Summary

According to the Central Pollution Control Board (CPCB), the Ganges River, which has a length of 2601 kilometers, has been subjected to serious pollution in recent decades. Most industries, tourism operations, pilgrimage, hotels and lodges, and shops in close proximity to all of these establishments, are the largest source of pollution to the Ganges. In 2020 the novel coronavirus disease (COVID-19) halted almost all the industrial-scale anthropogenic activities across the globe, resulting in improvements in the water and air quality in many regions across the world. In this report, we quantify and analyze the changes in water quality in the Ganges river passing through the city of Varanasi using four different parameters.

Study Area

The study area is 631 Square kilometers area towards the South East of the city of Varanasi. The city of Varanasi on the banks of River Ganga is one of the oldest living cities in the world. The river receives large amounts of untreated sewage, agricultural runoff containing pesticides, fertilizers, and other chemicals from catchment areas, resulting in water quality degradation. Being a popular pilgrimage region, every year millions of people bathe in Ganga River ghats in the Varanasi region. Ganges's water quality also affects the underground water quality in the city, which has been on a [steady decline in recent years](#).

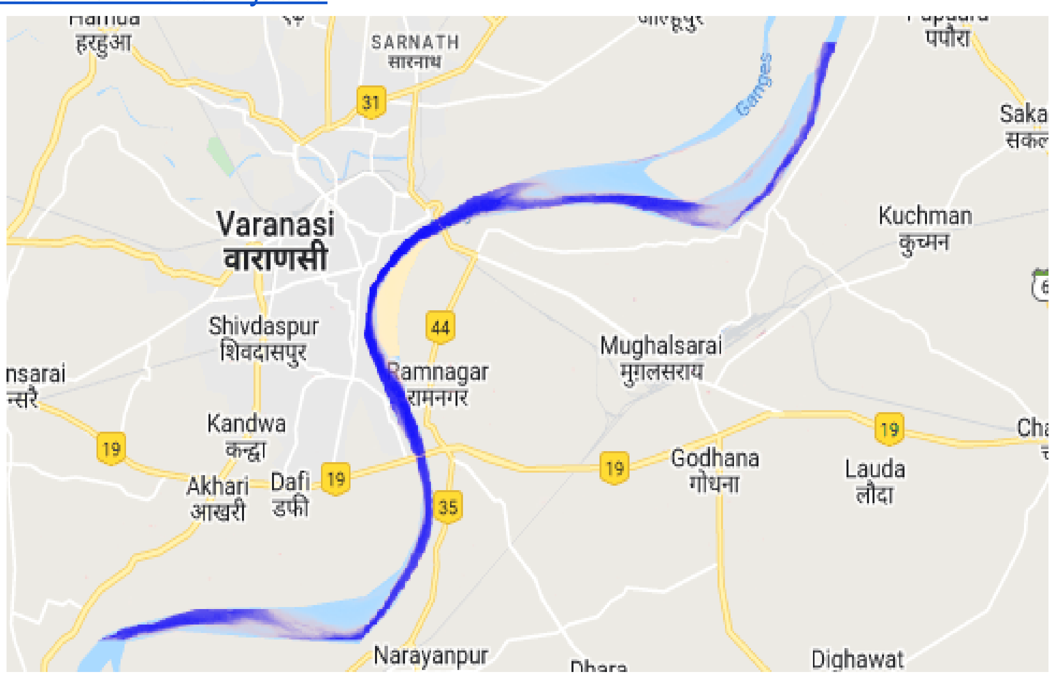

Fig 1. Water extent in the study region in 2020, JRC Global Surface Water Extent

Water quality

To assess the water quality in rivers, lakes, and wetlands, we look at a number of different features of the water. Physical factors (such as water clarity and temperature), chemical concentrations (such as nutrients, metals, minerals, and contaminants from human activities), and biological traits are among them (like the amount and types of bugs, bacteria, algae, and other organisms that live in the water). When these measurements are added together, they give us an idea of how healthy the water is and, more crucially, how it is changing over time.
In this project, we evaluate the quality of water based on the Secchi depth, Trophic state, Water temperature, and Chlorophyll content. The change in each of these parameters is compared during pre and post covid scenarios below.

1. Secchi depth

The depth at which a disc lowered into the water can no longer be visible from the surface is known as the Secchi depth. Secchi depth is a measurement of how far light can penetrate into the water and is connected to water clarity. Secchi depth can be used as an indicator of lake productivity since water clarity is altered by the amount of algae present. The higher the value of Secchi depth higher would be the water clarity.

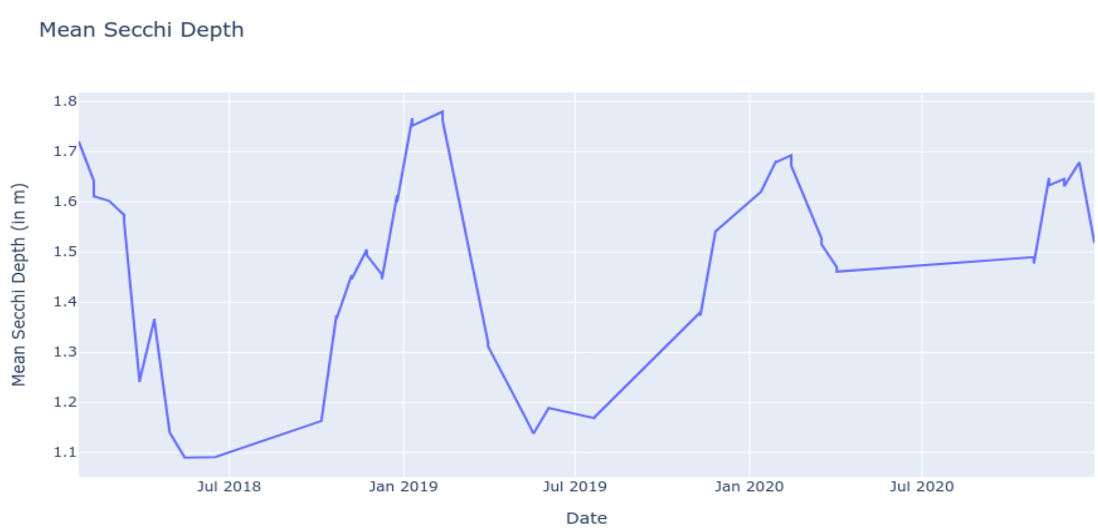

Fig 2. Mean Secchi Depth across the years

In 2018, the Mean Secchi Depth (MSD) in the region was about 1.38 meters, it rose to about 1.39 meters in 2019. During the COVID period in 2020, the water clarity improved significantly throughout all the months leading to an average MSD of 1.59 meters.

2. Trophic State Index

The Trophic State Index (TSI) is a categorization system that ranks water bodies according to their biological productivity.
A water body's TSI is measured on a scale of zero to one hundred. Water bodies are classified as follows on the TSI scale:

- **Oligotrophic** (TSI 0–40, having the least amount of biological productivity, "good" water quality);
- **Mesotrophic** (TSI 40–60, having a moderate level of biological productivity, "fair" water quality); or
- **Eutrophic** to **Hypereutrophic** (TSI 60–100, having the highest amount of biological productivity, "poor" water quality).

Fig 3. Mean Trophic Index

The Trophic State Index (TSI) in the Ganges river shows a strong seasonal pattern, its the lowest during January reaching a peak during the summer months of June. In 2018 and 2019 the average TSI in the region was 55. In 2020 it reduced to about 53 but the stream still remained in the overall category of Mesotrophic.

3. Water Temperature

The temperature of a lake's water is a major determinant of its quality. Most aquatic animals have a body temperature that is the same as the surrounding water and changes with it. Most aquatic species have evolved to exist in a specific temperature range, and they will perish if the temperature falls too low or rises too high. As the temperature rises, the solubility of oxygen and other gases drops. This means that lakes and streams that are cooler can store more dissolved oxygen than those that are warmer. Water that is excessively warm will not be able to hold enough oxygen for aquatic life to live.

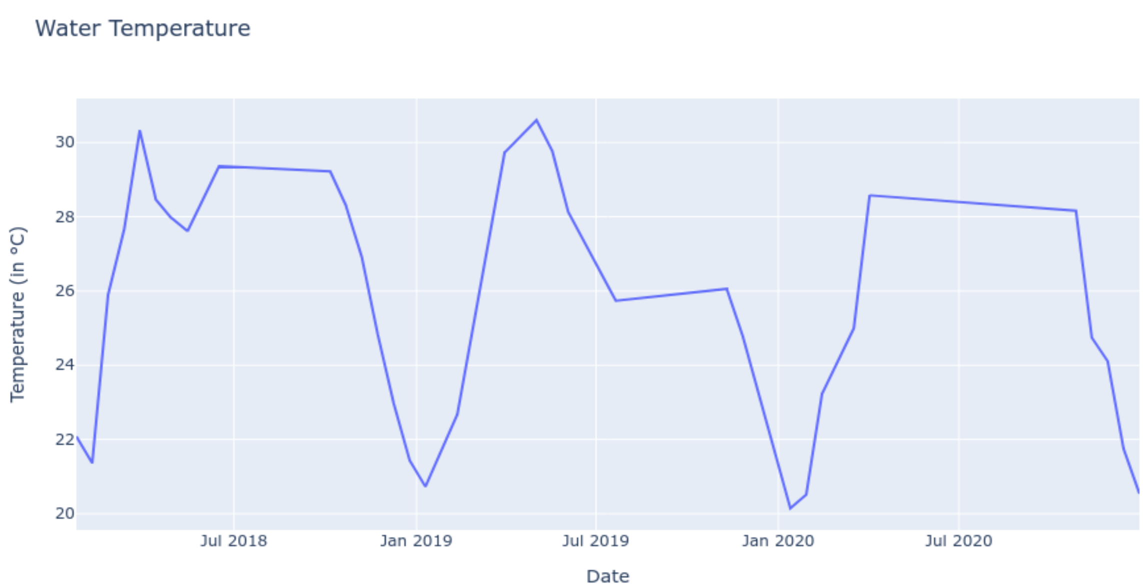

Fig 4. Mean Water Temperature

In 2018, the average surface water temperature in the region was about 26.45 degrees, in 2019 it was 26.19. During the COVID period in 2020, the water temperature reduced to 23.98 degrees.

4. Chlorophyll

Chlorophyll is a green pigment found in all green plants and cyanobacteria (blue-green algae). Along with TSI, chlorophyll is often used to estimate productivity in a water body. Similar to the Trophic State Index, the Chlorophyll content in the region reduced during the COVID19 period.

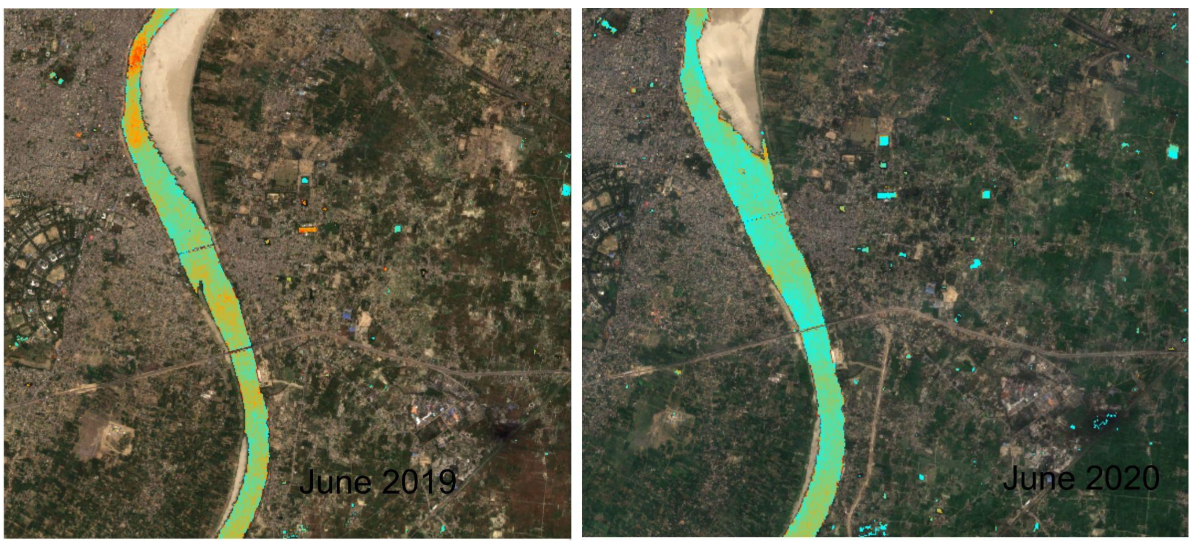

Fig 5. Chlorophyll Content on 2019 and 2020

Statistical Tests

To test the statistical significance of the COVID19 impacts on the water quality parameters, a one-way ANOVA test was used. The null hypothesis was that covid had no impact on water quality parameters. It was assigned an alpha value of 0.05. In the case of Mean Secchi Depth, the outcome of the test had a p-value of 0.0003925 thereby rejecting the null hypothesis that covid had no impact. In the other two tests, the p-values were greater than 0.05 which proved the null hypothesis. Based on the ANOVA tests it's difficult to identify if there were statistically significant changes in the water quality in 2020.

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p value of the test is 1.0
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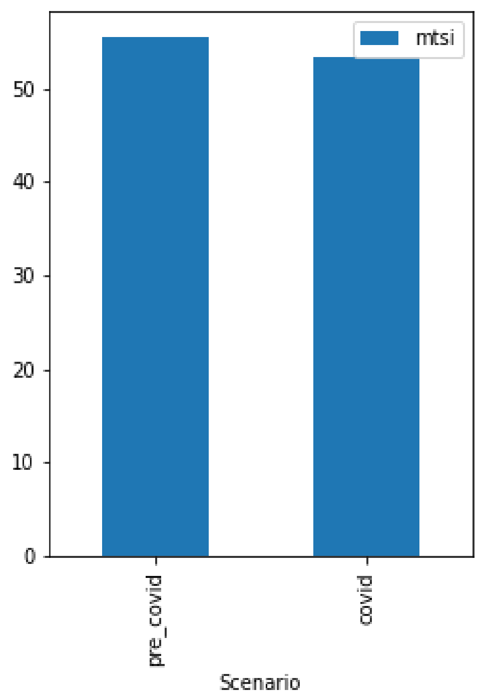


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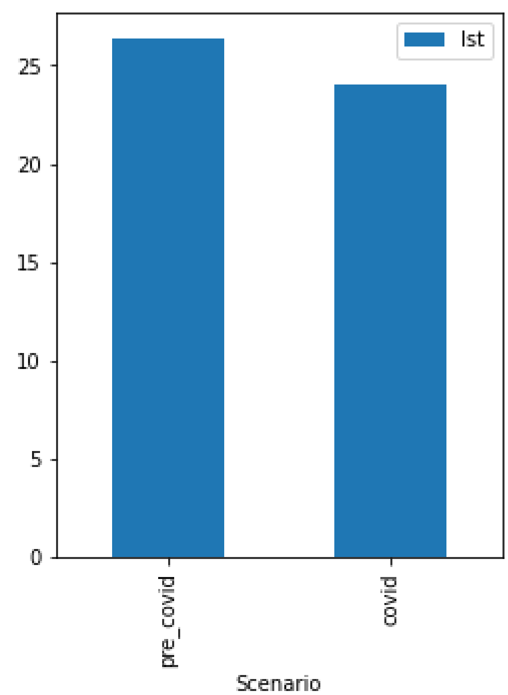

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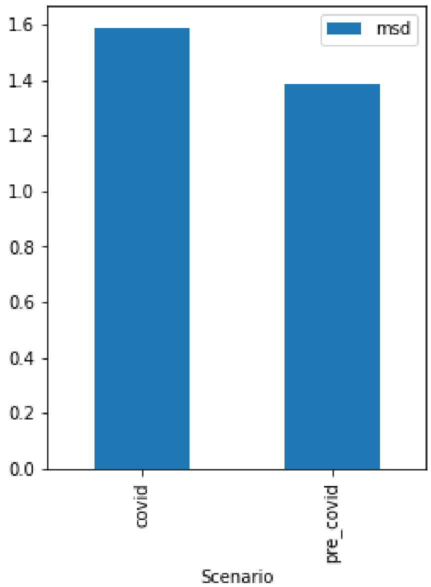

Data and Methodology

To develop this project geospatial data was used from the following sources listed below.

- USGS Landsat 8 Collection 1 Tier 1 TOA and SR products, bands: B2, B3, B4, B5, B6 and B7.
- Sentinel-2 MSI: MultiSpectral Instrument Level-2A, bands: B2, B3, B4,B5 and B8.
- JRC Global Surface Water Extent

To map the water clarity parameters, the harmonized image processing workflow developed by Page et al was used. A normalized difference chlorophyll index-based model formulated by Mishra & Mishra was used to estimate the chlorophyll content. Google Earth Engine was used for developing and performing all of the remote sensing analyses.

Scope for improvements

In order to improve the results of this study, the following steps can be considered,

- **Validating remotely sensed observations with ground truths**: It is important to validate and quantity the inaccuracies of satellite observations and machine learning models when compared with in situ data. Currently, there is no regular monitoring of water quality data, the only ground data available are from irregular CPCB surveys and small-scale measurements done by researchers. Similar to OpenAQ, a cross-border network of real-time water quality sensors, can help greatly in understanding and predicting the health of water bodies in India.
- **Forecasting parameters using Physics and ML-based models**
- **Higher spatial and temporal resolution data:** the remote sensing data used in this study have a resolution between 10 to 30 meters. Higher-resolution data from commercial providers such as Planet, Maxar, etc can help in monitoring the water bodies more regularly and providing a finer look at their state.
- **More interactivity:** static reports like this have less impact when used by decision-makers. The map and data produced in this study can be used to create pipelines in the form of APIs which can provide updates to the users. Cloud Optimized GeoTIFF format can be used for storing and serving the raster maps to the users quickly.