Reduction in turbidity of Indian lakes through satellite imagery during COVID-19 induced lockdown

Ashish Joshi1 · Shefali Agrawal2

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Abstract The lakes of India are getting significantly polluted due to the rapid growth of industries, plastics, and anthropogenic waste. Due to the non-functioning of the industries and human activities during the COVID-19 pandemic lockdown, industrial and other waste going to the lakes was significantly reduced. Moreover, with the reduction of human activities and tourism in the cities and lakes, anthropogenic pollution in the lakes was also reduced. Turbidity is the key indicator of water pollution in the lakes. It has a direct relationship with surface water reflectance and can be estimated through satellite imagery. In this paper, the relative comparison of turbidity values of five Indian lakes in the Rajasthan state was done through Satellite imagery of Sentinel-2 during the pre-lockdown and lockdown period. The relative turbidity is also calculated through reflectance values of Sentinel images and then the empirical method is applied to the reflectance values of the red band of Sentinel-2 & Landsat-8 data to estimate the turbidity. Relative comparisons of turbidity values estimated through satellite imagery during the pre-lockdown and lockdown period showed that the turbidity of lakes was reduced in Kaylana Lake (49.6%), Fatehsagar Lake (55.4%), Pichola Lake (54.3%), Rajsamand Lake (58.3%), and Man Sagar Lake (44.8%) during the lockdown period. Spectral curve analysis also showed that there was a decrease in the surface water reflectance in all five lakes and this indicates the reduction in the turbidity of the water during the lockdown period.

Keywords COVID-19 · Lakes · Lockdown · Sentinel-2 · Turbidity

1 Introduction

Lakes are often contaminated by industrial waste, plastics, heavy metals, and human activities [1–3]. Fresh surface water natural resources such as rivers, lakes, and ponds have been severely affected by anthropogenic as well as natural disturbances [4]. Due to the continuous rise in the population, rapid industrialization, and toxic chemicals used by agricultural and business industries, there is an increase in the rate of release of pollutants into the atmosphere and hydrosphere [5]. Turbidity is an important parameter for the characterization of the surface quality of the lakes [6]. Turbidity is defined as the reduction of transparency of liquids caused by the presence of suspended particulate matter (SPM) (ISO 7027). It is a measure of scattering, which is directly related to the concentration of SPM and determined by the concentration, size, shape, and refractive index of suspended particles [7]. Particles suspended or dissolved in water scatter light and increase the turbidity in the water [8]. Particulate matter can comprise fine organic and inorganic matter, sediments, soluble organic compounds, and microscopic organisms like algae. Thus, turbidity can be used as an estimate of SPM concentration [9–11]. Turbidity often varies seasonally due to the discharge of rivers and the growth of phytoplankton (algae and cyanobacteria) [12]. Since turbidity has a direct relationship with reflectance, hence it can be estimated through satellite imagery [13, 14]. Satellite imagery retrieved data can provide an efficient
method to monitor SPM concentration and turbidity which are important parameters for describing the water quality of natural waters [15, 16].

The novel coronavirus disease (COVID-19) pandemic started affecting the global population at the beginning of the year 2020. The widespread cases of COVID-19 forced various countries to lockdown entire industrial and human activities to prevent the spreading of the disease. India had also imposed a nationwide lockdown on 25/03/2020 to prevent the spread of COVID-19 disease. Industrial activities, business activities, and people’s movements were strictly prohibited during the COVID-19 lockdown. Thus, an improvement in the atmosphere and hydrosphere was observed due to the reduction in air and water pollution during the lockdown period. Due to the reduction in the functioning of the industries during the lockdown period, atmospheric pollutants like aerosols, NO₂, CO, etc. were significantly reduced [17]. Air quality improvement in the major cities in China, Russia, Mexico, and other countries has been analysed during the COVID-19 pandemic [18–20]. Air quality in Indian cities has also been improved during the COVID-19 lockdown [21, 22]. Apart from the air quality, improvement in water quality of the rivers and lakes in various cities was also reported due to a significant reduction of industrial and anthropogenic waste which was responsible for water pollution [23, 24]. An improvement in the surface water quality based on the suspended particulate matter (SPM) concentration of Vembanad Lake in India is recently observed through satellite imagery [25].

In the present study, the main objective is to study the impact of COVID-19-induced lockdown on the five Indian lakes situated in the Rajasthan state through Remote sensing techniques. Since there are travel restrictions during the lockdown, thus, satellite imagery is the only source of data to analyse the impact of lockdown on Indian lakes. The surface water reflectance of the lakes was analysed through spectral curves by plotting spectral curves for different lakes during the pre-lockdown period and lockdown period. The turbidity was estimated through satellite imagery using the empirical method and relative comparisons were done between turbidity values of the different lakes during the pre-lockdown and lockdown period.

2 Material and methods

2.1 Satellite imagery

Sentinel-2B level-2A images were acquired over the Kaylana Lake (Jodhpur), Fatehsagar Lake (Udaipur), Pichola Lake (Udaipur), Rajsamand Lake (Rajsamand), and Man Sagar Lake (Jaipur) situated at Rajasthan state in India were used for the analysis of the relative turbidity level of different lakes during the pre-lockdown and lockdown period. The datasets were downloaded from Copernicus Open Access Hub website (scihub.copernicus.eu/dhus/#/home). The Sentinel-2 mission comprises a constellation of two polar-orbiting satellites (Sentinel-2A/2B) placed in the same sun-synchronous orbit, phased at 180° to each other [26]. It aims at monitoring variability in land surface conditions and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites). The detailed information on Sentinel-2A/2B different bands is described in Table 1.

The Sentinel-2 datasets used for the present study are given in Table 2. The cloud-free datasets of Sentinel-2 were used for the study.

| S.No | Lakes                  | Date of pass                                      |
|------|------------------------|--------------------------------------------------|
| 1    | Kaylana Lake, Jodhpur  | 22/02/2020, 03/03/2020, 02/04/2020               |
| 2    | Fateh Sagar Lake, Udaipur | 22/02/2020, 13/03/2020, 02/04/2020               |
| 3    | Pichola Lake, Udaipur  | 22/02/2020, 13/03/2020, 02/04/2020               |
| 4    | Rajsamand Lake, Rajsamand | 22/02/2020, 13/03/2020, 02/04/2020               |
| 5    | Man Sagar Lake, Jaipur | 29/02/2020, 20/03/2020, 19/04/2020               |

Table 1: Sentinel-2A/2B Multispectral band description

| Sentinel-2A/2B Bands          | Central Wavelength (μm) | Resolution (meter) |
|-------------------------------|-------------------------|--------------------|
| Band-1 Coastal Aerosols       | 0.443                   | 60                 |
| Band-2 Blue                   | 0.490                   | 10                 |
| Band-3 Green                  | 0.560                   | 10                 |
| Band-4 Red                    | 0.665                   | 10                 |
| Band-5 Vegetation Red Edge    | 0.705                   | 20                 |
| Band-6 Vegetation Red Edge    | 0.740                   | 20                 |
| Band-7 Vegetation Red Edge    | 0.783                   | 20                 |
| Band-8 NIR                    | 0.842                   | 10                 |
| Band-8A Vegetation Red Edge   | 0.865                   | 20                 |
| Band-9 SWIR-Cirrus            | 0.945                   | 60                 |
| Band-10 SWIR                  | 1.375                   | 60                 |
| Band-11 SWIR                  | 1.610                   | 20                 |
| Band-12 SWIR                  | 2.190                   | 20                 |
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Table 3 Landsat-8 band description

| Band       | Spectral range (µm) | Resolution (meter) |
|------------|---------------------|--------------------|
| Band 1 Visible | 0.43—0.45          | 30                 |
| Band 2 Visible | 0.450—0.51          | 30                 |
| Band 3 Visible | 0.53—0.59          | 30                 |
| Band 4 Red   | 0.64—0.67           | 30                 |
| Band 5 Near-Infrared | 0.85—0.88   | 30                 |
| Band 6 SWIR 1| 1.57—1.65           | 30                 |
| Band 7 SWIR 2| 2.11—2.29           | 30                 |
| Band 8 Panchromatic (PAN)| 0.50—0.68 | 15                 |
| Band 9 Cirrus| 1.36—1.38           | 30                 |
| Band 10 TIRS 1| 10.6—11.19         | 100                |
| Band 11 TIRS 2| 11.5—12.51         | 100                |

Table 4 Details of the Landsat-8 datasets used in the present study

| S.No | Lakes                      | Date of pass        |
|------|----------------------------|---------------------|
| 1    | Kaylana Lake, Jodhpur      | 02/03/2020, 03/04/2020 |
| 2    | Fatehsagar Lake, Udaipur   | 24/02/2020, 12/04/2020 |
| 3    | Pichola Lake, Udaipur      |                     |

OLI has nine spectral bands and Thermal Infrared Sensor (TIRS) has 2 bands. The details of the bands of Landsat-8 are given in Table 3. Landsat-8 Open Land Imager (OLI) level-2 data sets acquired over the Kaylana Lake (Jodhpur), Fatehsagar Lake (Udaipur), and Pichola Lake (Udaipur) were also used for the analysis of turbidity levels. The Level-2 datasets were downloaded from the United States Geological Survey (USGS) website (earthexplorer.usgs.gov.in). The details of the datasets are given in Table 4.

Since seasonal rainfall also affects the turbidity of the lakes, thus rainfall data was also analysed during the period of acquisition of satellite imagery during the period of pre-lockdown and lockdown period. Rainfall data for India was downloaded from the website https://indiawris.gov.in/wris/.

2.2 Spectral curve method

The reflectance of the water is the key indicator of the turbidity of water. In the present study, the main focus is to compare the turbidity of the lakes during the pre-lockdown and lockdown period, thus reflectance values from satellite imagery will provide information about the turbidity level of the lakes. The spectral curve represents the reflectance values of a particular feature at different wavelengths. The spectral curve also gives an indication of turbidity in the lake. In the visible spectrum, the reflectance of the clean water is lower than turbid water and hence, turbidity effects in the lakes can be visualized through the spectral curve. Hence, the visualization of the spectral curves is one of the approaches to find the relative comparisons of the turbidity level of water through satellite imagery.

2.3 Turbidity estimation method

Turbidity is the key parameter for estimating the water quality in the lake. Since turbidity depends on the reflectance of the water, thus several semi-empirical and empirical models were established to estimate turbidity through Satellite imagery [15, 16]. In site-specific empirical models, satellite imagery-derived reflectance is fitted with the ground collected turbidity values. There exists a very good correlation between turbidity and reflectance in the red band of satellite imagery. The turbidity can be expressed in terms of the reflectance through the bio-optical model [9, 16] and calibrated parameters can be used to generate the turbidity maps. Many of the researchers [14, 25] used this model and calibrated parameters to derive turbidity and suspended particulate matter (SPM) using satellite imagery. During the COVID-19 pandemic, there was a nationwide traveling restriction in India and thus Satellite imagery was the only source to access the quality of the lakes during the lockdown period. Hence, in this paper, the main focus is to analyse the relative changes in the turbidity of the lakes, and thus calibrated parameters [14, 16] were used to estimate the relative turbidity values through satellite imagery during the lockdown period. Turbidity (T) is calculated by using Eq. 1 [16] and expressed in Formazin Nephelometric Units (FNU)

\[
T = \frac{A^p \rho_{W}}{1 + C^p}[\text{FNU}]
\]

where \(A^p\) and \(C^p\) are empirical constants for a particular wavelength and \(\rho_w\) is the surface reflectance of water. The \(A^p\) and \(C^p\) coefficients were taken from the tables provided by [16] for the closest wavelength. In the present study, turbidity estimation is done for the red band of Sentinel-2 & Landsat-8 data. For Sentinel-2, the values of empirical constants for the red band (665 nm) are \(A^p = 282.95, C^p = 0.1728\) and for Landsat-8, the values of empirical constants for the red band (655 nm) are \(A^p = 289.29, C^p = 0.1686\).

2.4 Sentinel-2 data pre-processing for turbidity retrieval

The Digital number values (DN) in the level-2A product of the Sentinel-2 images are converted into reflectance values by dividing with the quantification factor (Q).
where, for Sentinel-2A/2B, \( Q = 10000 \)

The water body is extracted through NDWI and then turbidity estimation is done on the extracted water body. The NDWI for the Sentinel-2 images is calculated as

\[
NDWI = \frac{Band3(Green) - Band8(NIR)}{Band3(Green) + Band8(NIR)}
\]

The threshold of zero has been taken to extract the water body from reflectance values in the Sentinel-2B images. That is, the image pixel is water if \( NDWI > 0 \) and it is non-water if \( NDWI \leq 0 \). The flow chart of the turbidity estimation from the Sentinel-2 data is given in Fig. 1:

### 2.5 Landsat-8 data pre-processing for turbidity retrieval

Reflective band DN’s can be converted to surface reflectance using the rescaling coefficients in the auxiliary file. The DN values of the Landsat-8 images can be converted to surface reflectance through the equation

\[
\rho'_\lambda = M_\rho \ast DN + A_\rho
\]

where, \( \rho'_\lambda \) = Surface reflectance; \( M_\rho \) = Multiplicative rescaling factor from the metadata for a particular band; \( A_\rho \) = Additive rescaling factor from the metadata for a particular band; \( DN \) = Digital number of level-2 product.

The NDWI for the Landsat-8 OLI images is calculated as

\[
NDWI = \frac{Band3(Green) - Band5(NIR)}{Band3(Green) + Band5(NIR)}
\]

A similar threshold of zero has also been taken to extract the water body from reflectance values in the Landsat-8 images. The flow chart of the turbidity estimation from the Landsat-8 data is given in Fig. 2.

### 3 Results and discussion

#### 3.1 Spectral curve analysis

Spectral curves were plotted for the water signatures for Kaylana Lake, Fateh Sagar Lake, Pichola Lake, Rajsamand Lake, and Man Sagar Lake during the pre-lockdown and lockdown period. Five samples in each of the lakes are taken and mean reflectance is used for plotting the spectral curve. For each sample, a 3*3 kernel is used to plot the spectral curve. It was observed that reflectance of the water was lower in the visible part of the spectral curve during the lockdown period as compared to the pre-lockdown period which indicates that turbidity of water was improved in all the lakes during the lockdown period. Since rainfall also affects the reflectance of the lakes, thus rainfall data is also analysed and no major rainfall is observed during the pre-lockdown and lockdown period of acquisition of satellite imagery. Detailed analysis of rainfall data for each of the lakes is discussed in Sect. 3.2. Figure 3 shows the spectral curves of different lakes.

#### 3.2 Turbidity estimation

The turbidity of the different lakes was estimated during the pre-lockdown and lockdown period for Sentinel-2A/2B data. The turbidity for the different lakes was computed and given in Table 5. The reduction in percentage change of turbidity...
values shows that the turbidity of the lakes was improved during the lockdown period. The analysis of different lakes is described in the following sections.

3.2.1 Kaylana lake (Jodhpur)

Kaylana Lake is situated in Jodhpur City in the Rajasthan State of India. Turbidity estimation was done for Kaylana Lake acquired through the Sentinel-2B on dates 22/02/2020 (pre-lockdown), 03/03/2020 (pre-lockdown), and 02/04/2020 (lockdown). It was observed that the turbidity level was decreased from 16.1 FNU to 8.1 FNU with a change of 49.6%. Figures 4a, b, and c show the false colour composite (FCC) and turbidity images of Kaylana Sagar lake acquired through Sentinel-2B during dates 22/02/2020, 03/03/2020, and 02/04/2020 respectively. The unit for the Turbidity scale is FNU.

The Landsat-8 data for the dates 02/03/2020 (pre-lockdown) and 03/04/2020 (lockdown) was also analysed for the Kaylana Lake and it was observed that the turbidity level decreased during the lockdown period which was showing a similar trend as analysed for the Sentinel-2 data. Figure 4d and e shows the false colour composite (FCC) and turbidity images of Kaylana Lake acquired through Landsat-8 during dates 02/03/2020 and 03/04/2020 respectively.

During the pre-lockdown period of Jodhpur, satellite imagery data was acquired on 22/02/2020 and 03/03/2020 and it was observed that there was no rain for the period between 14/02/2020 to 03/03/2020 (pre-lockdown period). For the lockdown period, satellite imagery data was acquired for 02/04/2020 and there was no rain observed from 28/03/2020 to 02/04/2020. Figure 4f shows the rainfall data for the Jodhpur city.

3.2.2 Fateh Sagar Lake (Udaipur)

Fateh Sagar Lake is situated in Udaipur City in the Rajasthan State of India. Sentinel-2B images of Fateh Sagar Lake on dates 22/02/2020 (pre-lockdown), 13/03/2020 (pre-lockdown), and 02/04/2020 (lockdown) were analysed. It was observed that the turbidity level decreased from 9.2 FNU to 4.1 FNU with a change of 55.4%. Figures 5a, b, and c show the false colour composite (FCC) and turbidity images of Fateh Sagar Lake acquired through Sentinel-2B during dates 22/02/2020, 13/03/2020, and 02/04/2020 respectively.

The Landsat-8 data for dates 24/02/2020 (pre-lockdown) and 12/04/2020 (lockdown) was also analysed for the Fateh Sagar Lake and it was observed that the turbidity level decreased during the lockdown period which was showing a similar trend as analysed for the Sentinel-2 data. Figure 5d and e shows the false colour composite (FCC) and turbidity images of Fateh Sagar lake acquired through Landsat-8 during the dates 24/02/2020 and 12/04/2020 respectively. From the rainfall data, it was observed that there was no rain for the period between 15/02/2020 to 24/02/2020 (pre-lockdown period) and 09/03/2020 to 13/03/2020 (pre-lockdown period). During the lockdown period, satellite imagery data was acquired on 02/04/2020 and it was observed that there was no rain for the period between 29/03/2020 to 02/04/2020 (lockdown period). Figure 5f shows the rainfall data for Udaipur city for the pre-lockdown and lockdown period.

3.2.3 Pichola Lake (Udaipur)

Pichola Lake is situated adjacent to Fateh Sagar Lake in Udaipur City in the Rajasthan State of India and satellite images of Pichola Lake were acquired from the Sentinel-2B satellite.
-2B on dates 22/02/2020 (pre-lockdown), 13/03/2020 (pre-lockdown), and 02/04/2020 (lockdown) were analysed. It was observed that the turbidity level decreased from 8.1 FNU to 3.7 FNU with a change of 54.3%. The Landsat-8 data for dates 24/02/2020 (pre-lockdown) and 12/04/2020 (lockdown) was also analysed for the Pichola Lake and it

Fig. 3 Spectral signatures of different lakes during pre-lockdown and lockdown period a Kaylana Lake b Fateh Sagar Lake c Pichola Lake d Rajsamand Lake e Man Sagar Lake
was observed that the turbidity level decreased during the lockdown period which was showing a similar trend as analysed for the Sentinel-2 data. Figures 6a, b, and c show the false colour composite (FCC) and turbidity images of Pichola Lake acquired through Sentinel -2B during dates 22/02/2020, 13/03/2020, and 02/04/2020 respectively. Figure 6d and e shows the false colour composite (FCC) and turbidity images of Pichola lake acquired through Landsat-8 during the date 24/02/2020 and 12/04/2020 respectively. Lake Pichola is situated in Udaipur, thus rainfall analysis is the same as Fateh Sagar Lake.

3.2.4 Rajsamand Lake

Rajsamand Lake is situated in the Rajsamand district in the Rajasthan State of India. It was observed that the turbidity level decreased from 10.5 FNU to 4.3 FNU with a change of 58.3% during the lockdown period. Figures 7a, b, and c show the false colour composite (FCC) and turbidity images of Rajsamand Lake acquired through Sentinel-2B during the dates 22/02/2020, 13/03/2020, and 02/04/2020 respectively. From the rainfall data, it was observed that there was no rain for the period between 15/02/2020 to 22/02/2020 (pre-lockdown period), however, there was a slight rainfall of 0.05 mm on 11/03/2013 for the data acquired on 13/03/2020 (pre-lockdown period). For the lockdown period, satellite imagery data was acquired on 02/04/2020 and there was no rain observed from 28/03/2020 to 02/04/2020. Figure 7d shows the rainfall data for the Rajsamand for the pre-lockdown and lockdown period.

3.2.5 Man Sagar Lake (Jaipur)

Man Sagar Lake is situated in Jaipur City in the Rajasthan State of India. It was observed that the turbidity level decreased from 23.9 FNU to 13.2 FNU with a change of 44.8%. From the rainfall data of Jaipur, it was observed that there was no rain for the period between 14/02/2020 to 29/02/2020 (pre-lockdown period) and 12/03/2020 to 20/03/2020 (pre-lockdown period). During the lockdown period, satellite imagery data was acquired on 19/04/2020 and it was observed that there was no rain for the period between 09/04/2020 to 19/04/2020 (lockdown period). Figures 8a, b, and c show the false colour composite (FCC) and turbidity images of Man Sagar Lake acquired through Sentinel -2B during dates 29/02/2020, 20/03/2020, and 19/04/2020 respectively. Figure 8d shows the rainfall data for Jaipur city for the pre-lockdown and lockdown period.

4 Conclusions

During the nationwide lockdown due to COVID-19 in India, the hydrosphere of India was significantly improved. Due to a reduction in the operation of industries, fewer human activities, and the restriction of tourism, industrial and anthropogenic waste in the lakes was significantly reduced. The turbidity of the five Indian lakes situated in Rajasthan is estimated from surface water reflectance values acquired through satellite imagery. The surface reflectance of the water in the lakes was also analysed through the spectral curve during the pre-lockdown and lockdown period. The turbidity estimated through the satellite imagery of all the lakes showed that water quality improved during the lockdown period. Turbidity estimated through satellite imagery showed that the turbidity of lakes was reduced in Kaylana Lake (49.6%), Fatehsagar Lake (55.4%), Pichola Lake (54.3%), Rajsamand Lake (58.3%), and Man Sagar Lake (44.8%) during the lockdown period. Both Sentinel-2 and Landsat-8 satellite imagery showed a similar trend of reduction in turbidity in the lakes. The spectral curves of the water for five Indian lakes in Rajasthan also showed that reflectance of the water was lower in the lockdown period compared to the pre-lockdown period, thus it indicates that turbidity of the water was decreased during the lockdown period. Since rainfall may also affect the turbidity, hence rainfall data was also analysed for the pre-lockdown and lockdown period. It was observed that there was not much rainfall during the period of acquisition of satellite imagery of different lakes during the pre-lockdown as well as the lockdown period. However, due to COVID-19 lockdown traveling restrictions, no field observation was collected to validate the satellite observations but relative comparisons of reflectance and turbidity values estimated through satellite

| S.No | Lakes                        | Mean Turbidity during pre-lockdown period (FNU) | Mean Turbidity during lockdown period (FNU) | Mean Percentage Change (%) |
|------|-----------------------------|-----------------------------------------------|-------------------------------------------|----------------------------|
| 1    | Kaylana lake, Jodhpur       | 16.1                                         | 8.1                                       | −49.6                      |
| 2    | Fateh Sagar Lake, Udaipur   | 9.2                                          | 4.1                                       | −55.4                      |
| 3    | Lake Pichola, Udaipur       | 8.1                                          | 3.7                                       | −54.3                      |
| 4    | Rajsamand Lake, Rajsamand   | 10.5                                         | 4.3                                       | −58.3                      |
| 5    | Man Sagar lake, Jaipur      | 23.9                                         | 13.2                                      | −44.8                      |
Fig. 4 Sentinel-2B and Landsat-8 image of Kaylana lake for FCC and Turbidity (FNU) for different dates

(a) 22/02/2020 (Sentinel-2B)
(b) 03/03/2020 (Sentinel-2B)
(c) 02/04/2020 (Sentinel-2B)
(d) 02/03/2020 (Landsat-8)
(e) 03/04/2020 (Landsat-8)

(f) Rainfall data for Jodhpur for pre-lockdown and lockdown period
Fig. 5 Sentinel-2B and Landsat-8 image of Fateh Sagar lake for FCC and Turbidity (FNU) for different dates a 22/02/2020 (Sentinel-2B) b 13/03/2020 (Sentinel-2B) c 02/04/2020 (Sentinel-2B) d 24/02/2020 (Landsat-8) e 12/04/2020 (Landsat-8) f Rainfall data for Udaipur for pre-lockdown and lockdown period
Fig. 6 Sentinel-2B and Landsat-8 image of Pichola lake for FCC and Turbidity (FNU) for different dates a 22/02/2020 (Sentinel-2B) b 13/03/2020 (Sentinel-2B) c 02/04/2020 (Sentinel-2B) d 24/02/2020 (Landsat-8) e 12/04/2020 (Landsat-8)
Fig. 7  Sentinel-2B image of Rajsamand lake for FCC and Turbidity (FNU) for different dates a 22/02/2020 (Sentinel-2B) b 13/03/2020 (Sentinel-2B) c 02/04/2020 (Sentinel-2B) d Rainfall data for Rajsamand for pre-lockdown and lockdown period
imagery showed that the water quality of all five lakes was improved during the lockdown period.

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Declarations

Conflict of interest The authors declare that there is no conflict of interest regarding the publication of this paper.

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