TURKGEO
TURKISH JOURNAL OF GEOSCIENCES

ISSN: 2717-7696
Review Article
Vol; 01, Issue; 01, pp. 1-7, 2020
DOI:
Journal homepage:
https://dergipark.org.tr/en/pub/turkgeo

Geospatial Data Science Response to COVID-19 Crisis and Pandemic Isolation Tracking

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Keywords
COVID-19
Epidemic Spreading
Community Resilience
Pandemic Isolation
Geospatial Information

ABSTRACT

A novel Coronavirus (COVID-19 or SARS-CoV-2) pandemic has become a unique issue topping the global agenda in 2020. Georeferencing any pandemic brings in a spatial extent to monitoring such public health crises. This will be possible only if data patterns about the pandemic cases have practical and biologically relevant value. This article investigates the use of geospatial data science for monitoring the outbreak and reviews the outcomes of the studies carried out. These studies consist of a variety of techniques, such as real-time geospatial databases for pandemic cases, monitoring medical needs, geospatial dashboards, environmental change detection during the pandemic and data collection. Moreover, this study discusses the concept of pandemic isolation tracking and emphasizes its impact during prevention and recovery phases. As a conclusion, the article presents some recommendations and future perspectives for the use of geospatial data science in epidemiological research and community resilience.

1. INTRODUCTION

Geospatial data science plays a vital role to understand, analyse and visualise the spatial distribution of any phenomenon occurring on Earth. Geographic information systems (GIS) are one of the most valuable tools for managing geospatial data flow. Satellite imagery, on the other hand, enables the researchers to monitor land cover and land use to extract highly meaningful geospatial information. Not only crowdsourcing approach using social media and mobile apps, but also the widespread use of smart sensors are modern opportunities for leveraging geospatial big data. Geospatially labelled and instantaneous datasets present effective solutions for global and local difficulties by using big geospatial data analytics methods (VoPham et al., 2018).

By the beginning of 2020, a novel Coronavirus (COVID-19 or SARS-CoV-2) pandemic has become a unique issue topping the global agenda. On March 11, 2020, the World Health Organisation (WHO) announced COVID-19 a pandemic and most countries have preferred to shut down schools and public areas, including travel bans, mass quarantines or nationwide lockdowns (Cohen & Kupferschmidt, 2020; Hui et al., 2020).

Epidemiology is a branch of science that monitors the distribution of factors and phenomena affecting directly the public health. It tries to establish the relationships between the diseases and their possible pathogenesis. The variety of environmental, social and personal factors which cause an outbreak of a particular disease should also be examined through spatial and temporal data sets (Porta, 2014).

In this context, this review article scrutinises the importance of the geospatial information for the studies of infectious diseases' epidemiology. For this purpose, the article begins with a literature review that identifies the key functions of the geospatial data use and related examples in previous infectious diseases research. Then, it deeply investigates the geospatial data science's responses to COVID-19 crisis, by reviewing the outcomes of the academic and institutional case studies. These studies cover a variety of techniques, such as recording pandemic cases in a real-time geospatial database, monitoring medical needs, establishing local and global geospatial dashboards, monitoring environmental changes during the lockdowns and the collection of pandemic datasets.

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Cite this article

Iban, M.C. (2020). Geospatial Data Science Response to COVID-19 Crisis and Pandemic Isolation Tracking. *Turkish Journal of Geosciences*, 1(1), 1-7.

Received: 11/04/2020; Accepted: 03/05/2020

Furthermore, this article introduces the pandemic isolation tracking projects that are being implemented across the globe and it presents the Turkish example to discuss data privacy issues. In the conclusion part, the article presents some recommendations and future perspectives for the use of geospatial data science in epidemiologic researches.

2. GEOSPATIAL DATA SCIENCE RESPONSES TO COVID-19

2.1. Mapping the Infectious Diseases

Previous studies have utilised GIS and satellite images to model how the infectious diseases spread, to determine typical environmental factors (e.g. temperature, humidity, flora and fauna) that cause the outbreak, and to identify which communities and human settlements are under the risk of these diseases (Boone, 2000; Brooker & Michael, 2000; Tran et al., 2016). Apart from infectious diseases, in many countries, GIS techniques have been used as a tool to extract geo-relationships between cancer cases and the environment (for Turkish examples, see Colak et al., 2015; Yomralioglu et al., 2009). Furthermore, there have been also several studies for monitoring the infectious diseases in plants (the ones that are consumed by human beings) caused by pathogenic viruses; consequently, it has been possible to map the infected plants and decreased agricultural productivity using geospatial datasets (Gáborjányi et al., 2003).

Infectious diseases have been geo-localised using a variety of geospatial data since John Snow for the first time mapped the London cholera epidemic in 1854. He found out that contaminated water from a street pump had caused the epidemic even though the foul air had been considered to be the reason (Bynum, 2013).

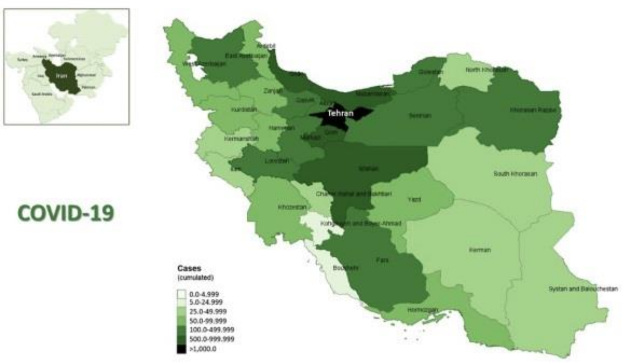


Figure 1. An example from Iran: Mapping cases at province level (Arab-Mazar et al., 2020)

2019-20 Coronavirus pandemic is also being mapped and analysed at global and local scale with real-time case information (for Iranian case, see Figure 1) (Arab-Mazar et al., 2020; Fanelli & Piazza, 2020). While the number of infected people increases, their travel stories and close contact with other people are being recorded in many countries. Such a record inventory is helpful to decrease the spread of the pandemic and to implement the preventive measures.

2.2. Recording COVID-19 Cases in a Real-time Geospatial Database

A recent study from China, published in *Nature's Scientific Data* journal, shows how real-time infection cases are recorded in a geospatial database, especially in Wuhan City where the virus was first identified. This study presents a geospatial database which contains real-time data sets such as hospital, the date and time when the tests resulted positive and the treatment started, age and gender, observed symptoms, the travel story of the infected individuals. The attention-grabbing aspect of this study is that all recorded cases are geo-coded precisely at the district or even building scale. Such a precise geospatial database has been converted into an automatically-updated interactive web application using Mapbox open-source platform and JavaScript codes. Afterwards, the data sources of other countries (e.g. Western Europe, the United States, Iran and Japan), which record their infection cases at local levels, have been added to this geospatial database; therefore, an open-source global data visualisation tool (Figure 2) has become available (Xu, Gutierrez, et al., 2020; Xu, Kraemer, et al., 2020).

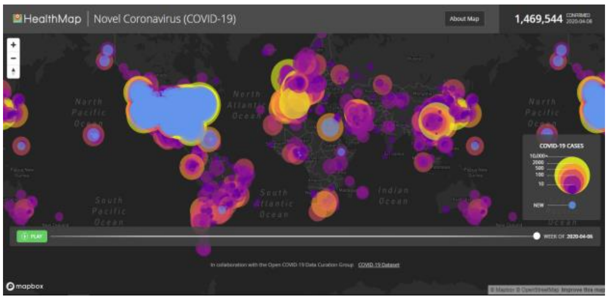


Figure 2. Global COVID-19 Map (Xu, Kraemer, et al., 2020)

The most notable and cited example of a global pandemic map is the interactive web-based dashboard (Figure 3) developed by John Hopkins University Centre for Systems Science and Engineering. The details about this dashboard were published in *The Lancet Infectious Diseases.* Collected data is freely available in their GitHub repository. To track the progression of the pandemic, there have been dozens of similar dashboards at country scale supported by ESRI's ArcGIS Atlas of the World (Dong et al., 2020).

By these dashboards, the users can click on any location and a pop-up displays reported cases in that location. There are several boxes on the right side of the dashboards summarising the total deaths and recoveries as well as country-by-country details. The data is symbolised as graduated circles, whose size corresponds to the total number of confirmed cases at that location.

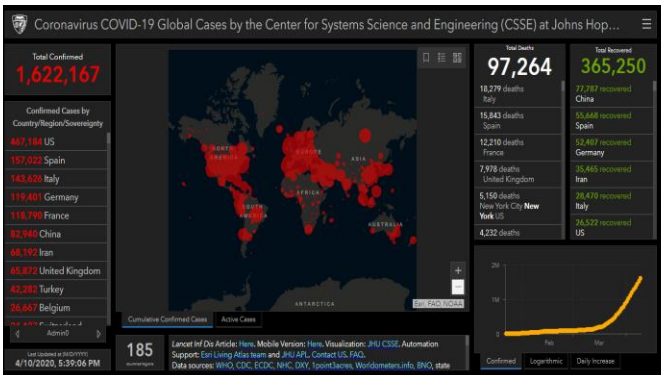


Figure 3. The interactive web-based dashboard (Dong et al., 2020)

2.3. Monitoring Risky Zones and Medical Supplies

Another study from China, published in *Geography and Sustainability*, summarises the short-term gains of big geospatial data management in the context of the fight against a pandemic. Open geospatial data management enables to monitor the contagiousness of the virus throughout the country, from the first case until the latest identified cases. This helps to determine the corridors where the virus travels and to delineate buffer zones depending on the risk density. By mapping the risky areas (see Figure 4), preventive measures can be implemented in those affected areas.

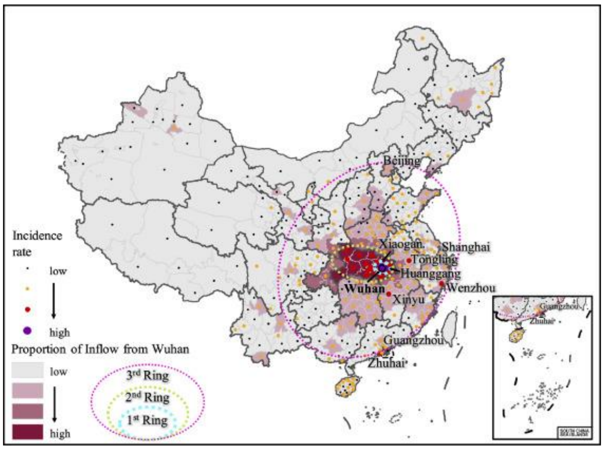


Figure 4. Determining the Risky Areas in China (Zhou et al., 2020)

Another gain is that such a big geospatial inventory can collect the instantaneous medical needs of the institutions across the country (Figure 5). Such a data flow should be open to the public in order to make the medical industry fulfil the needs of the doctors immediately. Manufacturing companies, public health institutions and logistic chains will be able to monitor the need and transport of medical supplies more straightforwardly, as proven by the study (Zhou et al., 2020). Another example of accelerating medical supply and patient transportation is the Copernicus satellite imagery usage of European Commission (EC). The EC was able to speed up the customs procedures at member states' borders to let the vehicles pass through the long queues rapidly.

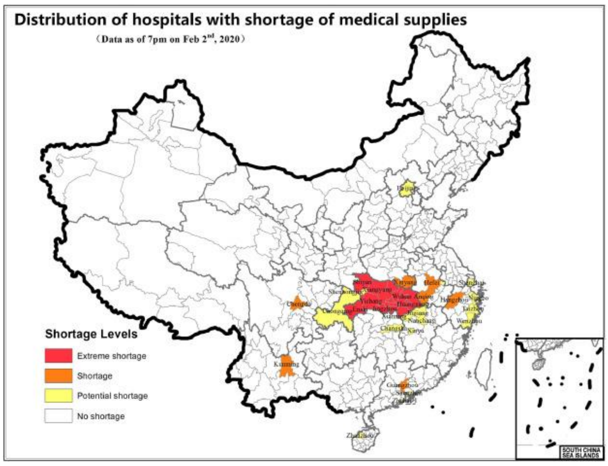
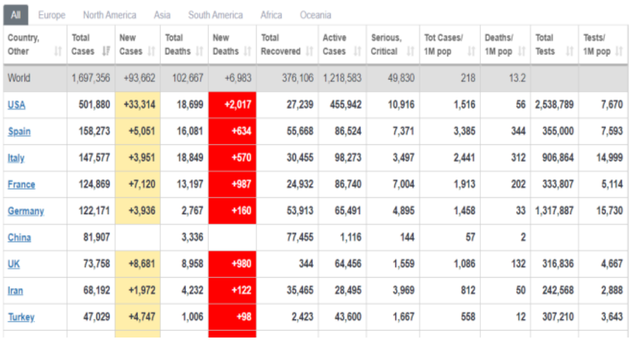


Figure 5. Distribution of Medical Supply Needs (Zhou et al., 2020)

2.4. Collection of Pandemic Datasets

Governmental institutions every day publish COVID-19 datasets for identified cases, recovered and dead patients. However, datasets mostly are not published in a machine-readable format (such as .xls or .csv files and JSON file format). For instance, the Italian Civil Protection publishes their daily reports with PDF format or scanned files on their website (Borruso, 2020). Turkish Health Ministry also has not published any machine-readable dataset, instead, it uses pdf files and screenshotted maps (Turkish Ministry of Health, 2020). To cope with such a big non-machine-readable data flow, volunteer data analysts rewrite these data and publish them in personal GitHub repositories, Kaggle or many other data warehouses (Borruso, 2020).

Worldometers (an international team of developers) every day collects the published data of each country (Figure 6) and researchers can freely extract this tabular dataset via web requests (Worldometer, 2020). The positive cases in Turkey are being mapped at street level through a mobile application (named as *Hayat Eve Sığar*) by the Ministry of Health; however, these datasets are neither downloadable nor machine-readable (Figure 7). The aim of this application is to warn the users about the risks in their territory. Practically, there is not an open-source, vector-format GIS for geo-localising COVID-19 cases in Turkey.



All | Europe | North America | Asia | South America | Africa | Oceania

Country, Other	Total Cases	New Cases	Total Deaths	New Deaths	Total Recovered	Active Cases	Serious, Critical	Tot Cases/ 1M pop	Deaths/ 1M pop	Total Tests	Tests/ 1M pop
World	1,697,356	+93,662	102,667	+6,983	376,106	1,218,583	49,830	218	13.2		
USA	501,880	+33,314	18,699	+2,017	27,239	455,942	10,916	1,516	56	2,538,789	7,670
Spain	158,273	+5,051	16,081	+634	55,668	86,524	7,371	3,385	344	355,000	7,593
Italy	147,577	+3,951	18,849	+570	30,455	98,273	3,497	2,441	312	906,864	14,999
France	124,869	+7,120	13,197	+987	24,932	86,740	7,004	1,913	202	333,807	5,114
Germany	122,171	+3,936	2,767	+160	53,913	65,491	4,895	1,458	33	1,317,887	15,730
China	81,907		3,336		77,455	1,116	144	57	2		
UK	73,758	+8,681	8,958	+980	344	64,456	1,559	1,086	132	316,836	4,667
Iran	68,192	+1,972	4,232	+122	35,465	28,495	3,969	812	50	242,568	2,888
Turkey	47,029	+4,747	1,006	+98	2,423	43,600	1,667	558	12	307,210	3,643

Figure 6. A part of Worldometer's case report (Worldometer, 2020)

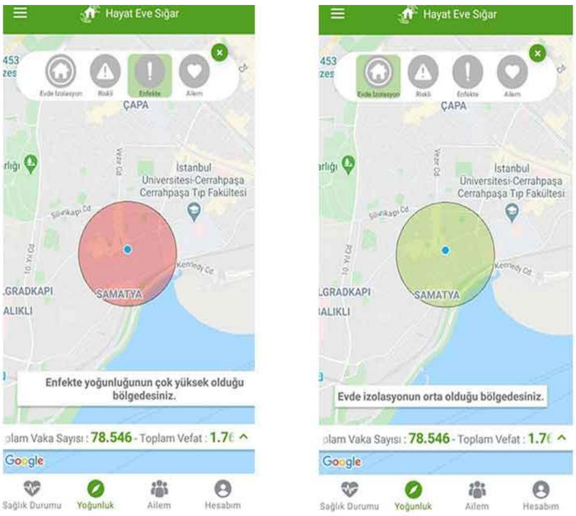


Figure 7. *Hayat Eve Sığar* Mobile App by Turkish Ministry of Health

2.5. Environmental Monitoring during a Pandemic

NASA and European Space Agency (ESA) pollution monitoring satellites (TROPOMI sensor on ESA's Sentinel-5 and OMI sensor on NASA's Aura) sensed a remarkable decline in nitrogen dioxide (NO_2) over China (Figure 8). This situation proves an economic slowdown after the outbreak of COVID-19. NASA scientists stated that NO_2 levels declined firstly in Wuhan area, then this phenomenon spread across all China, due to the fact that millions of people have been in quarantine (ESA, 2020; NASA Earth Observatory, 2020).

The same situation happened also in Europe. Scientists from the Royal Netherlands Meteorological Institute (KNMI) observed both meteorological and TROPOMI data and monitored the significant reduce in NO_2 concentrations over European cities (Figure 9). Such a decrease in pollutant particles in the atmosphere proves the decrease in demand for oil at the beginning of 2020.

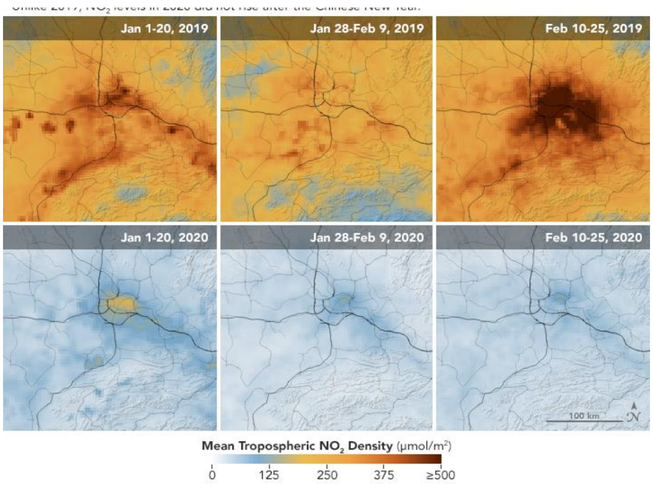
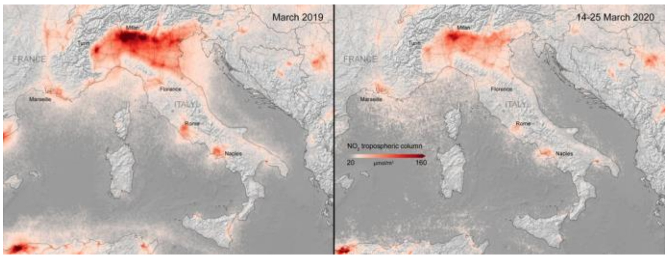


Figure 8. Pollutant Drops in Wuhan in 2019 and 2020 (NASA Earth Observatory, 2020)



(a) (b)

Figure 9. A comparison of NO_2 levels of March 2019 (a) and March 2020 (b) over Italy (ESA, 2020)

3. PANDEMIC ISOLATION TRACKING

Some countries have imposed isolation or curfew measures during the COVID-19 outbreak. The countries, such as South Korea, Singapore, China, Taiwan, Italy, Russia and Israel, have monitored the infected individuals by mobile phone signals and applications. The public services send an SMS message if an infected person leaves their house or anybody that passes nearby a quarantine zone, suggesting them returning to home and isolating themselves. The countries that monitor and map the infected people's mobility aims at controlling the outbreak spread and implementing strict measures to prevent the close contact; however, it is also commented that such a monitoring process violates the personal freedom and data privacy (The Washington Post, 2020).

3.1. Turkish Pandemic Isolation Project

The Turkish Ministry of Health also announced that they had developed a Pandemic Isolation Tracking Project (in Turkish *Pandemi İzolasyon Takip Projesi*) to slow the spread of COVID-19 outbreak and ensure the isolation of infected individuals. The Directorate of Communications stated that this practice would be implemented in cooperation with the Ministry of Health, Information Technologies and Communications Authority and all GSM operators. Within the scope of the project, it is planned to monitor whether those who have positive coronavirus tests comply with the isolation and social distancing rules required for the health of themselves, their relatives and the society. The mobility of the quarantined people can be monitored and related analyses can be made to prevent the spread of the pandemic.

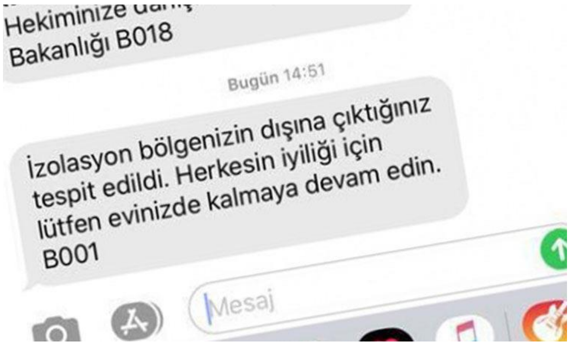


Figure 10. SMS sent to those who leave their home quarantine (Image Credit: *Cumhuriyet Newspaper*)

If the people leave their houses instead of being under home isolation, a warning message (Figure 10) will be sent to their mobile phones. These people will be contacted instantly through automatic call technology and they will be asked to return to where they need to be under isolation. The situation of those who do not comply with the warning and continue with the violation will be shared with the security units, and necessary administrative measures and sanctions will be implemented. The road control police teams also will be able to find out whether the person has violated the isolation by controlling their latest mobility (BBC Turkish, 2020).

3.2. Data Privacy Issues

The Directorate of Communications stressed that the data obtained within the scope of the project will not be used out of pandemic purposes and will be destroyed when the risk of the pandemic ends. Additionally, it was stated that this project does not constitute a violation of Law of Protection of Personal Data (No. 6698) since the third paragraph of Article 6 of the law allows the processing of special personal data without the explicit consent of those concerned, in case there is an exceptional purpose pursued by authorized institutions and organizations for the protection of public health, preventive medicine, medical diagnosis, treatment and care services (BBC Turkish, 2020).

4. RECOMMENDATIONS AND CONCLUSIONS

This review article sums up the geospatial data science responses to the COVID-19 crisis by underlining key outcomes of several academic and institutional initiatives. On the other hand, it identifies the pandemic isolation tracking projects, giving the Turkish example, and underpins the data privacy issues.

Georeferencing any pandemic brings in a spatial extent to monitoring such public health crises. This will be possible only if data patterns about the pandemic cases have practical and biologically relevant value. Moreover, the case studies cited in this review article are good examples and evidence for the importance of determining epidemic trajectories, which require geospatial data sources. The countries should record all COVID-19 cases at a scale as precise as possible (the district, street, even building level) and store them in a geospatial database. These datasets should be opened to at least researchers, national scientific committees, private sector stakeholders (in consulting), local administrations and municipalities that are obliged to implement the preventive measures. If the central administration of countries do not prefer to open such data freely to the public, they need to set up a secure intranet web among these responsible stakeholders. The case studies from China obviously remark that the preventive measures can be relaxed or extended by monitoring the risky zones and the corridors of contagiousness.

The countries need to set up some sort of web applications to fulfil medical doctors' immediate needs. A front-end application with a geospatial dataset, where the medical doctors can insert their supply needs, will be a useful tool to implement immediate actions to supply these medical needs. The ministries will also be able to switch medical supplies between hospitals if one of them needs more than the others.

The literature review shows that tracking pandemic isolation is a new and hot topic for the governance and there has not been any scientific research to identify the data privacy issues and to test the reliability and applicability of the tracking process.

Finally, geospatial data scientists and researchers in the digital earth domain should set up the standards of geospatial data related to pandemic during and after this COVID-19 crisis immediately.

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