has been recorded at all the stations except at Haridwar from 2017 to 2020.
- In the middle stretch, an increase in sand percentage was observed at all the stations except at Varanasi and Buxar from 2017 to 2019.
- In the middle stretch, an increase in sand percentage was observed at all the stations from 2017 to 2019.
- In the estuarine stretch, there was an increase in sand percentage was recorded at D. Harbour and decreases at Fraserganj from 2017 to 2019.

Silt (%)

Silt % are the larger components of the soil, which is having size range of (0.002 to 0.02 mm). The silt are floury elements having uniform size.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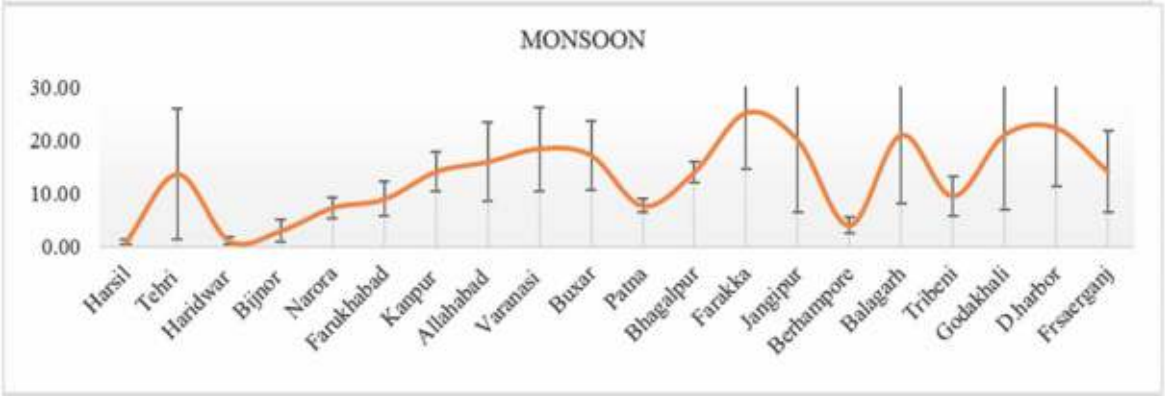
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhamp…
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj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Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
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Patna
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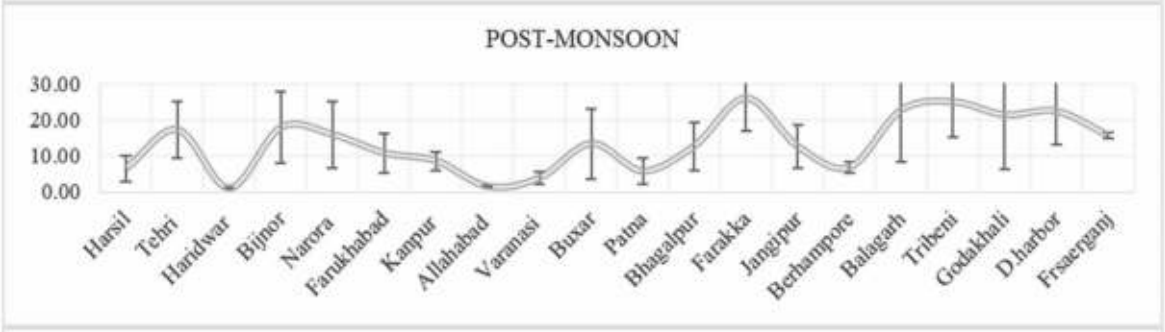
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj


POST-MONSOON
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Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
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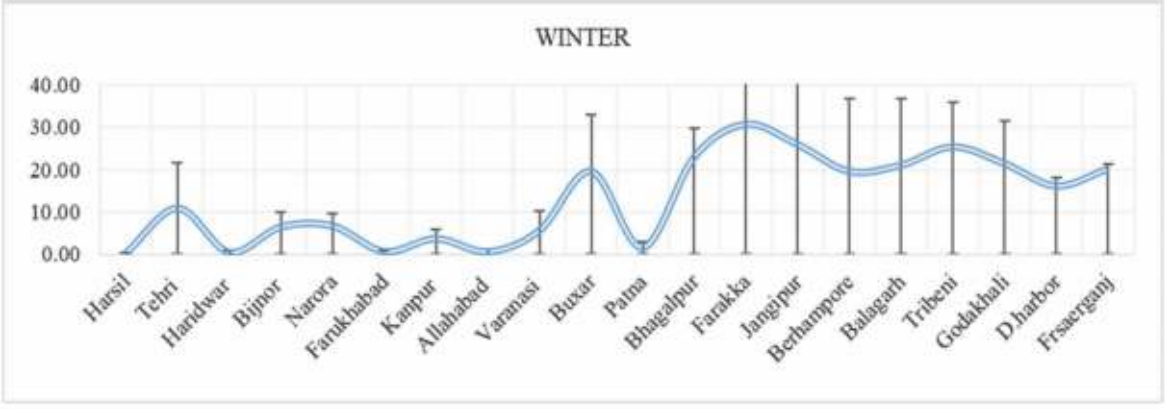
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj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10.00
0.00
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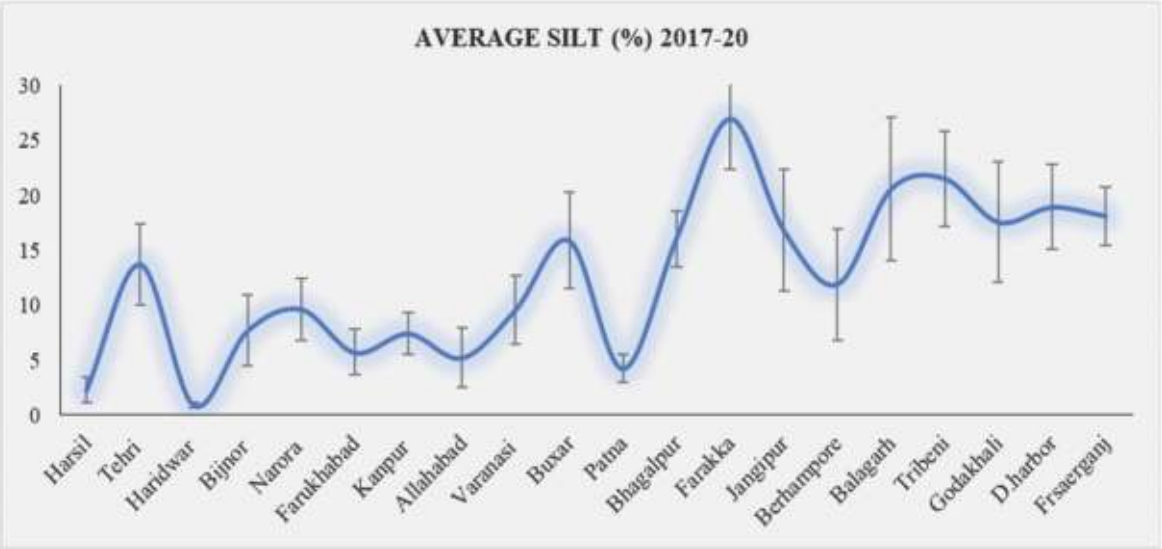
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj



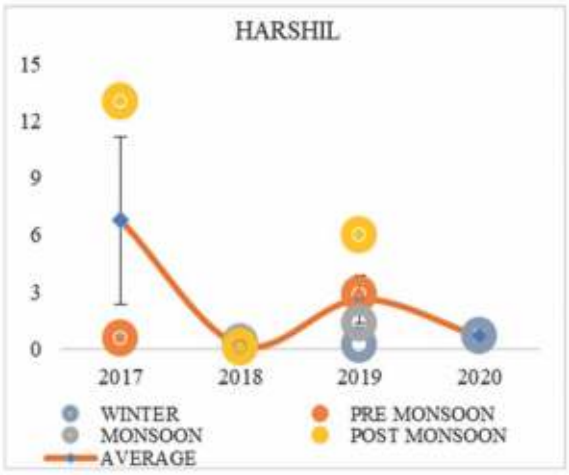
CHANGING PATTERN OF SILT (%) OVER THE YEARS

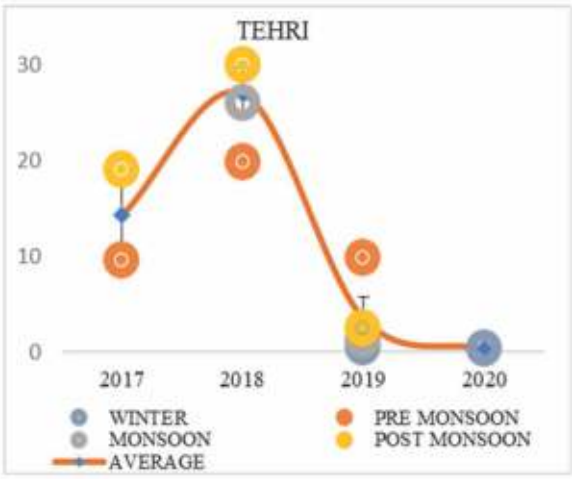
Stretches	Period	Silt
Haridwar	2001-2006	0.5
Varanasi	2014	25
Farakka	2001-2006	33
Barrackpore	2019	67
Dimond Harbour	2019	51
Gangasagar	2019	20

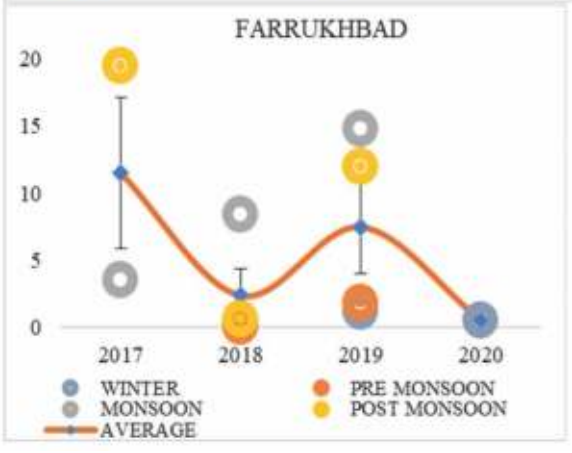
BRIEF DESCRIPTION

The percentage of silt in sediment in the entire stretch ranges from 1 to 27%. Highest average silt value of 27% was recorded at Farakka. During the pre-monsoon the average silt value was 10%. During monsoon, the average silt value was 13%. The average silt value during post monsoon was 13%. whereas, in winter average silt value was 13%.

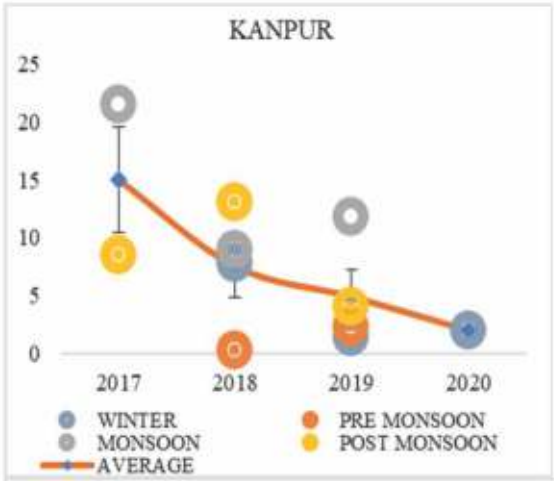
TIMESCALE CHANGES OF SILT (%) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)

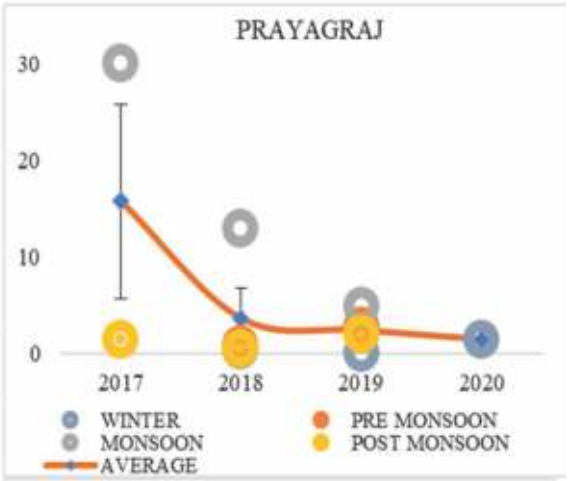


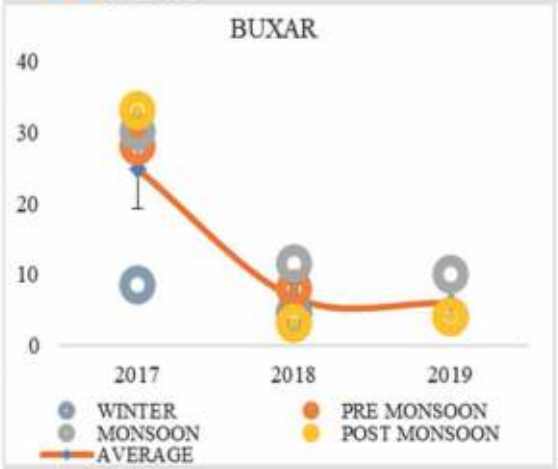


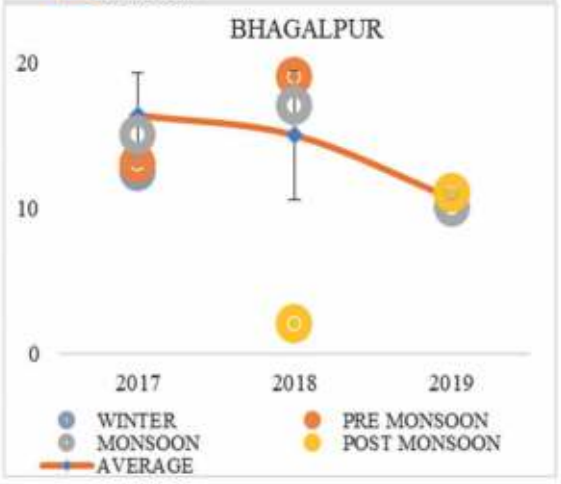


TIMESCALE CHANGES OF SILT (%) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2020)

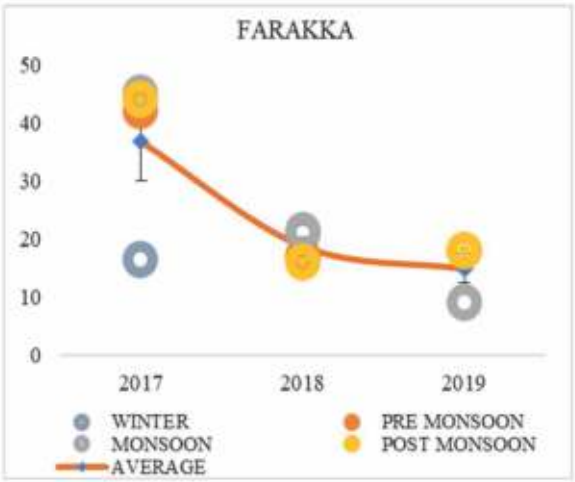


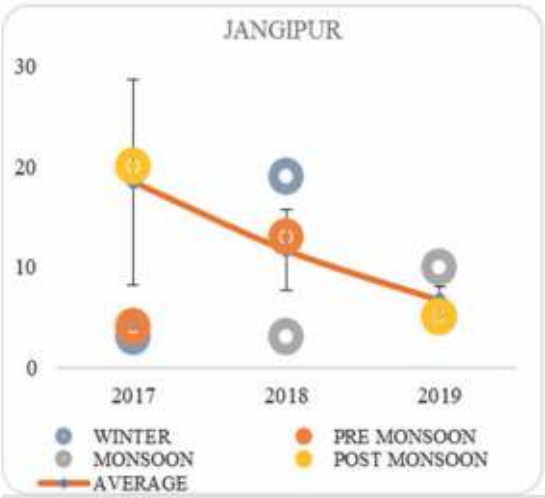


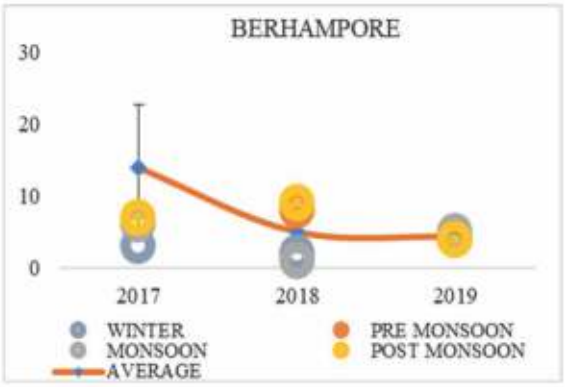


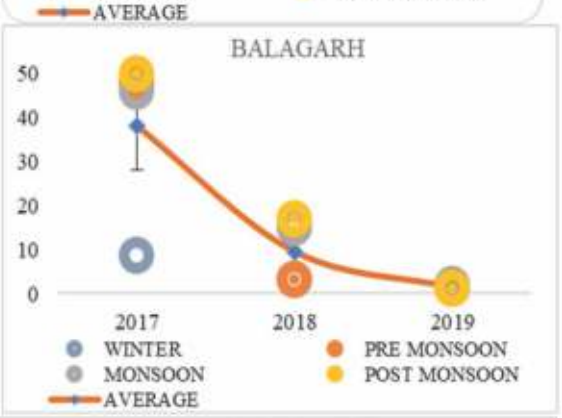


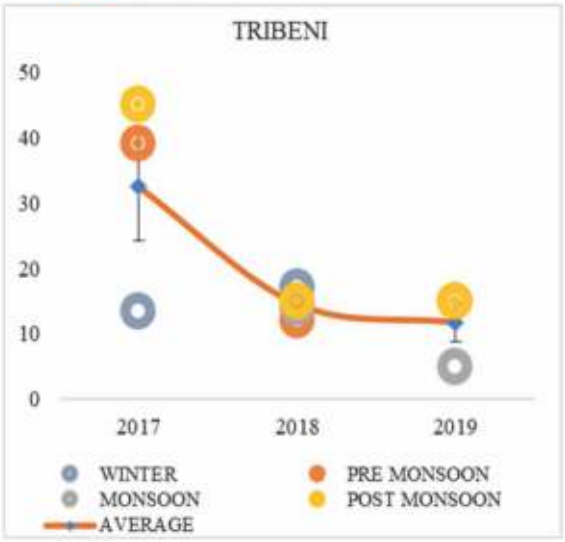
TIME-SCALE CHANGES OF SILT (%) IN THE LOWER STRETCH OF RIVER GANGA (2017-2019)

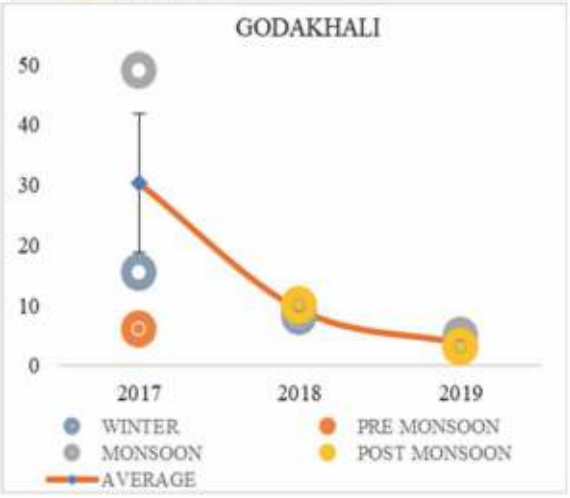




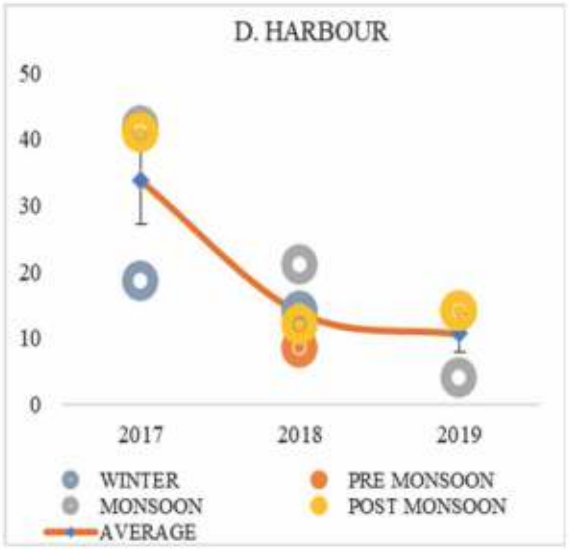


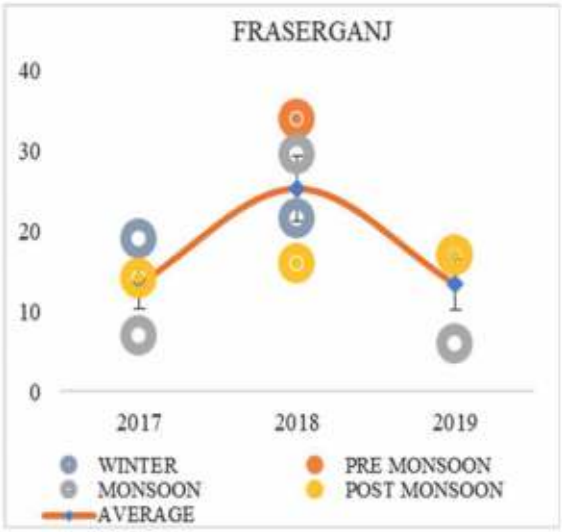






TIMESCALE CHANGES OF SILT (%) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)



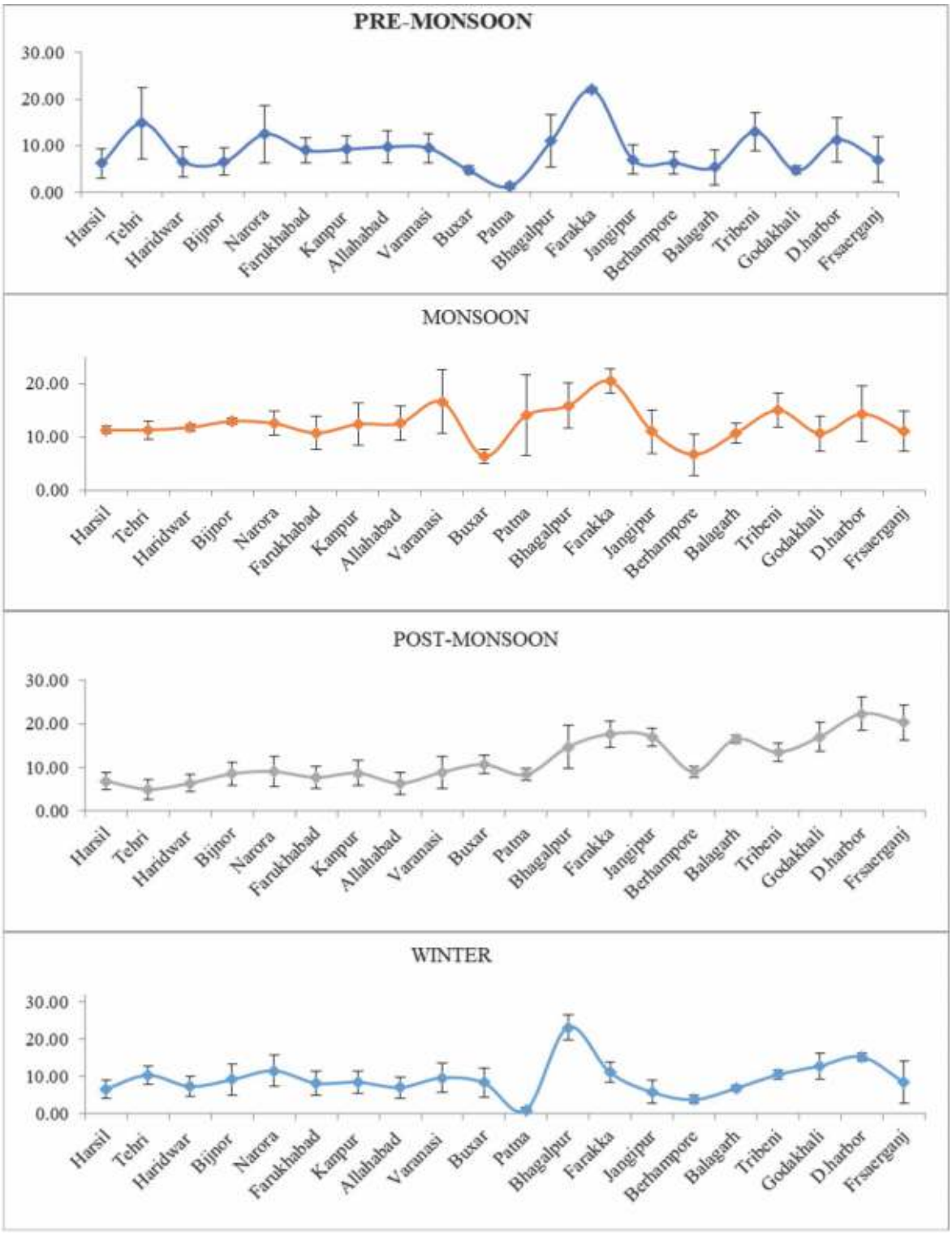


SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch a decrease in silt percentage was recorded at all the stations from 2017 to 2020.
- In the middle stretch, a decrease in silt percentage has been observed at all the stations from 2017 to 2019.
- In the middle stretch at all the sampling sites, a decrease in silt percentage has been observed from 2017 to 2019.
- In the estuarine stretch, an increase in silt percentage has been recorded at D. Harbour while a decrease was observed at Fraserganj from 2017 to 2019.

Clay (%)

Clay % are the important constituent of the soil, having < 0.002 mm. Clay have large surface area. The clay has relatively higher water holding capacity than silt and sand.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0.00
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Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
MONSOON
20.00
10.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
POST-MONSOON
30.00
20.00
10.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
Buxar
Patna
Bhagalpur
Farakka
Jangipur
Berhampore
Balagarh
Tribeni
Godakhali
D.harbor
Frsaerganj
WINTER
30.00
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10.00
0.00
Harsil
Tehri
Haridwar
Bijnor
Narora
Farukhabad
Kanpur
Allahabad
Varanasi
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Tribeni
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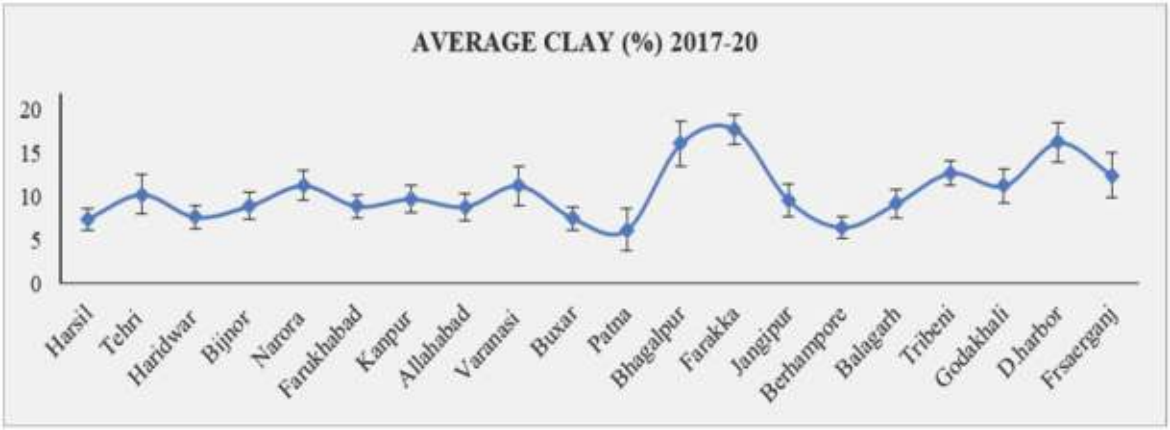
D.harbor
Frsaerganj

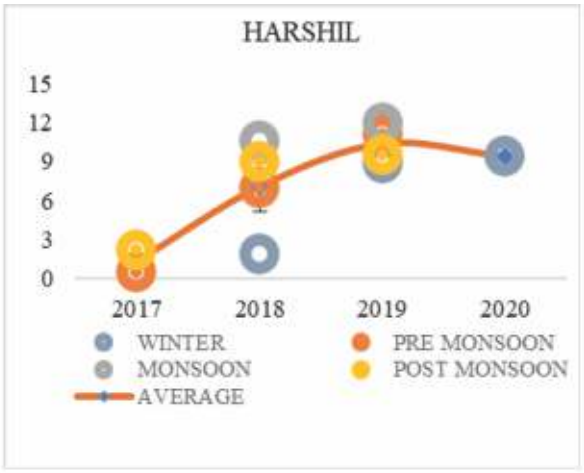


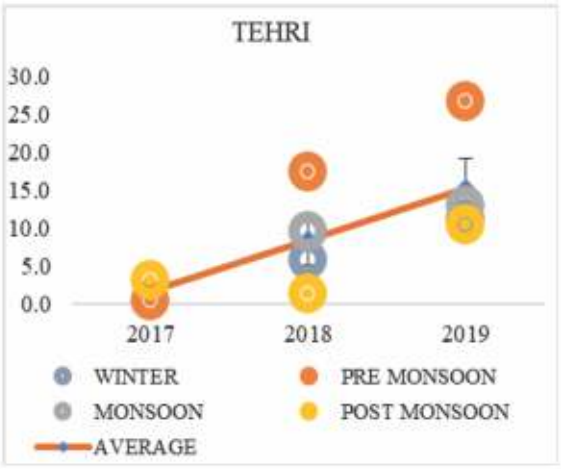
CHANGING PATTERN OF CLAY (%) OVER THE YEARS		
Stretches	Period	Clay (%)
Tehri-Patna	2010	0-12
Varanasi	2014	3
Barrackpore	2019	31
Dimond Harbour	2019	31
Gangasagar	2019	60

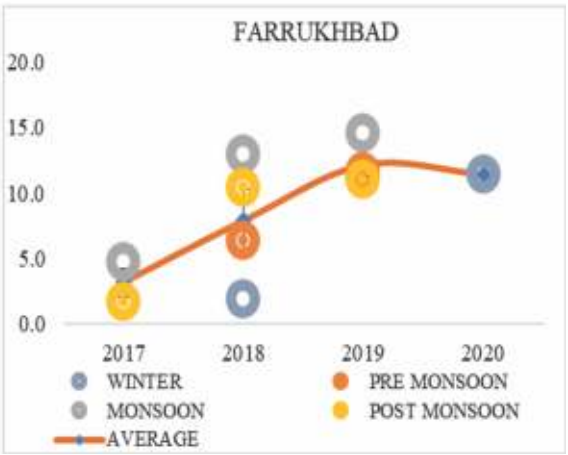
BRIEF DESCRIPTION

The percentage of clay content of sediment in the entire stretch ranged from 6 to 18%. Highest average clay value at 18% was recorded at Farakka. In pre-monsoon the average clay value was 9%. In monsoon the average clay value was at 12%. The average clay value in post monsoon was at 12%. Whereas, in winter average clay value was 9%.

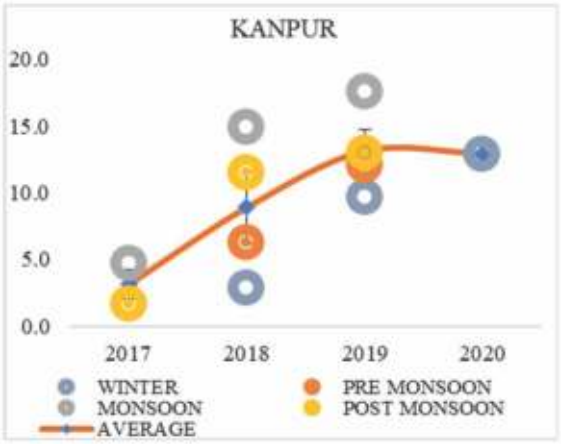
TIMESCALE CHANGES OF CLAY (%) IN THE UPPER STRETCH OF RIVER GANGA (2017-2020)

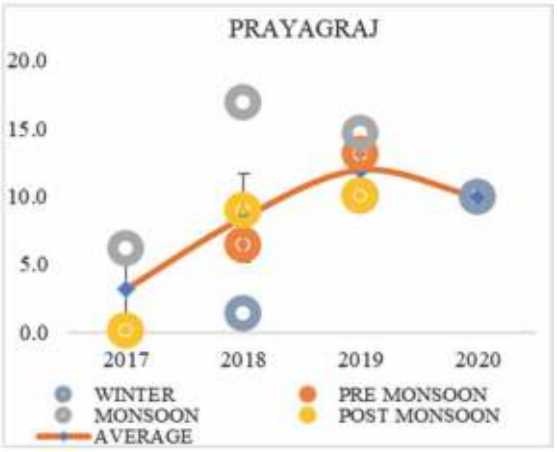


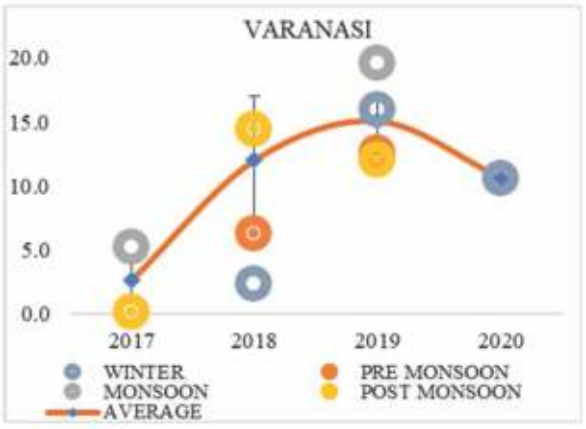


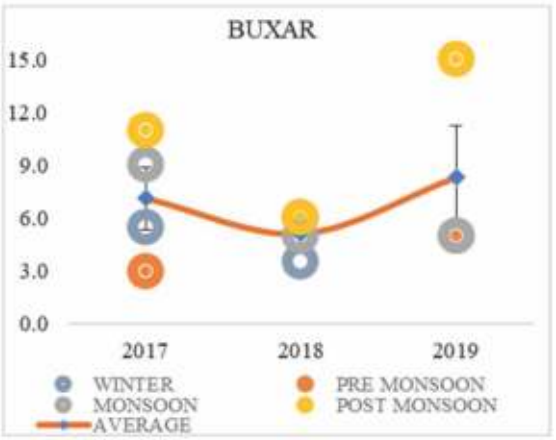


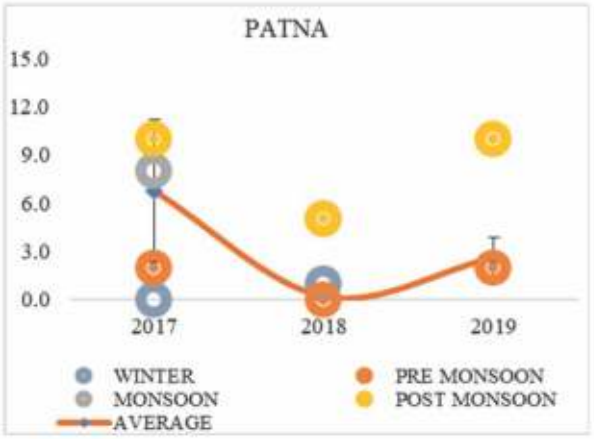
TIMESCALE CHANGES OF CLAY (%) IN THE MIDDLE STRETCH OF RIVER GANGA (2017-2020)

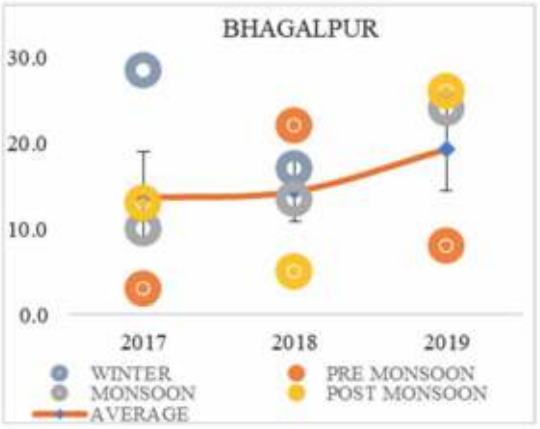




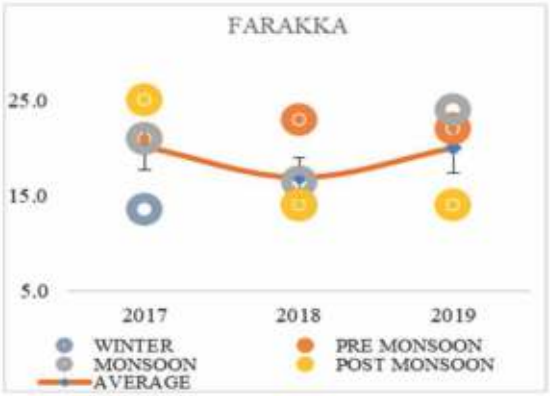


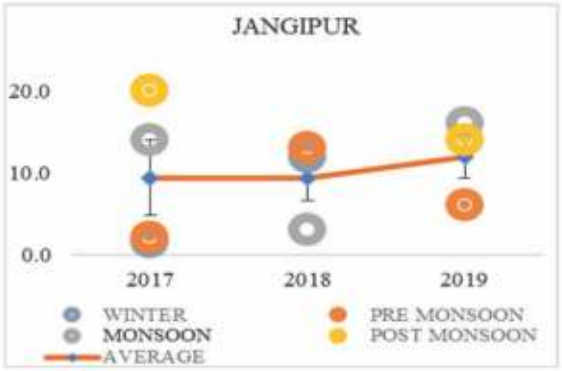


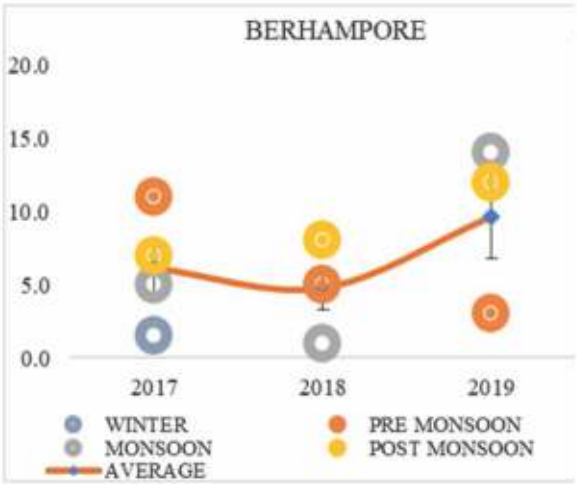


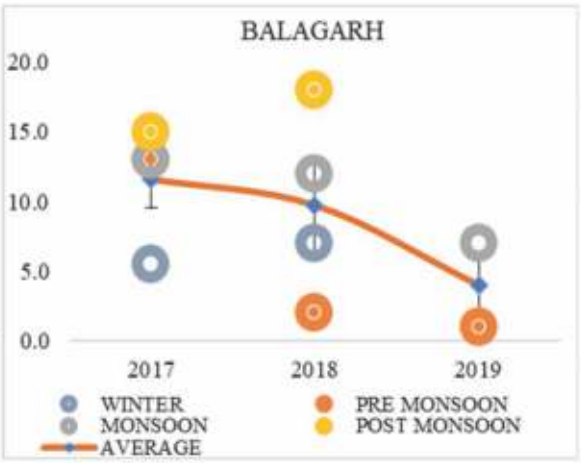


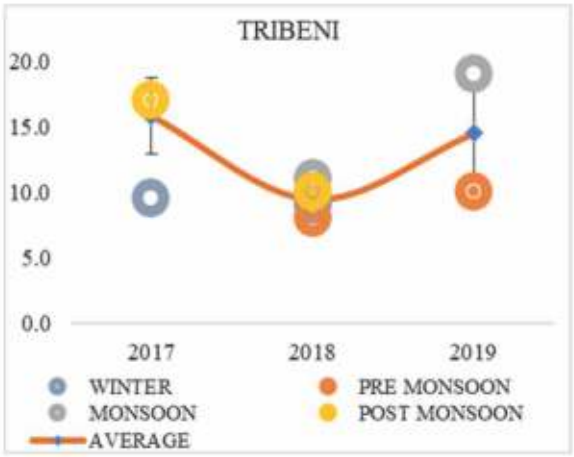
TIME-SCALE CHANGES OF CLAY (%) IN THE LOWER STRETCH OF RIVER GANGA (2017-2019)

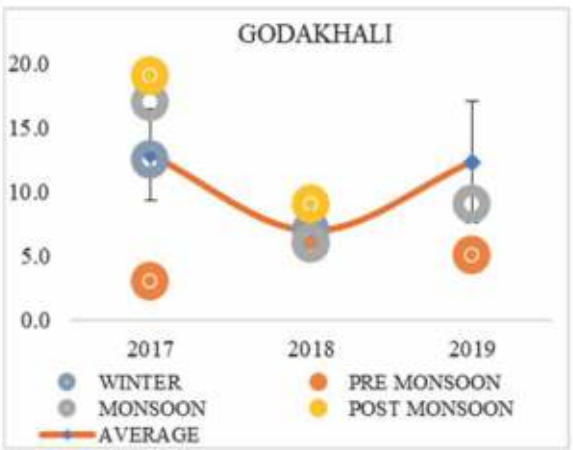




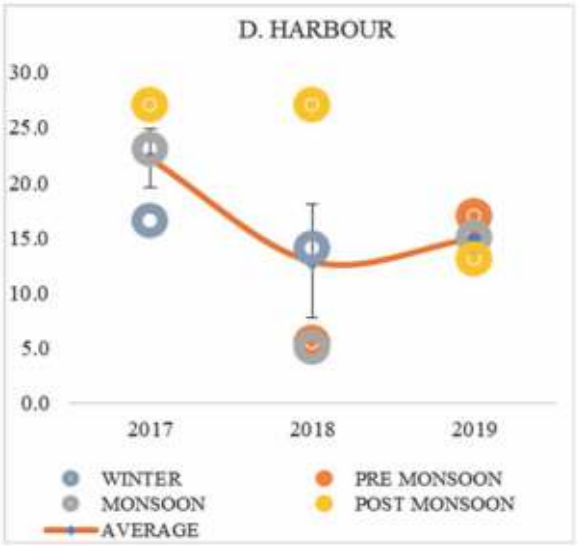


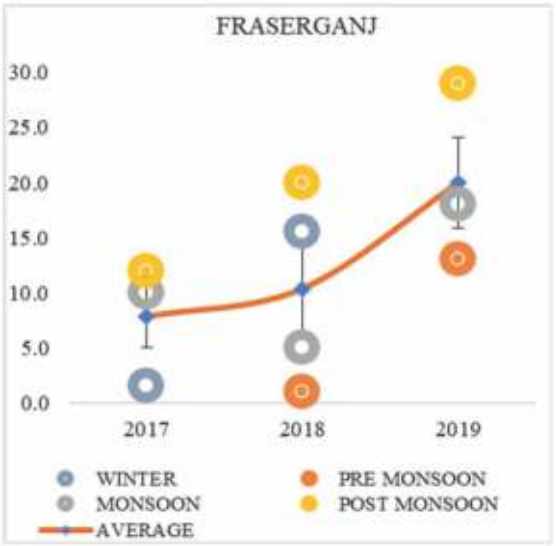






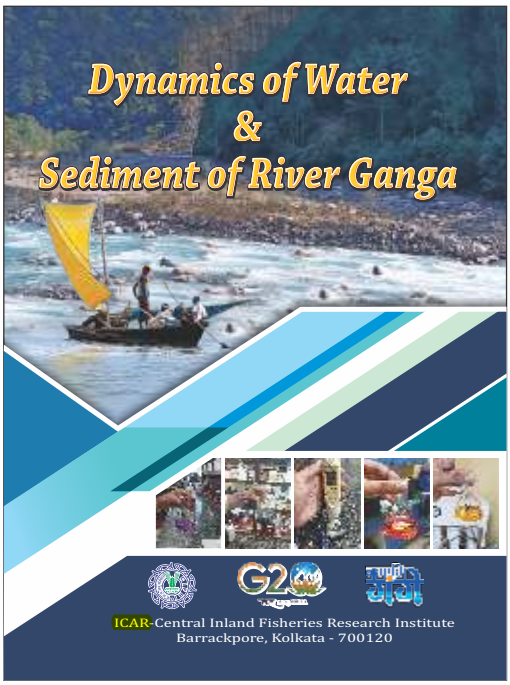
TIMESCALE CHANGES OF CLAY (%) IN THE ESTUARINE STRETCH OF RIVER GANGA (2017-2019)





SALIENT TIMESCALE OBSERVATIONS

- In the upper stretch, an increase in clay percentage has been recorded at all the stations from 2017 to 2020.
- In the middle stretch increase in clay percentage was noticed at all the stations except at Patna from 2017 to 2020.
- Among the sampling stations of lower stretch, a decrease in clay percentage has been recorded at all the stations except at Jangipur and Berhampore from 2017 to 2020.
- In the estuarine stretch, a decrease in clay percentage was recorded at D. Harbour while increased at Fraserganj from 2017 to 2019.



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