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A Review of Perspectives from Earth Observation Data to Investigate the Effects of COVID-19 on The Environment

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ABSTRACT

Background: Earth observation data has established themselves as extremely useful and very diverse domains for research associated with space, spatio-temporal components, and geography. Following the outbreak of Severe Acute Respiratory Syndrome CoronaVirus 2 (SARS-CoV-2) last December 2019 in China. This study aims to systematically review and synthetize perspectives from earth observation data to investigate the effects of COVID-19 on the environment.

Material and Methods: A total of 41articles were first collected from four main digital databases including Web of Science, SCOPUS, PubMed/MEDLINE, and Google scholar. It will go on comprehensively review and synthesize applications of earth observation data in studies the COVID-19 impacts on environment. Specifically, the content is presented under three sub-sections; namely the use of earth observation data in (i) studies of impacts on water quality, (ii) studies of impacts on air quality, and (iii) studies of other impacts on the environment, respectively.

Results: It was found that change in the intensity of air and water pollution after reduced anthropogenic activities around the world were captured by remote sensing - supplying concrete evidence that can help inform improved environmental policy during the COVID-19 pandemic.

Conclusion: It can be concluded that the varied use of remote sensing techniques affirms the value of earth observation data to studies of infectious diseases to environment, especially in times of such large-scale disasters as the COVID-19 pandemic.

KEYWORDS: Review, Earth observation data, Effects, COVID-19, Environment, Air quality, Water quality.

INTRODUCTION

When COVID-19 was discovered in late December 2019 in Hubei province, China, as the causative agent of a cluster of pneumonia cases, around 27.5 million cases in 215 countries worldwide have been recorded as of the end of August 2020 (Figure S1, Supplementary section), with approximately 0.89 million deaths. (1). World Health Organization (WHO), on January 30, 2020, reconvened the Emergency Committee (EC) to declare the '2019-nCoV' as an outbreak that constituted a Public Health Emergency of International Concern (PHEIC). The virus known as SARS-CoV-2 was renamed by the International Committee on Taxonomy of Viruses (ICTV) on February 11, 2020. It has demonstrated a stronger genetic resemblance to the SARS outbreak that occurred in 2003 as a result of SARS-CoV (2–4). Later, the novel disease caused by SARS-CoV-2 was given the name COVID-19 by the World Health Organization (2). The WHO declared COVID-19 as a worldwide pandemic by March 11, 2020 (5). As of August 2023, the COVID-19 pandemic has caused over 772.8 million confirmed cases and 6.9 million deadths worldwide (6). The tourism, aviation, agricultural, and financial sectors have suffered losses as a result of the rapidly spreading COVID-19 pandemic. Furthermore, governments everywhere have been compelled to substantially cut the economy's supply and demand. (7). As a result, numerous attempts have been made to apply cutting-edge technology and approaches to aid in the fight against the COVID-19 epidemic.

The application and utilization of geospatial analysis tools and methodologies, satellite imagery, and remote sensing platforms offer a wide range of advantages to experts, practitioners, and the scientific community (8). Real-time tracking of reported and verified case numbers and simpler, more comprehensible visualizations are just a couple of these advantages (8). Spread direction and contact tracing, which can identify hotspots to manage community dispersion and spread, are other advantages. It is important to note that the COVID-19 pandemic did not introduce the use of geographic analysis in solving public health-related issues (9). Numerous research in the past have made use of geographic information systems (GIS) and spatial analysis. They were even in use prior to the mid-1960s birth of GIS software (10). The visualization, mapping, analysis, and detection of patterns of various diseases, particularly infectious disease mapping, are among the applications of geospatial analytics and GIS (10). One technique that is frequently used to gather physical data that will be incorporated into a GIS is remote sensing. It is the practice of employing a satellite or airplane to measure the radiation that is emitted and reflected from a particular geographic location at a distance in order to identify and track its physical features (11). Human activity is measured, recognized, and tracked using satellite photography (12). Data that are closely associated with certain geographic locations are referred to as geospatial data. Furthermore, GIS is one sort of geographic imagery and mapping technology that falls under the wide category of "geospatial" technology (13). By contact tracing and enforcing lockdowns, a number of geospatial, satellite imaging, and remote sensing techniques, software, and procedures have been used to stop the spread of COVID-19 (9). One of the greatest instances of the COVID-19 pandemic's use of GIS and geography is John Hopkins University (8,9,14). Furthermore, the World Health Organization (WHO), as well as local and regional organizations, took the same course (14).

Since the COVID-19 epidemic has spread around the world, attempts have been made to apply GIS and remote sensing in COVID-19 studies. However, there hasn't been much focus on the investigation of the effects of COVID-19 on the environment using earth observation data. It is, therefore, this research attempts to comprehensively review and synthesise applications of earth observation data in studies the COVID-19 impacts on environment. Specifically, the content is presented under three sub-sections; namely the use of earth observation data in (i) studies of impacts on water quality, (ii) studies of impacts on air quality, and (iii) studies of other impacts on the environment, respectively.

MATERIALS

We searched papers from main databases such as Google Scholar, SCOPUS, PubMed/MEDLINE, and Web of Science. All study types from any year were covered in these English-language articles. Three main topics were used to group the 41 publications that satisfied the inclusion criteria. The selection of these articles was based on their substantial citation count and pertinence to COVID-19, earth observation data, and environmental concerns.

METHODS

Initially, four digital databases namely Web of Science, Google Scholar, PubMed/MEDLINE, and SCOPUS, were queried using three distinct themes. Regarding the first theme, which is the use of earth observation data in studies of COVID-19 impacts on water quality. Numerous different keyword combinations were utilised, including "application," "the use," "COVID-19" "SARS-CoV-2" "impacts," "COVID-19," "SARS-CoV-2" and " Sentinel-3B" or "Sentinel-2A", "Landsat-5 TM", " Landsat-8 OLI", and " Remotely sensed images". Combinations of keywords like "application" "the use" "MERRA-2 and AIRS data", "VIIRS NTL data" "high resolution remote sensing data" "OMI and AIRS data" and "MODIS images" have been used in connection with applications of earth observation data in studies of air quality. And last, we come to the final theme, which is the use of earth observation to study other impacts on the environment. The following combinations of key words have been used including "application", "the use", "Aqua MODIS images", "satellite data", "surface and satellite observation data", "COVID-19", and "environment". Finnally, the uses of earth observation data in studies of the COVID-19 impacts on the environment were summarised and discussed.

RESULTS AND DISCUSSION

Studies of impacts on water quality

Studies of impacts on water quality in the COVID-19 pandemic were summarised in Table 1. One of the earliest research on the COVID-19's effects was successfully conducted (15). This study examined the impact of social distancing on water quality along the Jakarta coast using remote sensing data obtained in January and February 2020 from the Copernicus Sentinel-3B Ocean and Land Color Instrument. It was discovered that social separation and activity limits caused declines in the amounts and regions of chlorophyll-a along the coast (15). A few weeks later, the effects of the COVID-19 quarantine that affected the Alboran Sea (Spain) both before and during (beginning on February 3, 2020) and after (ending on June 22, 2020) were studied using Sentinel-2A photos and ArcGIS software. A few weeks later, another research has studied the effects of the COVID-19 quarantine that affected the Alboran Sea (Spain) both before and during (beginning on February 3, 2020) and after (ending on June 22, 2020), using Sentinel-2A photos and ArcGIS software (16). The study results of a study indicated that seawater quality has been improved after the quarantine caused by COVID-19 (16). Later, Niroumand-Jadidi et al. (2020) used PlanetScope imagery to obtain water quality data in order to examine the effects of the 2020 COVID-19 lockdown and the 2019 extreme flood in the Venice lagoon (northeast Italy) (17). The findings in a recent study have demonstrated a noteworthy decrease in turbidity during the COVID-19 pandemic lockdown, as well as the collection of high total suspended matter (TSM) values during the flood situation (as shown in Figure 1) (17).

A recent study demonstrated that, when compared to normal days, the water quality of the Ganga River was improved during India's COVID-19 lockdowns (24 March to 18 May 2020) using Sentinel-2A, -2B, and optical satellite data (18). Utilising various multi-temporal optical remotely sensed images obtained from November 2019 to April 2020, such as China's GaoFen-1 (GF-1) Wide Field of View (WFV) images and Landsat-5 Thematic Mapper (TM), Landsat-8 Operational Land Imager (OLI), and TSS concentrations in the Lower Min River (China) were investigated during COVID-19, according to a study, the lockdown measures caused TSS concentrations in February 2020 to drop by 48% (19). Additionally, a recent study also came to the conclusion that the river's TSS drop during the shutdown era appears to be mostly caused by industrial output, social and economic activity, and river shipping. Most recently, the Landsat-8 sensor Operational Land Imager (OLI) was used to evaluate the indicative lake water quality for Lake Hussain Sagar (India) in order to comprehend the consequences of the COVID-19 shutdown (20). The results of this investigation demonstrated a considerable decrease in lake water pollution as well as a decrease in the concentrations of chlorophyll-a (Chl-a) and coloured dissolved organic matter (CDOM) (20). \

Table 1. Types of earth observation data used in studies of impacts of COVID-19 on water quality.

Types of earth observation data	Purposes of study	Study area	Study
Copernicus Sentinel-3B Ocean and Land Color Instrument	Investigating the effects of social distancing on water quality during COVID-19	Jakarta, Indonesia	(15)
Sentinel-2A images	Assessing effects of before and during the quarantine caused by COVID-19	Alboran Sea, Spain	(16)
PlanetScope imagery	Studying the impacts of the 2020 COVID-19 lockdown	Venice, Italy	(17)
Sentinel-2A, -2B, and optical satellite data	Assessment of water quality during COVID-19 lockdowns	Ganga River, India	(18)
Landsat-5 TM, Landsat-8 OLI, and China's GF-1 WFV images	investigating the lockdown effects of the COVID-19 on total suspended solids	Lower Min River, China	(19)
Landsat-8 OLI images	Assessing the indicative lake water quality during COVID-19 lockdown	Lake Hussain Sagar, India	(20)
Remotely sensed images	Assessing water pollution in Yamuna river due to lockdown	Yamuna river, India	(21)
	Investigate surface water quality status and prediction during COVID-19	Malaysia	(22)
Landsat-8 OLI images	Assessing lake water quality during the lockdown	India	(23)

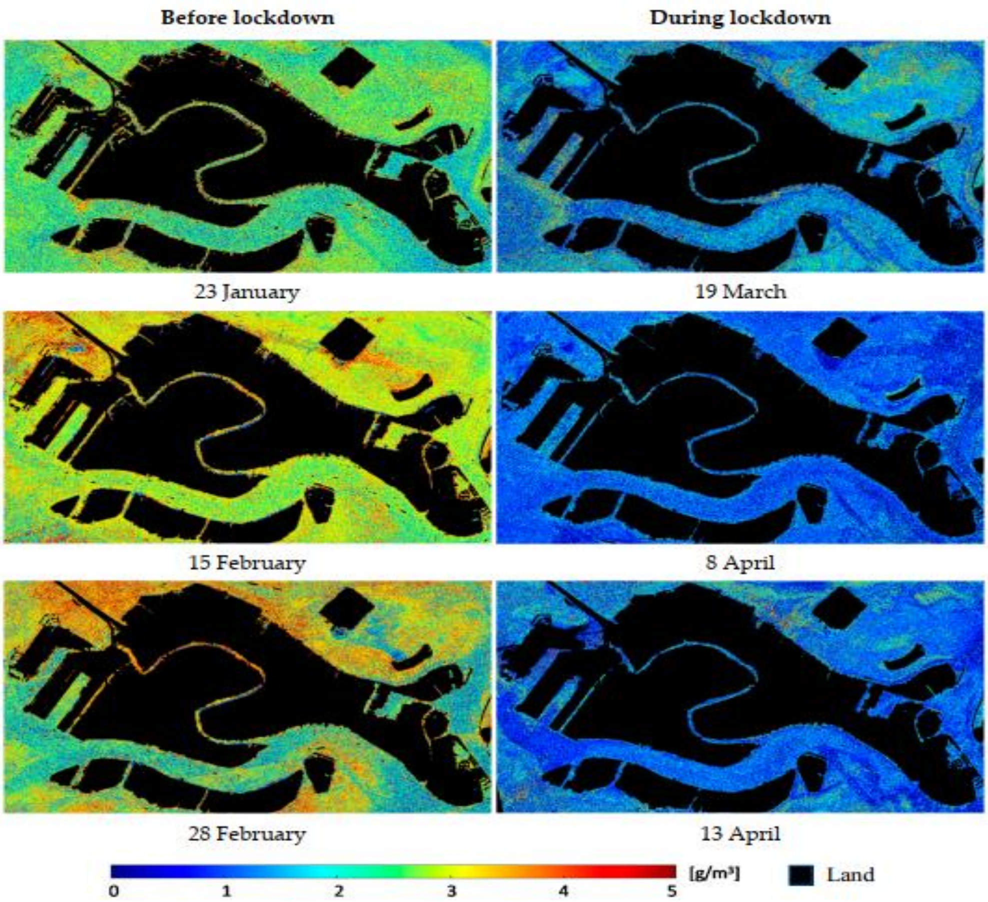

Figure 1. Multitemporal maps of concentration of total suspended matter before and during the COVID-19 lockdown in Venice, Italy (17).

Based on the preceding discourse, it may be inferred that the water quality has improved throughout the COVID-19 lockdown. These results were in line with numerous research' conclusions (21–23). Whereas, reduction in water pollution in Yamuna river due to lockdown under COVID-19 pandemic was assessed (21). Later, a study on surface water quality status and prediction during movement control operation order under COVID-19 pandemic was carried out in Malaysia (22). In India, lake water quality as improved during the COVID-19 lockdown using Landsat-8 OLI images (23).

Studies of impacts on air quality

Table 2 summarises research on the COVID-19 pandemic's effects on air quality. Nitrogen dioxide (NO_2) concentrations measured from remotely sensed photos had been proven to decline by as much as 30% across China and by as much as 50% across portions of central Europe during the early phases of the Covid-19 epidemic, which was first found in Wuhan city, PR China.(NASA 2020). Subsequently, one of the initial investigations of how the COVID epidemic affected air quality was conducted (24). Using MERRA-2 and AIRS data, modelling the worldwide air quality conditions from the perspective of COVID-19-stimulated lockdown periods, it was concluded that in fully lockdown countries, concentration levels of aerosol optical depth (AOD), sulphur dioxide (SO_2), ozone, carbon monoxide (CO), particulate matter (PM2.5), and black carbon (BC) have decreased dramatically throughout the lockdown (24). Subsequently, research using remotely sensed imagery on certain nations and areas was gradually published. Using data on nocturnal light and air quality, a Google Scholar ranking of the most highly referenced studies on the spatiotemporal patterns of COVID-19 influence on human activities and environment in mainland China was conducted (25). In that study, it was discovered that a notable decline from January to March 2020 in the daily average Air Quality Index for mainland China, with most provinces having better air in February and March than in January 2020 (25).

Table 2. Types of earth observation data used in studies of impacts on air quality during COVID-19.

Types of earth observation data	Purposes of study	Study area	Study
Remotely sensed images	Estimating nitrogen dioxide (NO_2) concentrations	Wuhan, China	(23)
MERRA-2 and AIRS data	Modeling global air quality during COVID-19 lockdown	Global	(24)
VIIRS NTL data	Spatio-temporal patterns of COVID-19 impact on human activities and environment	Mainland China	(25)
Satellite data	Estimating the decline and rebound in CO_2 emissions during the COVID-19 pandemic	China	(26)
High resolution remote sensing data	Investigating driving force of CO_2 emissions	China	(27)
OMI and AIRS data	Estimating the extent of the reduction of major pollutants	South-east Asian	(28)
MODIS images	Assessing air pollution scenario over China during COVID-19	Beijing-Tianjin-Hebei Northeast,Central China	(29)
Aqua MODIS images	Assessment of reductions in NO_2 in the urban area during partial lockdown	São Paulo, Brazil	(30)
Ground- and satellite-based data	Investigating the COVID-19 transmission change under different lockdown scenarios	Dhaka city, Bangladesh	(31)
Different types of remotely sensed images	Studying air quality improvement during the COVID-19 lockdown	England	(32)
Satellite data	Tropospheric nitrogen dioxide and spread of SARS-CoV-2 infection	Italy	(33,34)
Earth observation data	Earth observation data in support of slum communities with evidence	Brazil	(35)
Surface and satellite observation data	Air quality and mortalities under COVID-19 lockdown	Italy	(36,37)

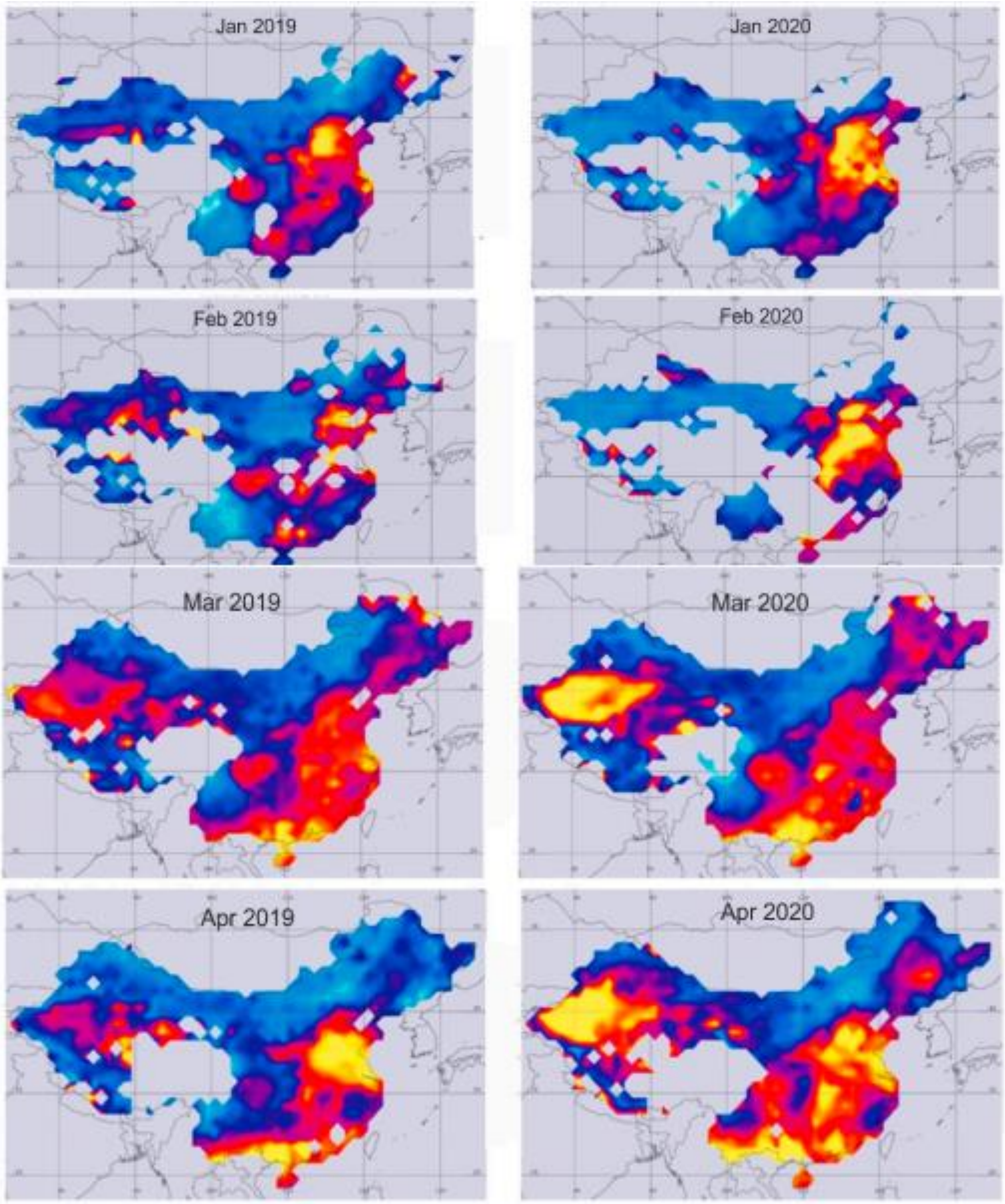

Figure 2. Aqua MODIS monthly aerosol optical depth before and after the COVID-19 pandemic (modified from (29)).

With the help of satellite data, the decline and rebound in China's CO_2 emissions were estimated during the COVID-19 pandemic (26). Similar to those of the finding in a study of (26), It was also revealed that the driving force of China's CO_2 emissions fell by more than 40% compared with the same period in 2019 when the city was closed from the end of January to the beginning of 2020 (27). Using OMI and AIRS data to estimate the extent of the reduction of major pollutants such as carbon monoxide, nitrogen dioxide, and sulfur dioxide in the south-east Asian regions from January to April 2020, a recent study discovered that air quality improved in India and China during the COVID-19 outbreak in which NO_2 was reduced the most; CO to some extent and SO_2 experienced a nominal reduction (28). Similar to those reported by a study of (28), during COVID-19, there was a reduction in NO_2 throughout the Beijing-Tianjin-Hebei region as well as most of Northeast and Central China as shown in Figure 2 (29) and significant drops in NO_2 (up to -54.3%) during the partial lockdown of the city (30). Most recently, when investigating how COVID-19 spreads under various lockdown circumstances in the city of Dhaka, Bangladesh, a study of (31) showed that overall, 26, 20.4, 17.5, 9.7, and 8.8% declined in PM 2.5, NO_2, SO_2, O_3, and CO concentrations, respectively, in Dhaka City during the partial and full lockdown compared to the period before the lockdown. Recent research from severely affected nations also supported the improvement in air quality during the COVID-19 lockdown, quarantine, and social separation measures utilising various types of remotely sensed imagery such as England (32), Italy (33,34), Brazil (35), and most recently India (36,37).

Studies of other impacts on the environment

Studies of other impacts on the environment in the COVID-19 pandemic were summarised in Table 3. In addition to the primary effects on water and air quality that were previously discussed, numerous studies have been carried out utilising remotely sensed imagery to examine the COVID-19 pandemic's additional environmental effects, such as urban heat islands (38–40) and ecology

(33). In the study of urban heat islands, when carrying out research on the use of remote sensing to evaluate variations in the urban heat island effect in relation to the lockdown measures put in place to slow the spread of the COVID-19 virus in Pakistan, a recent study of (38) had come to a conclusion that the surface urban heat island effect clearly decreased as a result of mobility constraints in the cities, especially in megacities. This finding is consistent with those recently reported in studies of (39) using the Level 2 Sentinel 5P data in the United Arab Emirates and in a study using MODIS images in Montreal, Canada (40). The effect of the COVID-19 lockdowns on the urban surface ecological state in the cities of Milan and Wuhan was most recently evaluated in the study of ecological status (41). It was discovered that built-up, bare soil, and green spaces for Milan and Wuhan significantly decreased as a result of the COVID-19 lockdowns (41).

Table 3. Types of earth observation data used in studies of COVID-19's impacts on the environment.

Types of earth observation data	Purposes of study	Study area	Study
Satellite data from the European Space Agency	Relationship between nitrogen dioxide and spread of SARS-CoV-2 infection	Italy	(33)
Remotely sensed images	Impacts of the COVID-19 pandemic on urban heat islands	Pakistan	(38)
Level 2 Sentinel 5P data	Investigating surface urban heat island effect during the COVID-19 pandemic	United Arab Emirates	(39)
MODIS images		Montreal, Canada	(40)
Landsat-8 images	Assessing impacts of the COVID-19 lockdowns on urban surface ecological status	Milan, Italy Wuhan, China	(41)

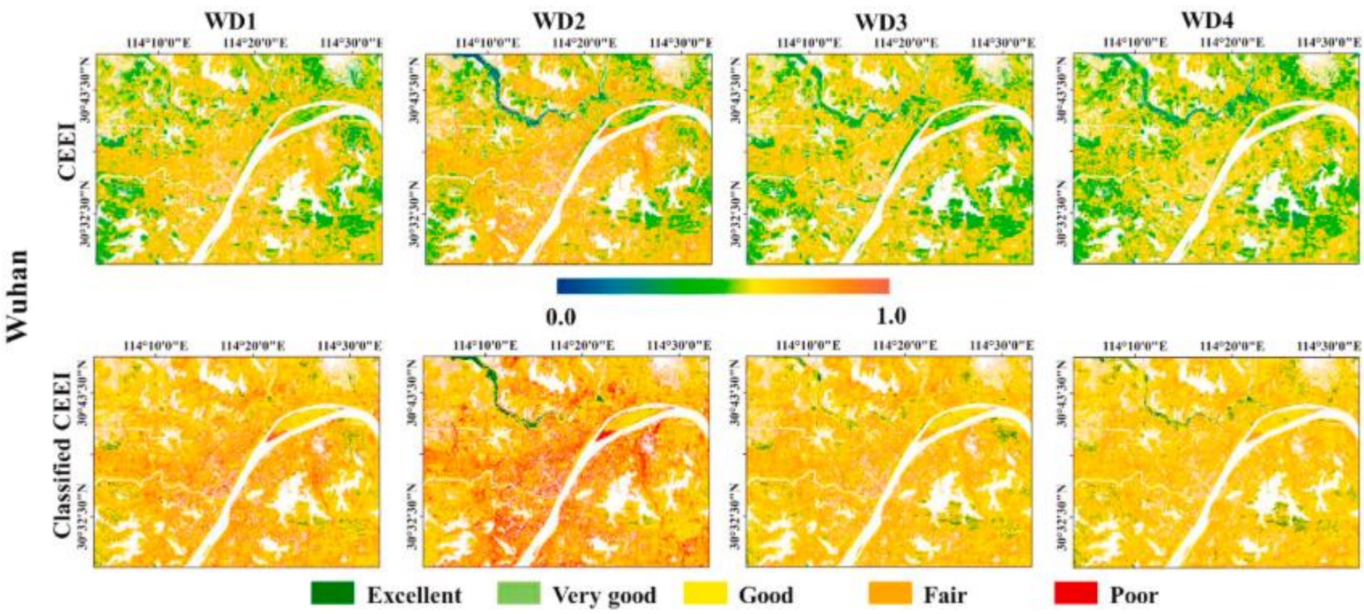

Figure 3. The urban surface ecological status maps of Wuhan city at pre-lockdown (WD1, WD2 and WD3 for Wuhan) and during the lockdown (WD4) dates (modified from (41)).

CONCLUSION

The purpose of this study is to systematically review and synthetize perspectives from earth observation data to investigate the effects of COVID-19 on the environment. A total of 44 articles were first collectedrom four main digital databases including Web of Science, SCOPUS, PubMed/MEDLINE, and Google schoolar. A comprehensively review and synthesis of applications of earth observation data in studies the COVID-19 impacts on environment was carried out. Specifically, the content is presented under three sub-sections; namely the use of earth observation data in studies of impacts on water quality, studies of impacts on air quality, and studies of other impacts on the environment, respectively. It was found that change in the intensity of air and water pollution after reduced anthropogenic activities around the world were captured by remote sensing - supplying concrete evidence that can help inform improved environmental policy during the COVID-19 pandemic. It can be concluded that the varied use of remote sensing techniques affirms the value of earth observation data to studies of infectious diseases to environemtn, especially in times of such large-scale disasters as the COVID-19 pandemic. As techniques for analyzing and extracting valuable information advance and data quality and quantity both rise, the value of earth observation data should likewise rise with time. We should keep creating and promoting platforms such as online or mobile applications that enable non-expert stakeholders to easily access valuable information in order to encourage the usage of earth observation data.

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CONFLICT OF INTEREST

None

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