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Geospatial Information Technologies in Support of Disaster Risk Reduction, Mitigation and Resilience: Challenges and Recommendations

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This chapter presents Geospatial Information Technologies in the context of sustainable development goals (SDGs), in particular, SDG 11 and SDG13. It contributes to the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) in its efforts in disaster loss reduction, mitigation and resilience. Particularly, the chapter discusses what these technologies can bring to support the implementation of Sustainable Development Goals (SDGs).

6.1 Introduction

SDGs are conceived for a wide range of issues in local, national, regional, and global contexts. These include the major development issues related to poverty, hunger, health, natural hazards, agriculture, education, and gender inequality. In addition, SDGs cover specific topics such as energy, infrastructure, economic growth and employment, inequality, cities, sustainable consumption and production, climate change, forests, oceans, and peace and security (Figure 6.1).

The objective of this chapter is to (1) participate in the global sharing of experiences on utilizing geospatial information technologies to address disasters

FIGURE 6.1

The global goals for sustainable development

resilience and challenging issues of determining the vulnerability of buildings; and (2) demonstrate examples of the support-integrated geospatial information technologies including earthquake and structural engineering disciplines followed by utilizing drone images for rescue.

This chapter briefs an example on the need of environmental and geospatial information laws and regulations. Finally, recommendations are proposed that might be helpful to other countries having similar issues.

Today's challenges push everyone to ponder how we, as people living on the Earth, should play a role in SDGs to transform research into real life practices for improved condition and a better way of living together in a better world. Geospatial information technology is a collection of information communication tools [34], to store, capture, manipulate, transform, analyze, and generate information related to our planet. This technology is used for global management, and there is no doubt that, in this era of multilateralism with integrated technologies, there is a crucial need today to work together and face global challenges within a defined proposed ecosystem in the SDGs global context.

Based on a UN report, there is an increase in naturally occurring disasters [38]. Currently, earthquakes can occur almost anywhere in the world including Australia, Canada, Chile, China, England, India, Iran, Mexico, New Zealand, Pakistan, the US and many other countries in seismic zones such as Italy and Nepal. While very large earthquakes may still not occur frequently, the frequency of minor or medium-sized earthquakes is increasing. Indeed, some countries are exposed to many minor and major earthquakes annually. It needs significant consideration to formulate the strengthening of buildings against future earthquakes. At present, there are numerous weak structures in many countries particularly in developing countries that are not able to withstand an earthquake. Public and private developers intend to use the scientific methods to prioritize and optimally allocate budget in order to reinforce the structures, because of limited financial resources, time and availability of an appropriate model. It seems logical to renew our structures with mitigation resilience utilizing the integration of geospatial information technology and engineering. Nowadays, there is sufficient data on the effects caused by earthquakes. And recently, there is greater research on the challenges at various scales by using

Geographical Information System (GIS) for emergency response to disasters [7, 25, 10, 11, 40, 33, 32, 31, 37, 4, 13, 36, 3, 36, 20, 16, 21, 24, 39, 29]. For example, Liu (2018) in [30] studied the seismic identification and reinforcement design of building structures of China after the earthquake in Wenchuan in 2008. She suggested some reasonable improvement methods for the future development of buildings. Also, [35] evaluated a number of buildings in Esfahan city and classified the buildings from low-to-high based on their vulnerability to seismic activity and collapse due to earthquakes. The result was that, at present, numerous structures are still not able to withstand an earthquake.

Nevertheless, the integration of geospatial information technologies with engineering parameters to develop a platform has been an interest of researchers for mitigation resilience, quality efficiency, saving costs, and enriching the quality of the hazard mitigation for loss reductions. Most of the current systems are local and have various limitations mainly because of adaptation of the local instruction of building code or any other infrastructure instruction codes [22, 23, 18]. For example, maps cannot be retrieved to represent buildings geospatially correlated with the evaluation parameters. Tools are not in place to screen buildings for potential seismic hazards with the implementation of 3D reconstruction models. The local system is also often based on a particular region and the scalability remains a challenge. In addition, recent advances in computer vision, artificial intelligence, machine learning and robotics combined with geospatial information using digital cameras are suitable tools for many applications such as rescue and emergency management. The use of cheap platforms with low-end imaging cameras makes this technology available to the public. The amount of data in the images is high but this can be provided online during the search and rescue operation particularly when using drones.

In this chapter, examples are presented showing how geospatial visual screening works for pre-earthquake and post-earthquake preparation. There is also a brief section on how drone images help in human search and rescue.

6.2 Why are technologies alone not enough in disasters loss reduction

To protect the environment through technology, there must be global cooperation. Although science and technology have progressed, there has been little changes to the sustainability of the environment and the preservation of our planet. Though technology has been advancing rapidly, many events such as the catastrophic flood of the Dez river in Iran, and the deforestation of mangroves and salinity of water in the Persian Gulf in Iran (Figure 6.2) happen due to the ineffective national and regional policies including a mismanagement of decision makers in the pursuit of nature and the lack of use

of appropriate technology. In conclusion, it seems that at a global level, earth and the environment are at higher risk than before, and the number of disasters are rising all over the world: Natural disasters like earthquakes, floods and storms as well as human related emergencies such as wars and deforestation are ever-increasing.

(a)

(b)

FIGURE 6.2

(a) Recent flood in Iran, (b) plantation of mangroves for sustainable environment and desalinization in Booshehr, Persian Gulf, Iran

6.3 Integration of Geospatial Knowledge

With rapidly growing technologies, critical thinking and problem-solving, including a momentum to sustain the continuing development and enhancing skills in practice, are not only supporting the representation of the real-world but also present as a challenge.

These days the requirements of a desired software and hardware product emphasizes on using artificial intelligence and deep machine learning; however, they depend on the applications and needs of the people for creating a sustainable environment and the economic growth in various sectors. It is required to work with big geo-data and geospatial technologies in conjunction with innovative soft computing solutions to develop products in many fields such as engineering, environmental issues, hazards, mapping, and construction support, augmented reality, and real-time asset management to support the business processes and to develop various types of mobile applications and software.

To utilize and implement the integration of geospatial data and techniques with other technologies requires a conceptual framework and also building

platforms to create a full global geospatial ecosystem. Building platforms and services such as GeoEngine (a geospatial rapid visual screening of buildings for developing ecosystems) is allowing digital transformation and enabling countries to support the implementation of SDGs. Different supporting integrated platforms are required to fulfill the needs of stakeholders, communities, citizens and the public at large. In this multilateralism era, the needs for geospatial information in required in daily life.

However, the author's experience in research and development indicated that the software and hardware engineering processes consist of many activities and require application based knowledge. They are requirements and analysis, specifications, software architecture, implementation, testing, documentation, training and support, and maintenance. Therefore, the integrated technologies, including machine learning, computer vision, and artificial intelligence are the best choices towards creating platforms and working to develop smart systems to connect all disciplines. For example, we can connect earth observation systems and geospatial information technologies for full infrastructure projects, and asset management systems implementation. This builds an intelligent world for the future generations in a GeoEngine platforms' ecosystem. Figure 6.3 shows an example of how geospatial information helps rapid visual screening processes and determines the vulnerability of buildings and estimation of risk. Another example is the platform on representing maps and disaster responses. The snapshot of architecture design of the model is illustrated in Figure 6.4.

FIGURE 6.3

Screening a building (Geospatial Rapid Visual Screening)

FIGURE 6.4

Architecture design of the disaster responses of the platform [1]

6.4 Geospatial Rapid Visual Screening for Earthquake Disaster Risk Reduction, Mitigation and Resilience

The modern space-based remote sensing integration with geospatial information technology has opened up efficient means for disasters risk reduction and resilience. The maximum economic casualties caused by natural disasters such as earthquakes, flood, tsunami, and landslide, between 1900-2018, occurred in Asia and the Pacific (<https://reliefweb.int/map/world/major-natural-hazards-asia-and-pacific-0>). Nevertheless, this section explains how geospatial information supports building inspection and safety for earthquake disaster risk reduction, mitigation plan and resilience.

In the context of SDGs, geospatial information rapid visual screening techniques can be interpreted in SDGs 11 and 13 in the aspects of disaster resilience, creating a safe and livable city and homes with the focus on housing condition. Geospatial rapid visual screening techniques allow screeners to determine the vulnerability of buildings and estimates risk with the potential to generate a 3D model for building and disaster applications beyond which it might be useful in building information management system (BIMS).

However, this technology aims to integrate geospatial technologies with engineering for risk assessment and 3D modelling utilizing computer vision

techniques for disaster risk reduction, mitigation and resilience. It seems that implementing geospatial rapid visual screening techniques can strengthen the buildings, increase mitigation of hardware and software infrastructures for disaster monitoring and warning. It also supports a disaster prevention process within the context of SDGs 2030.

For example, we attempted comprehensive sophisticated computing process to generate a damage index (DI) and building score utilizing the geospatial rapid visual screening technique with the Damage Index of Building (DIOB) algorithm and the Federal Emergency Management Agency (FEMA) approach [36, 35]. The damage index model (DIM) incorporation with geospatial information can be interactively utilized into the GIS to compute relevant engineering parameters for analyzing data and a better quality management on the web and cloud. Its resilience ability allows an easy accessibility of the geospatial data to evaluate buildings for earthquake mitigation and preparedness. This geospatial rapid visual screening techniques is a new combination of a geospatial integrated system and engineering disciplines for rapid evaluation of buildings, and for city planning by further combining GIS with building structural information, civil engineering and industrial engineering as required by the FEMA. All this in addition to the general information of the building, visualizing the 3D model of building, seismic data, soil data, land use data, structure, parcel, material type, foundation, ceiling, wall, floor, the interior and the exterior.

TABLE 6.1
Vulnerability scores on residential building

Score	Level of vulnerability
1–10	Demolishment
10–40	High vulnerability
40–70	Medium vulnerability
70–90	Low vulnerability
90–100	Invulnerability

6.5 Human Search and Rescue in Drone Images

The utilization of drones has become one of the recent good examples of such technologies empowered by machine learning and robotics.

Events, such as earthquakes, fires, floods, avalanches, and landslides occur all over the world. According to the Red Crescent instruction, the first and most important part of a search and rescue operation is to determine the location of injured people [14]. This stage can be very time-consuming, and

FIGURE 6.5

Most vulnerable buildings shown in dark red color

sometimes only a few extra minutes could be all that's needed to save the life of a person. In the event of avalanches, the use of trained rescue animals such as dogs is a common method, which, unfortunately, may not be enough to have a fast and accurate search operation [8].

Nowadays, with the advancement of technology, the application of intelligent relief equipment has become more possible than ever before. Therefore, the development of spatially enhanced tools that can automatically locate people in need of help is a key element for post-accident search and rescue tasks. In this context, drones are becoming very popular as they are capable of carrying out rescue missions automatically (Figure 6.7). In addition, they can perform tasks that may not be possible for a human operator to do such as collecting the required information without having to interfere with the working environment.

One of the major accessories used by such unmanned aerial vehicles UAVs are cameras. To date, a lot of research has been carried out on finding humans in images [2, 9, 28, 39, 29]. (2013)[12] reviewed the performance of the histogram of oriented gradients (HOG) descriptor in drone images and improved its performance for human detection. They considered the different viewing angles a person can be seen in a drone image. Following this, the Sector-ring Histogram of Oriented Gradients (SRHOG) feature [29] was developed. The

FIGURE 6.6
Recommendations of the building based on scores

FIGURE 6.7
Sample images showing how humans may appear on drone images

SRHOG focus is to change the way the gradient is calculated making it more resistant to rotation distortions. It has also a different way of forming image blocks and interpolating their values. As a result, it is able to create a rotation-invariant feature. The robustness of this feature descriptor makes it a suitable to be used in drone images where humans are imaged differently with respect to those taken on the ground.

Later in 2018, the SRHOG was improved by adding two additional filters to the gradient calculation process [19]. One of the filters was used for calculating the gradient in the radial direction, whereas the other was applied along the tangential direction. This feature was also used to develop an algorithm for human detection within drone images. This algorithm takes an input (test) image and outputs the position of the injured person, if any. For this, first a pyramid of images is created, each of which has a different resolution. At each resolution, a search window is moved along various parts of the test image

and the corresponding feature vector is computed. The result is, then, passed to a Support Vector Machine (SVM) classifier already trained with positive and negative images. An image is said to be positive if it contains all or part of a human body. Based on the training data provided, the classifier labels the test image with a positive or negative tag. If the image is positive, the location of the human is also delineated with a bounding box.

The new SRHOG-based feature was thoroughly evaluated using several data sets. The results suggested that the proposed method has a very good accuracy (90%) in situations where the human is either lying down or standing. Perhaps, this method can be used in a global scale for emergency response to support the SDGs 2030. However, it has a lower efficiency for sitting persons, as they appear very differently from above. It was observed that inappropriate lighting conditions can cause problems, and could be resolved to some extent using a preprocessing stage. In this context, an examination of the preprocessing techniques is required in future studies.

6.6 An Example of Lack of Laws in Geospatial and Environmental Issues

Governments need a set of binding legislation to regulate the relationships between their members and the environment, sometimes utilizing geospatial information technology and increasing spatial enablement [17]. This section briefly discusses an example of a lack of rules or inadequacies in the environmental and geospatial information field relating to agricultural-environmental issues and sustainability [15]. The detailed study by Ansari and Namadrian (2016)[5]; Arshadi and Pirasteh (2019)[6]; and (KWPA 2019)[27] showed that some environmental and geospatial regulations need to be revised or redefined more explicitly to reinforce their effects.

Today, the growth in population, irrational utilization of natural resources, biodiversity reduction, pollution and other causes of environmental destruction have impacted the world adversely, and for this reason geospatial information for achieving the 2030 SDGs has to play a significant role. The present quality of natural human life is a result of an unbalance and destruction of environment. It has led governments, organizations, and international communities to develop technologies such as geospatial information technology and to use them for disasters risk reduction and resilience. These bodies formulate and execute regulations to mitigate the environmental pollution and damages.

However, a case study attempted by Arshadi and Pirasteh (2019)[6]; and KWPA (2019)[27] have presented that the following are challenges and to be considered when the policy-makers decide to enrich the laws [26].

1. The authors determined that the traditional rules of environmental assess-

ments and data sharing, including geospatial information, are powerless. The provision of specific legislation in this regard is necessary.

2. The change in the legal sense “beneficiaries” and strengthening the role of non-governmental organizations are one of the most important strategies to support geospatial data sharing and protect the environment in the prosecution of cases.
3. There are no concrete and appropriate geospatial information regulations of data sharing. For example, during testing the geospatial rapid visual screening algorithms, we have not found adequate geospatial data of land use, seismic, soil and other relevant data for the city and building. Also, in one of the projects completed, there were severe challenges with collecting standard data for agricultural cadastral mapping and crop identification of Dezful, Iran (Figure 6.8). These included challenges such as flight permission and security when using drones for scanning the agricultural lands. Furthermore, during the agricultural cadastral mapping and crop identification of the Dezful project, it was concluded that there is no difference between drinking water and irrigation water, when distributing water. However, since the effects of contamination of drinking water are assessed much more robustly than contaminating agricultural water, the current existing law should have a clear definition of the law for all types of water.

FIGURE 6.8

Agricultural cadastral mapping of Dezful, Iran

6.7 Conclusions and General Remarks

The world is shifting to the second data revolution and transformative technology by the means of geospatial information and geoanalytics utilizing computer vision and artificial intelligence. Therefore, this revolution will impact disaster risk reduction and mitigation, tremendously, by the means of data sharing via web and cloud-based platforms. There is a big change towards the Internet of Things (IoT), block-chain technology, various open sources, drones and many other technological tools in support of SDGs achievements. For this reason, to recommend building smarter cities, there is a need for people, intelligence and integrated technologies, including computer vision and AI for global challenges.

This chapter indicated that without applying the power of geospatial information technologies and integration with other technologies such as artificial intelligence and machine learning, computer vision, digital transformation, and multi-disciplinary research, there will be even greater challenges for future generations. Therefore, educating the young generation in innovative and cutting-edge technologies and research in geospatial disciplines through the Academic Network and understanding of the problems with the help of the private industry sectors at the UN-GGIM will help enable the SDGs implementation and monitoring. This chapter also presented examples of geospatial information and integration of technologies for earthquake disasters risk reduction and management to build a better world.

It is recommended that each and every country build and develop its National Geospatial Information Infrastructure (NGII) that can enable coping with disaster risk reduction and mitigation resilience. It is suggested that every country develop its architecture of GGIM with a strategic road map based on the global development policy of the 2030 Agenda and beyond. In addition educational resources should be allocated for emerging technologies of robotic and AI, enabling the making of maps and improving the cartographic workflow and the training of map makers. This is possible when all countries can access satellite images, needed for SDGs implementation and monitoring.

As discussed, in order to recognize humans in drone images using the integration of geospatial information and computer vision associated with artificial intelligence, it is necessary to describe objects using proper features. In this context, there are several challenges such as the existence of various objects and complex backgrounds. The flexible nature of the human body leads to numerous situations. Different viewing angles and different dimensions related to distance from the camera are other challenges that most algorithms face. The environment in which the image is taken also affects how the injured person appears on the image.

Finally, there is a clear lack of environmental and geospatial information

laws and regulations. In order to move forward environmental and geospatial information laws need to be established or improved.

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