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THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN DISASTER MANAGEMENT: A CASE STUDY OF COVID-19 PANDEMIC IN MADABA GOVERNORATE (JORDAN)

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Abstract
The study examines the role of Geographic Information Systems in health emergency management through the comprehensive emergency management process and its four stages: mitigation, preparedness, response, and recovery. The main concern before a potential disaster occurs is to mitigate the impact of the risk. Here, Geographic Information Systems is supported in assessing risks and developing long-term mitigation strategies. In the preparedness and response phases, Geographic Information Systems may serve as an integrated hub for a comprehensive disaster preparedness and response system or as a portable source of on-site spatial information. In the aftermath of a disaster, Geographic Information Systems have become an integral part of supporting damage assessment and reconstruction.
Keywords: Geographic Information Systems; disaster management; COVID-19, Madaba Governorate (Jordan).

Introduction
It can be said that the tremendous development in information and communication technologies has changed lifestyle in various fields. The introduction of artificial intelligence and robots is undoubtedly part of the predictable cities of the future. Many cities already rely heavily on artificial intelligence to predict weather, traffic, air pollution, demographic developments, and many other factors; AI is also used to predict disasters before they occur and reduce their devastating effects on humans and the environment.
We can use modern technology to predict disasters (natural or man-made disaster or an accident) before they happen, depending on several factors (1). The main factor is climatic conditions caused by human activities such as air, water, and soil pollution. Geographic Information Systems (GIS) technology plays an important role in combating such disasters. The combination of geographic information systems, remote sensing techniques, and photogrammetry enables the seamless application of this technology at all stages of the disaster management from mitigation to recovery. Geographic information systems are systems that process, store, analyze, combine, and display data. Disasters can be predicted using a lot of data, which provides hundreds of thousands of information, such as population and their ages, gender details, facilities information, and land details for the entire country. (2)
Natural disasters are serious events resulting from natural processes on Earth, such as floods, earthquakes, hurricanes, volcanic eruptions, tsunamis, and other geological processes. Man-made disasters or anthropogenic disasters are caused by human activities that negatively affect humans, other living organisms, and ecosystems. Examples of man-made disasters include all types of

pollution, nuclear disasters, chemical disasters, biological disasters, terrorist attacks, and other accidental disasters (9).

Floods are considered one of the most important natural disasters that affect both the environment and humans. However, it is now possible, with the help of remote sensing techniques and geographic information systems, to predict them. Remote sensing techniques can be used beside geographic information systems photometry technology for effective and economic disaster management. Geographic information systems technology also plays a key role in identifying flood-affected locations and providing shelter to affected people and suitable places for constructing retaining wall structures and an alternative path for rainwater drainage. This process also helps in creating different levels of vulnerability maps indicating areas frequently affected by floods and base maps to show and prepare boat location and rescue team plans (23).

Natural risks are increasing worldwide. The year 2019 witnessed many cyclones, such as Lekima, Hagibis, Fani, and Idai, heat waves in many parts of Europe, South Eastern Asia, and South Asia, and floods. 2020 began with Australian bushfires, Indonesian floods, American storms, and the global pandemic Covid-19. These risks affect humans and animals. According to estimates by the United Nations Office for Disaster Risk Reduction (UNDRR), losses resulting from disasters, such as earthquakes, tsunamis, hurricanes, and floods range in value from 250 billion to 300 billion USD annually. This amount may increase in future under the influence of changing climate conditions. Therefore, countries have to develop management plans for each individual disaster to which they are vulnerable. The management plan highlights the steps that must be taken before, during, and after a disaster, and this exercise has been greatly aided by the emergence of new technologies, such as remote sensing (RS) and Geographic Information System (GIS), as shown in the United Nations Disaster Risk Reduction report in the following table (39):

Figures	**2022**	**2021**	**2020**	**2019**
Total losses in USD	270	280	210	166
Uninsured losses in USD	150	160	128	109
Insured losses are denominated in USD	120	120	82	57
Recorded accidents	387	407	380	505
Deaths	30,704	18,274	17,664	27,199
The number of people affected is in million	185	103.5	97.6	109.2
The number of people displaced due to disasters in millions	8.7	23.7	7	24.9
One million people live in acute food insecurity due to extreme weather events	56.812	23.58	15.715	33.825

14.9 million excess deaths were linked to the Covid-19 pandemic in 2020 and 2021. Excess deaths include deaths related to COVID-19 directly (due to the disease) or indirectly (due to the impact of the pandemic on health systems and society).

The results of 3D flood simulations provide more powerful information to quickly understand the effects of the disaster. A flash flood is a type of floods, which is a sudden flood that sweeps away water paths and results from many causes, such as heavy rain and melted water from snow/ice in the snow fields (7).

It can also be said that earthquakes are one of humanity's oldest enemies, but they can now be mapped and analyzed in a detailed manner. Geographic information systems support national, regional, and local emergency organizations in planning and managing preparatory programs. Geographic information systems based urban information systems are used to analyze demographic data and infrastructure locations. Remote sensing and geographic information systems technologies also provide precise location and spatial data for historical sites. The vision of remote sensing and. geographic information systems technology is to visualize critical vulnerabilities and damages and reduce the impact of disasters, and the results of geographic information systems technology can be responded to quickly during a disaster (39).

Experience has shown that deaths from earthquakes can increase due to secondary disasters, such as tsunamis and fires. Buffer analysis is a good remedy to reduce vulnerability to predict the damage that could be caused by a tsunami. Geographic information systems-based network analysis tool is also used to determine the location and routes that provide the quickest response to emergency needs, such as hospitals and fire stations. Real-time location tracking platform or web/mobile geographic information systems -based applications are enabled to interact with maps containing details of earthquake location and intensity, health facilities, nearby camp information, and damage assessment. The geographic information systems -based applications also serve as crowdsourced platforms to collect data about an infrastructure damage or fire incident and disseminate the information to relief teams involved in providing aid to those affected by disasters (15).

Hurricanes are the most destructive force of nature, causing widespread losses. Remote sensing technology is used to monitor and collect accurate information about the entire globe in terms of climate and meteorological/climate data. Moreover, temporal data of the same place has become powerful and dominant in identifying and predicting natural disasters to the environment and protecting and developing the ecosystem. Likewise, remote sensing technology and geographic information systems play a major role in other disasters, such as drought, heat and cold waves, climate change, and global warming and its impacts (8).

Pollution disasters, such as air pollution, water pollution, and soil pollution are consequences of climate and global warming. These types of disasters depend on the weather conditions of the sites/place. Geographic information systems technology has been vital to emergency preparedness through planning and implementation and has saved many lives in previous hurricanes. It has improved some of the extended boundaries, such as environmental understanding, making strategic decisions, monitoring the impact of climate change, and investigating future risks. They are mathematical functional algorithms to analyze geospatial data and display the output in a visual format. The data is visualized and patterns and relationships between them can be identified. Government agencies and non-governmental organizations that support disaster management can benefit from this technology because it helps them identify the most affected areas (42).

Geographic information systems also integrate qualitative and quantitative data through spatial relationships. Other excellent features, such as the query builder, overlay analysis, raster and vector analysis, and user interfaces allow for performing query-based analysis on multiple subject layers. Spatial analysis, such as developing different thematic maps such as elevation, slope, aspect and shadow of the hill using terrain analyzer is very useful in predicting landslide and avalanche disasters. Landslide/avalanche hazard mapping is a typical problem that requires a large database, and subsequent analysis of geographic information systems results allows users to better understand and visualize problems and outcomes (25).

As for biological disasters, Coronavirus (COVID-19) is a good example of understanding the importance of information through maps. In healthcare, geographic information systems technology is supported against the global pandemic disease COVID-19, by mapping available data such as current positive cases of coronavirus, quarantine centers, hospital infrastructure capacities, and identifying hotspots using IGIS-based COVID-19 response and surveillance solutions (23). Real-time geographic information systems mapping and spatial analysis skills also play a key role in the effective distribution of vaccinations.

Accidental disasters are also considered among the disasters that geographic information systems address, and they occur for several reasons: failure of operations and safety systems, human/technical/administrative errors, induced impact of natural disasters, hazardous waste treatment/disposal, and terrorist attacks/disturbances resulting in destruction. Identifying the accidental disaster point of location is used by Geographic Information Systems, Global Positioning System (GPS), and communication technology. The high user interface of mobile phone-based applications has integrated technology to provide effective and economical safety to the community (38).

Disaster management

Disaster management consists of two parts: pre-disaster events and post-disaster events.

• The pre-disaster stage:

Here, mitigation and preparation activities must be planned to reduce the impact of the disaster and reduce the effects of disasters before they occur. The government or local rescue teams take measures to save people's lives and property to reduce the consequences of disasters with the help of geographic information data. The goal of the mitigation process is optimally maintained using GIS technology by adopting and enforcing land use and zoning practices, implementing and enforcing building codes, elevating houses in flood-prone areas, and conducting awareness programs (43). The public sector is also heavily involved in disaster mitigation plans with the help of efficient geographic Information Systems -based forecast disaster maps. The ongoing short-term and long-term preparation of mitigation plans to reduce the impact of disasters will need to identify critical areas through interactive visualization in the optimal geospatial mode.

The second phase is the preparedness phase and includes the development of an emergency operations plan, where central/regional or local rescue teams respond to prepare emergency operations plan with a disaster response checklist for communities, exchange data across both governmental and non-governmental agencies, develop a geospatial database for infrastructure, and asset locations such as generators, construction machines, medical resources, and shelters.

• **Post-disaster stage**:

Response and recovery measures are taken to return to normal life.

• **Phase 3:** Response - Emergency situations to help people.

During a disaster, people need emergency assistance, so geospatial data can be used to determine answers to users' questions regarding emergency situations, such as health center operations and potential temporary shelter sites. The government or relief team addresses/responds to all those in need of assistance during the disaster control period with the help of geographic Information Systems technology (33).

• Phase 4: recovery - returning to normal life after the disaster

The organization/government provides support to affected people during the disaster to bring them into their daily routine using economic, social, and environmental support. Geographic Information Systems provide short-term objectives, such as environmental monitoring of damaged sites, tracking rehabilitation processes, and economic support for rapid recovery operations. Creating a long-term vision should lead to improved recovery, rebuilding, and mitigation plans combined with geographic Information Systems technology (17).

Geographic Information Systems technology helps identify disasters before they occur using forecasts or maps of risk areas. Remote sensing technology and geographic Information Systems for disaster management also work to create an emergency database for people who need all the help during a disaster. The emergency database also contains information about nearby hospitals and emergency shelters. Disaster risk maps or impact maps also focus on taking corrective action against disasters (32).

During a disaster or as a post-disaster emergency, geographic information systems technology uses a combination of GPS and 5G to enhance assistance as remote sensing technology and geographic information systems have a strong core to provide the solution to all types of disasters. Hence, disasters occur naturally or accidentally and cannot be stopped, but technology can be used to reduce the impact and damages.

The role of geographic information systems during COVID-19 pandemic

In December 2019, there was an outbreak of severe pneumonia of unknown etiology, and many cases were recorded in Wuhan, Hubei Province, China. Later, the causative agent of this infection was identified as SARS-CoV-2 (COVID-19), which was classified by the World Health Organization on March 11, 2020 as a global pandemic. The coronavirus is a single-stranded RNA virus with an envelope and a diameter of about 0.1 micrometers (16). The virus spreads through droplets, such as cough, direct contact with an infected person, or touching contaminated hands and surfaces. COVID-19 pandemic is the public health crisis of our time and the greatest threat facing humanity since World War II. The virus first appeared in Asia at the end of 2019 and then spread throughout the world. This pandemic is more than just a health crisis affecting many countries; it has the potential to cause devastating societal, economic, and political consequences that can leave deep and long-lasting scars. Every day, hundreds of citizens lose their jobs with no way to know when life will return to normal.

To confront the spread of the disease, geographic information systems have been used to map infected cases and reactions on social media to the spread of the disease, use predictive risk maps, population travel data, and track and map super-spread paths and communications across space and time to understand the source of the disease, dynamics and epidemiology, and effective response to it (20).

Health workers have long viewed traditional treatments, mapping, and more recently geographic information systems (GIS) as crucial tools in tracking and controlling infections. The oldest map depicting the relationship between place and health was in 1694 onward for the containment of the plague in Italy. It was followed by the service of understanding and tracking infectious diseases, such as yellow fever, cholera, and the 1918 influenza.

Web services allow GIS users to display disparate data inputs without hosting or central processing to facilitate data exchange and speed up the collection of information (30).

The World Health Organization directs and coordinates international health and infectious disease control through monitoring, preparedness, and response and applies geographic information systems technology alongside clinical and public health (2). On January 26, 2020 the WHO unveiled the ArcGIS COVID-19 Operations Dashboard, which also maps and lists coronavirus cases and the total number of virus cases and deaths by city and province in China, with information panels about the map and its data resources (13).

It is possible now for individuals to enhance their decisions with a personalized application that provides spatial scale details to support informed personal decisions about self-quarantine and seeking medical treatment. The Close Contact Detector app/platform uses big data from public authorities on people's movement (public transport data covering flights and trains [since booking a train seat in China requires entering ID information]). The app also tracks records of disease cases to check whether the user has been in close contact with someone or is suspected of being infected in the recent past. The platform can inform the user based on his/her location and recent movements whether he/she has been infected during the last two weeks (the supposed incubation period of Covid-19) if he/she worked, shared a classroom, lived in the same building, or traveled by train (all passengers and crew members in the same coach) or plane (staff cabin and passengers within three rows of the infected person) with a person with confirmed or suspected illness. The Close Contact Detector can be accessed via three of China's most popular social media and mobile payment apps, namely Alipay, WeChat, and QQ (32).

Mapping the spread of misinformation around the world about the coronavirus

During infectious disease outbreaks and social epidemics, the media play an important role in communicating verified facts and correct prevention advice to the masses. However, the media also have the risk of spreading misinformation “virally”, confusion, and fear among the public. In the case of COVID-19, false or misleading information; for example, it was circulated that sesame oil or garlic can help prevent and treat the coronavirus, and rumors and panic spread globally on social media much faster than the virus (10).

In fact, the World Health Organization is fighting the parallel epidemic (or “infodemic”) of misinformation alongside COVID-19. The World Health Organization has joined forces with social media giants such as Facebook, Twitter, YouTube, Google, and Pinterest to combat the spread of misinformation about Coronavirus (31).

Geographic information system (GIS) is a computerized information system through which users can capture, analyze, manage, present, retrieve, store, process and share all types of spatial or geographical data. Geographic information systems are easy-to-use computer programs that can show many different types of data on a single map or dashboard and enable the user to analyze and interpret data in the different locations drawn on the map to understand relationships, patterns, and trends (11).

Geographic information system provides an ideal platform for converging disease information and analysis in relation to populations, settlements, surrounding social and health services, and the natural environment, providing highly relevant data, analyzing data, and revealing trends. Surveillance is a mechanism applied to collect and interpret data related to the health of a population in order to accurately describe their health status in relation to specific diseases of concern. In general, surveillance aims to establish the absence of disease or infection, and to determine the occurrence or distribution of disease or infection, while also detecting as soon as possible strange cases and emerging diseases (37).

Human health monitoring is also considered an essential tool for detecting disease or infection, monitoring disease trends, facilitating disease or infection control, reducing the spread of disease or infection, providing data to analyze health risks, and proving the rationale for health measures. Human disease surveillance is the key to improving disease analysis, early warning, and preventing the spread of diseases. Surveillance is used to detect new or exotic diseases, with the aim of monitoring to detect changes in established or endemic infection levels that may indicate recurring disease outbreaks (36).

Monitoring the epidemiological patterns (human, spatial, temporal) of diseases and pathogens in a population provides a vitally important system for identifying changes in disease status among that population (whether that concerns all humans worldwide, or those within a country, region, city, or village). Therefore, most countries have better prevention systems than medicine:

technologies, such as human scene monitoring, spectrum monitoring tool, hex dashboard, and smart applications.

The “incubation period” means the time between infection with the virus and the onset of the symptoms. Most estimates range from 1 to 14 days incubation period for coronavirus (COVID-19), most often about five days. The face mask must be in good condition, and the mask must be disposed of in a closed trash immediately after use. Other instructions include washing hands, maintaining cleanliness, and rubbing hands with an alcohol-based solution; if hands are quite dirty, wash them with soap and water. So far, there is no vaccine and no specific antiviral medication to prevent or treat COVID-2019, but traditional or home remedies may provide relief (41).

Geographic information system is used to visualize disease hotspots, monitor newly infected or reinfected villages, and identify populations at risk, set cost-effective interventions, and monitor eradication efforts. The visual display of spatial phenomena provides great effectiveness and a descriptive analytical tool. Healthcare is also an important topic for medical geography given the pressures of the modern world to reevaluate health and the care system to accommodate today's healthcare needs. Geographic information systems plan the process of planning public health and preventing potential diseases, combining high population distribution, land cover, and the location and capacity of existing health services. Geographic information systems programs such as ArcGIS and MapInfo provide the necessary and appropriate tools to perform mapping. Geographic information system also serves as a common platform for the convergence of multiple disease surveillance activities, public health resources, and specific diseases, and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructure (11).

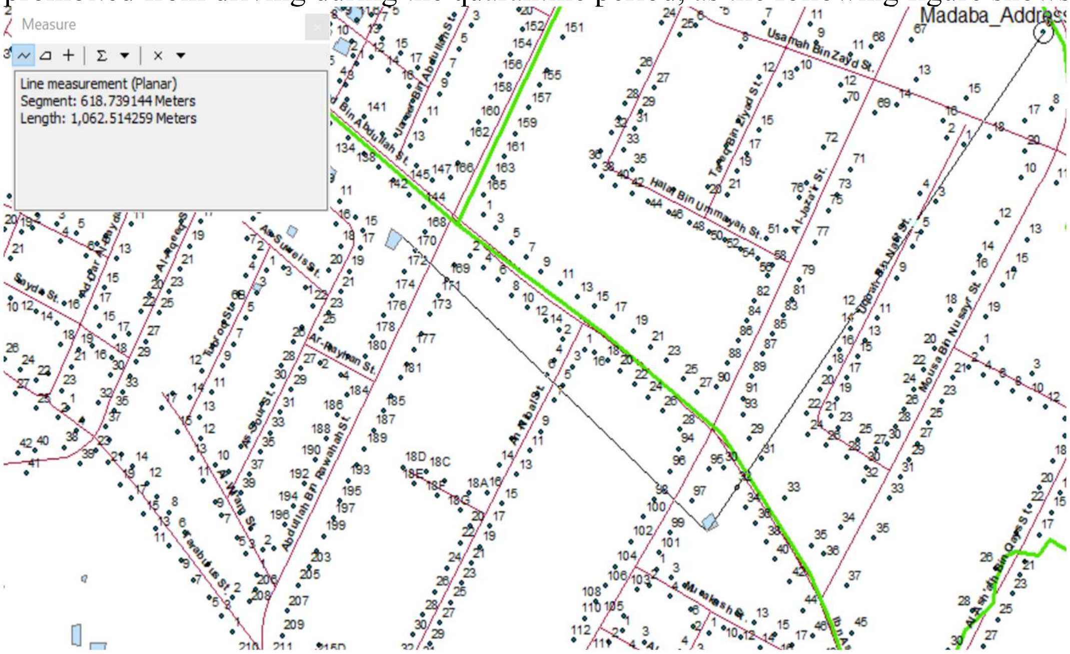
The Dashboard is a display of geographic information that helps you monitor events or activities; Dashboards are designed to display multiple visualizations working together on a single screen. it provides a comprehensive and attractive view of your data to present it for making decision-at a glance, such as web maps and web layers. Dashboards are also part of the ArcGIS geographic model information (28). It is designed to know what is happening now and to accommodate the rapidly changing nature of incidents, events and other activities. Some of them are more strategic and ideal for executive managers and other senior managers. They monitor their organization's key performance indicators (KPIs) and metrics, some of which are more analytical and used to identify data trends or other interesting data characteristics. Finally, some of systems are just informative, used to tell a story using data. The dashboard type is also used by different teams and people inside and outside the organization. Geographic information system users include chairpersons, operation managers, senior executives, Geographic information system managers, Geographic information system analysts, and even community members. Information panels also consist of elements, such as maps, lists, charts, measuring devices, and indicators (24).

Case Study: Madaba Governorate (Jordan)

Through geographic information systems and through the process of naming, numbering, and inquiring about the street name and building number, the following data has been collected (27):

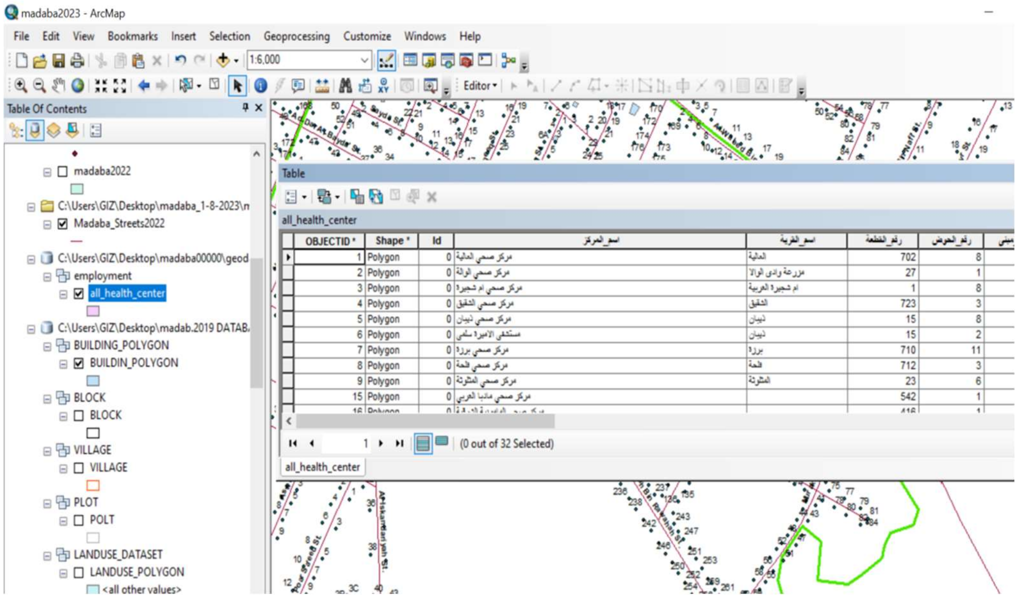
1. All data to deliver health services through hospitals, health centers, and civil defense centers.
2. Draw a clear picture of the distribution of bread and food supplies during the Covid-19 epidemic.
3. Dividing neighborhoods by layer, especially for distributing aid and medicine rations.
4. Distributing police and gendarmerie patrols at the entrances and exits of neighborhoods and tightening control.
5. Giving an idea of the population density in each neighborhood, and then distributing food supplies and rations so that population density equals needs.

6. The neighborhood is satisfied with its needs (self-sufficiency) through walking, as cars were prohibited from driving during the quarantine period, as the following figure shows:

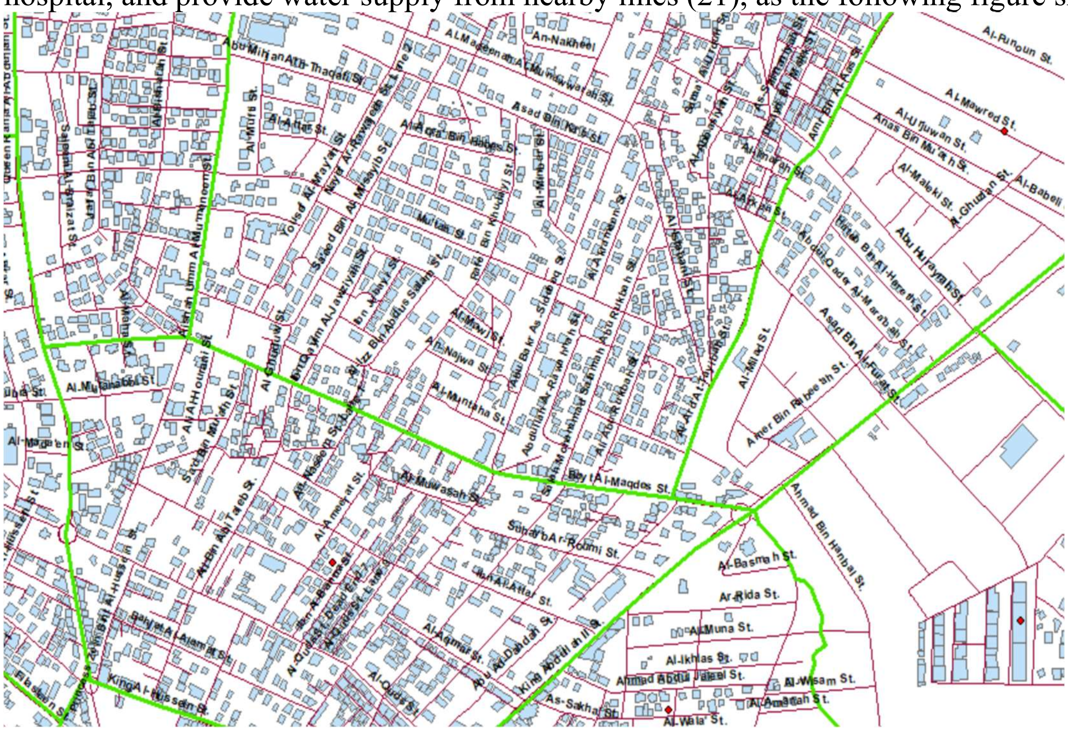


During COVID-19 period, the Municipality of Madaba created maps using geographic information systems software to identify the main streets, clarify hospitals and health centers, and determine the best and nearest health center to reach in case of infections in a specific area through geographic information systems. Geographic information systems were also used to identify epidemic areas, close affected areas, and determine the number of infected people and their continuous increase. Information systems helped control the epidemic and reduce its spread in terms of lockdowns and precautionary measures by identifying the affected area and not allowing people in infected places to move to uninfected places. If an area is confirmed infected, the number and extent of the increase in the number of infections can be determined. Through drawing a layer, it is possible to show the points of hospitals, health centers, maternity and childhood centers, Covid-19 testing centers, vaccine administration centers, and the number of residents covered by a health center (26).

In every neighborhood, there are ambulance cars for transporting patients, carrying pregnant women, and emergency dialysis, as well as complete data for the medical staff, the capacity of each medical center, and the number of beds in it, as the following figure shows:



The geographic information system shows uninhabited and inhabited places. A field hospital can be established in these uninhabited areas so that water supply, electricity, and communications services are connected to them, or it can be proposed to provide an electrical transformer for this hospital, and provide water supply from nearby lines (21), as the following figure shows:



Conclusion

It can be said that after three years, the COVID-19 pandemic still poses a challenge to health policies on both the global and local levels. Research focusing on recent variants reveals that the spread of Covid-19 is more transmissible than previous variants; thus, spatial spread affects medium-sized areas, rural service centers, and other municipalities. Therefore, taking rapid action in spreading drivers (functional urban areas) can help prevent the subsequent spread of the virus.

Daily tracking of epidemic trends at the municipal level using 3D boxes and analysis of emerging hotspots is essential to identify municipalities with hotspot patterns and design rapid control measures, such as restrictions on movement and gatherings or even large-scale preventive campaigns to limit the spread of the epidemic, especially when cases that do not show symptoms are detected, or improving vaccination levels.

There is a need for a multi-scale approach in the spatial analysis of the virus, and in this context, the use of geographic information system methods is essential. The methodology proposed here is adaptable and replicable in other case studies and uses other frontiers, such as basic health areas of interest. Based on the global principles of geographical prevention (health and safety areas) and the policy of the World Health Organization, local diagnosis appears to be an appropriate means of making local decisions adapted to recognized limits. Taking municipalities as a level for making decisions in epidemic management helps in vertical and horizontal coordination, and here urban health management requires strategic spatial reports such as the one described in this study, along with applying location information methods in geographic information system.

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