Perceptions of space-related non-governmental organizations in disaster risk management revealed from a questionnaire-based study

Krittanon Sirorattanakul[1,*], Alessandro Novellino[1,2], Swarnajyoti Mukherjee[1,3], Desire Muhire[1,4], Kristine Jane Atienza[1,5], Daniela Vargas-Sanabria[1,6], Rushanka Amrutkar[1,7,8], Md. Nazmus Sadat[1,9], Cindy L. Valdez[1], Henry Ibitolu[1,10], Ciro Farinelli [1], Charles-aimé Nzeussi Mbouendeu[1,11]

[1] Space Technology for Earth Applications (STEA) Project Group, Space Generation Advisory Council (SGAC)
[2] Multihazard and Resilience, British Geological Survey, Keyworth, UK
[3] Department of Aerospace Science and Technology, Politecnico di Milano, Milan, Italy
[4] Department of Physics, Chouaib Doukkali University, El Jadida, Morocco
[5] World Vision Philippines, Quezon City, Philippines
[6] Laboratorio de Investigación e Innovación Tecnológica, Universidad Estatal a Distancia, San José, Costa Rica
[7] Research and Development, Ashiyana Space Limited, London, UK
[8] Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Mumbai, India
[9] Natural Hazards and Disaster Management, Planner's Research Forum (PRF), Pabna, Bangladesh
[10] School of Engineering and Built Environment, Glasgow Caledonian University, Glasgow, UK
[11] School of Wood, Water and Natural Resources, University of Dschang, Ebolowa, Cameroon
[*] Corresponding author: krittanon.sirorattanakul@spacegeneration.org

Abstract

Space-related non-governmental organizations (NGOs) utilize products from space-based observatories or engage in issues related to space policy. They play a unique role in the Disaster Risk Management (DRM) framework as they integrate the scientific and non-scientific communities through outreach activities, education, space awareness, capacity building, and crowdsourcing of volunteers. This study explores the perception of space-related NGOs in DRM using an online questionnaire-based survey distributed worldwide to over 150 organizations. The results from the study suggest that personnel from the private sector, academia, and governmental agencies working in the field of DRM are conscious of the importance of space-related NGOs in DRM and their increasing presence across the world. International collaborations and Private-Public Partnerships (PPP) are believed to be fundamental in the implementation of successful DRM policies, especially in developing nations. The future of disaster response strategies is guided by the exciting field of artificial intelligence advanced through scientific research at universities and research institutes. Our analysis using the demographic data collected demonstrates the feasibility of using such questionnaire-based survey to further study the impact of political, economic, and cultural backgrounds on human perceptions.

Keywords Disaster Risk Management (DRM), Natural Disasters, Non-Governmental Organizations (NGOs), Public-Private Partnerships (PPP)

To cite this report

Sirorattanakul, K. et al. (2021), Perceptions of space-related non-governmental organizations in disaster risk management revealed from a questionnaire-based study, Space Generation Advisory Council project report, 1-18.

1 Introduction

Natural and man-made disasters have become a growing concern across the world in the twenty-first century. The frequency and magnitude of these catastrophes are rapidly increasing due to a worldwide demographic growth that is inducing urban sprawls into hazardous areas, thereby increasing the exposure of citizens to both dangerous substances and unsafe living conditions (Novellino et al. 2019). Based on the International Disaster Database (EM-DAT) managed by the Center for Research on the Epidemiology of Disasters (CRED), in the period between 1900-2019, natural disasters alone claimed a total fatality of over 30 million people, affected over 8 billion people, and resulted in over 2,500 billion U.S. dollars of infrastructure damages. These disasters span across different categories including droughts, earthquakes, epidemics, extreme temperature events, floods, landslides, storms, volcanic activities, and wildfires (see Table 1). The economical, physical, and emotional damages ensued by natural disasters cannot be prevented, but they can be mitigated through Disaster Risk Management (DRM). DRM is the direct implementation of risk reduction strategies that translate to disaster preparedness and response activities. Being able to identify the drivers of risk that could potentially aggravate conditions of vulnerability (e.g. poverty, urban development, environmental degradation, and climate change) is the first step toward successful DRM. The United Nations realizes that DRM underpins sustainable development and has developed a global agreement for DRM known as the Sendai Framework for Disaster Risk Reduction (Aitsi-Selmi et al. 2015).

Recent development in the space industry allows global remotely sensed data to be obtained at higher spatial and temporal resolutions (order of few meters and a few days, respectively). Having more precise and comprehensive satellite instrumentation can help direct DRM strategies (Velterop et al. 2019). Many of the Earth Observation (EO) missions, such as Sentinel, Landsat, and MODIS, adopt a free, full, and open data policy. This means that users can take advantage of the terabytes (TBs) worth of new data produced daily. Unfortunately, the non-scientific community involved in DRM, including non-governmental organizations (NGOs) and public sector (e.g., policymakers and first responders), are generally unaware of this data availability suggesting that better partnerships between different entities are needed for effective DRM.

Table 1 Casualties and economical losses from natural disasters between 1900-2019 grouped by disaster type. Data used is from the International Disaster Database (EM-DAT) from the Center for Research on the Epidemiology of Disasters (CRED).

Disaster Type	Total Fatalities	Total Affected	Total Damages in U.S. dollars
Drought	11,731,379	2,737,049,494	174,905,074,000
Earthquake	2,120,828	199,324,111	829,760,695,000
Epidemic and insect infestation	9,615,048	50,875,332	No Data
Extreme Temperature	186,450	103,605,513	63,266,343,000
Flood	6,985,307	3,842,247,704	831,605,321,000
Landslide	71,049	14,471,880	11,087,934,000
Storm	1,398,368	1,180,485,995	1,502,726,380,000
Volcanic activity	86,801	8,617,458	4,798,912,000
Wildfire	4,352	6,990,205	135,127,275

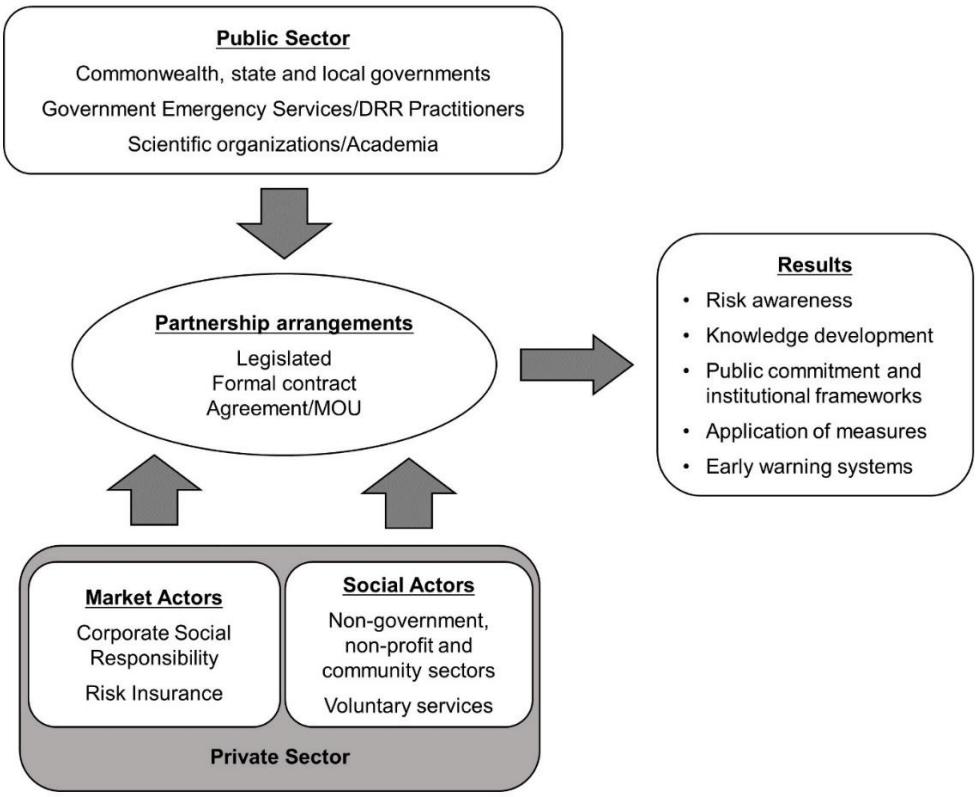

Figure 1 Public-Private Partnership (PPP) in the context of Disaster Risk Management (DRM) developed from Auzzir, Haigh, and Amaratunga (2014) and International Strategy for Disaster Reduction (2004).

We broadly define space-related NGOs as those not-for-profit organizations that utilize products from space-based observatories or engage in issues related to space policy. Unlike other entities, space-related NGOs can bridge the gap between the scientific and non-scientific communities through outreach activities and education (Liao et al. 2020), space awareness (Decoopman and Stark 2020), capacity building (Lukaszczyk and Williamson 2010), and crowdsourcing of volunteers (Hicks et al. 2019). There are over 300,000 NGOs worldwide in 2005 (Turner 2010) and this number continued to increase rapidly in the past decade. We are not aware of any reliable statistics outlining how many of these are space-related.

In the context of DRM, Public-Private Partnership (PPP) is a relatively new concept that describes cooperative arrangement between government agencies and private companies to develop products or services (Teisman and Klijn 2002; Roeth 2009; Lassa 2018). Auzzir et al. (2014) developed a conceptual framework for developing countries in which space-related NGOs constitute social actors in this framework. A successful partnership from all entities, including space-related NGOs, will lead to an improvement in the following (International Strategy for Disaster Reduction 2004; see Figure 1):

- Risk awareness and assessment including hazard analysis and vulnerability/capacity analysis,
- Knowledge development including education, training, research, and information,

- Public commitment and institutional frameworks, including organizational, policy, legislation and community action,
- Application of measures including environmental management, land-use and urban planning, protection of critical facilities, application of sciences and technologies, partnership and networking, and financial instruments, and
- Early warning systems including forecasting, dissemination of warnings, preparedness measures, and reaction capacities.

Even though it has recently become unmistakable that partnership is key to a successful attempt to manage disasters, and that space-related NGOs are one of the critical players in this framework, we are still uncertain if the DRM communities are already aware of the importance of space-related NGOs. In this study, we explore the perceptions of the roles of space-related NGOs in DRM through an online questionnaire-based survey study.

2 Methods

Data regarding perceptions of space-related NGOs working in the realm of DRM was collected through a questionnaire-based survey. The survey and informed consent form were distributed in an electronic format through emails and online contact forms between June 25th, 2019 and June 7th, 2020. Over 150 organizations worldwide were contacted, with our focus being on NGOs and institutions working with NGOs in DRM. In order to keep private information confidential, participants were not required to provide the name of their organization. Since multiple responses from independent individuals in the same organization were accepted, we are unable to track the total number of responses from each organization to identify the number of organizations that have at least one participant responding to our survey. The Space Generation Advisory Council (SGAC) leadership reviewed and approved that our questionnaire-based survey and study procedures conform with the ethical guidelines provided by both the Belmont report (United States 1978) and the Declaration of Helsinki (World Medical Association 2001).

Our survey titled “Roles of Space-related Non-Governmental Organizations in Disaster Management” includes a total of 18 questions (Qs), divided into three main sections. The first section delves into the general demographic information of participants and their respective organizations. For this segment, the survey asks the participants to select their region based in (Q1), position in the organization (Q2), age group (Q3), the number of years interacting with NGO(s) (Q4), categorization of their organization in the DRM framework (Q5), and the specific region(s) that their organizations are interacting with (Q6) from multiple options provided. The second section instructs participants to numerically rank the degree to which they agree or disagree with 10 statements made about the space-related NGOs, disaster preparedness, collaborations, and future outlooks of disaster management (see Table 2, Q7 to Q16). The ranking utilizes the 5-point scale with integer scores ranging between 1 to 5 (1 = strongly agree, 2 = somewhat agree, 3 = neutral, 4 = somewhat disagree, 5 = strongly disagree). The last section presents participants with two open-ended questions. The first question is regarding the technical tools that might be helpful for space-related NGOs to improve their operations in DRM (Q17) and the second question explores if participants utilize any satellite imagery in their work (Q18). An option for participants to write in any comments related to either our study or the roles of space-related NGOs in disaster management was also provided toward the end of our survey.

Table 2 List of all questions used in the questionnaire-based survey. Q1 to Q6 are multiple choice. Q7 to Q16 ask participants to rank each statement the extent to which they agree/disagree using the standard 5-point scale (1=strongly agree; 5=strongly disagree) to that statement. Q17 and Q18 are open-ended questions without a word limit.

	Section 1: Demographic distribution
Q1	In which region are you based?
Q2	What is your position in your organization?
Q3	What is your age?
Q4	Have you interacted with space-related non-governmental organizations? If so, for how long?
Q5	How would you categorize your organization?
Q6	Which region(s) does your organization interact with?
	Section 2: Main Survey
	Category: Roles of space-related NGOs
Q7	Space-related NGOs play significant roles in disaster risk reduction and management.
Q8	Space-related NGOs can draw public attention to issues that may be overlooked and avoided by state organizations.
Q9	Space-related NGOs reach narrower regions and have less impacts on disaster relief than governmental agencies or private companies.
	Category: Preparation for disasters
Q10	Establishment and operations of space-related NGOs are more challenging in developed countries than developing countries.
Q11	For disaster risk reduction and management related space-related NGOs, training members with knowledge related to remote sensing is not necessary.
	Category: Collaborations between different sectors
Q12	Working outside official channels, space-related NGOs can more effectively establish international collaborations not bounded by state policies that may inhibit negotiations between states.
Q13	More collaborations are needed between space-related NGOs, governmental agencies, and the private sector for disaster risk reduction and management.
Q14	Collaboration between space-related NGOs and space agencies are not necessary to a successful disaster management system.
	Category: Future outlooks of Disaster Risk Management (DRM)
Q15	Artificial intelligence will be used more extensively in the future to assist with disaster risk reduction and management.
Q16	Scientific research done by universities and research institutes is not useful to disaster risk reduction and management.
	Section 3: Open-ended questions
Q17	What tools would be helpful in order to improve the operation of space-related NGOs for disaster risk reduction and management?
Q18	Do you use any satellite data to assist with disaster risk reduction and management? If so, what type of information do you utilize?

2.1 Quality Control

To ensure that participants were paying close attention to the statements presented, we intentionally included two questions (Q13 and Q14), asking for their opinion on similar issues but from opposing viewpoints. We expect the interpretation of the responses between these two questions to be similar for a reliable survey response. Our first-order quality control involves the inversion of the score from the second statement, hence inverting the viewpoint of that statement. We then compare this score with the score from the first statement. Since Q13 and Q14 are on issues that are similar but not identical, we set ±2 as the tolerance threshold for the discrepancies. Any responses outside of this range are discarded from the analysis in the following sections.

2.2 Survey response statistics

Following the first-order quality control, we perform routine statistical analysis of the results from the main section of the survey (Q7-Q16). Based on the distribution of the responses, we infer the continuous probability density function (PDF) of our discrete data using the non-parametric kernel density estimation (KDE) method implemented in the *seaborn* python library (Waskom et al. 2017). Assuming that data $x = \{x_i\}_{i=1}^{n}$ is independent and identically distributed (i.i.d.) sample drawn from some unknown PDF, KDE asserts that with some kernel, K_h, and a smoothing parameter called bandwidth, h, the best estimate for the unknown PDF is given by (Rosenblatt 1956; Parzen 1962):

$$\hat{a}_h(x) = \frac{1}{n}\Sigma_i K_h(x - x_i) = \frac{1}{nh}\Sigma_i K\left(\frac{x - x_i}{h}\right)$$

The bandwidth, h, is a free parameter to be chosen. The selection is often based on the trade-off between the bias of the estimator and its variance. A few criteria are available through the *seaborn* (Waskom et al. 2017) python libraries such as Scott's (Scott 1979) and Silverman's (Silverman 1986) rule-of-thumbs.

Furthermore, to understand the dependence of perceptions on demographic distribution, we also categorize the responses based on demographic groups (Q1-Q6). This analysis can assist with identification of implicit biases due to political, economic, and/or cultural backgrounds. Lastly, we summarize the responses to the open-ended questions (Q17-Q18).

2.3 Correlation test

The statistical analysis described in Section 2.2 only explores responses to an individual question. We further explore relationships between responses to different questions with Spearman's rank correlation test. This is a non-parametric correlation measure, meaning that it assumes that the relationship between the two given variables can be described by a monotonic function without an assumption that the variables follow specific type of distributions. Since our survey responses are discrete, they have tied ranks. We use the following formula to calculate Spearman's rank correlation coefficient between two variables $x = \{x_i\}_{i=1}^{n}$ and $y = \{y_i\}_{i=1}^{n}$ (Zwillinger and Kokoska 2000):

$$\rho = \frac{\Sigma_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma_i (x_i - \bar{x})^2 (y_i - \bar{y})^2}}$$

The correlation coefficient lies between -1.0 and +1.0. The absolute value of the correlation coefficient measures the strength of the relationship and hence the ability to predict the value of another variable when given the value of one variable. The positive sign reflects that when one variable increases, the value of another variable also increases. The negative sign reflects the opposite such that when one variable increases, the value of another variable decreases.

Spearman's rank correlation test is implemented in the *seaborn* (Waskom et al. 2017) and *scipy* (Virtanen et al., In Press) python libraries used in this study. The library is also capable of producing correlation matrix in which Spearman's rank coefficients are calculated between responses from all possible pairs of questions. This method has been proven successful in prior studies about public perceptions on various topics (Fat et al. 2012; Lobo and Guntur 2018).

3 Results and Discussion

3.1 Quality Control

We distributed the online survey to points of contact from over 150 organizations worldwide and received a total of 104 responses. We imposed a quality control check, before conducting our statistical analysis, using the method described in Section 2.1. The results show that there were 8 responses with residual values outside of the tolerated range. Removing these 8 responses, we analyze the remaining 96 responses in the following sections.

3.2 Survey response statistics

3.2.1 Summary

Survey participants (N=96) were from varied backgrounds across the full range of defined demographics responses (Q1-Q6) as summarized in Figure 2. Based on the region based in (Q1), most participants were from the Americas and Europe, with minimal participation from Australia, Oceania, and the Middle East. For a participant's positions in respective organizations (Q2), they spread out evenly between students, executives, and volunteers, though there is a clear peak in the number of technical staff responses. 15 survey participants identified themselves with multiple positions and are thus accounted for multiple times within the statistics. As a result, the histogram for this question sums to more than 100%. Based on the age group (Q3), survey participants were dominated by young adults (18-34 years old), but there was also representation for middle-aged adults (35-54 years old) and older adults (> 55 years old). Moreover, looking at the participant's experience working with NGOs (Q4), the exposure ranged from those who have never worked with any NGO before to those who have worked with NGOs regularly for more than 5 years. Based on organization type (Q5), most survey participants represented space-related NGOs or educational institutions, but there was also representation from private sector and governmental agencies. Those identified as private sector spanned from engineering firms to software developers. Governmental agencies incorporate staff from national geological surveys, responders to natural disasters, and state officials. From these organizations, over 40% were working with two or more regions around the world (Q6). This demonstrates the globalization trend of the DRM community.

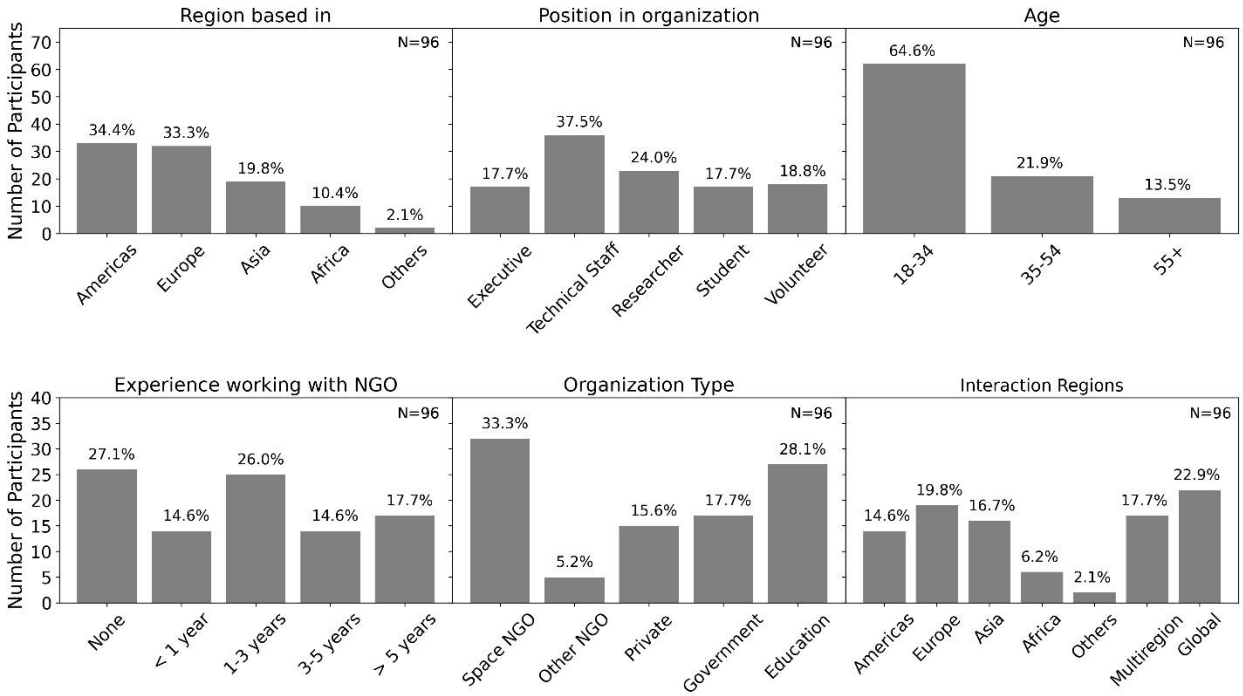

Figure 2 Demographic distribution of survey participants (N=96) based on region based in, position in the organization, age group, experience working with NGO, organization type, and region(s) that the organizations are interacting with. For statistics on position in organization, 15 participants identified themselves as multiple positions in their respective organization, so we have counted participants with multiple positions multiple times. For statistics on organization interacting region(s), the first five options (Americas, Europe, Asia, Africa, and others) refer to organizations that only interact with a single region. Multiregion refers to organizations that interact with two or more regions, but not worldwide like those referred to as global.

Since our selection of participants is diverse, we infer that the responses reflect the views of the DRM community on space-related NGOs. Without classifying participants into different demographic groups, Figure 3 summarizes all responses to the main part of our survey (Q7-Q16). We found that both Scott's and Silverman's rule-of-thumbs for kernel density estimation are not appropriate for our dataset as our data is discrete and sparse. Through visual inspection, we selected 0.5 as the best bandwidth value for calculating the probability density function.

Q7, Q8, and Q9 address the roles of space-related NGOs in the DRM framework. Participants generally perceived space-related NGOs as somewhat important in DRM (Q7). This perception seems to underestimate the importance of space-related NGOs in DRM. Space-related NGOs provided maps of flooded areas, structural damage, blocked roads, and temporary shelters to first responders (Zooniverse 2017). Without such data, it is impossible to effectively rescue affected individuals. Moreover, participants generally agreed that space-related NGOs can often draw public attention to issues overlooked by state organizations (Q8). Lukaszczyk and Williamson (2010) argued that the ability to work outside official channels allows NGOs to engage in issues that may be overwhelming for state organizations due state regulation and policy. When comparing the ability of space-related NGOs to reach affected people and their impacts during disaster relief

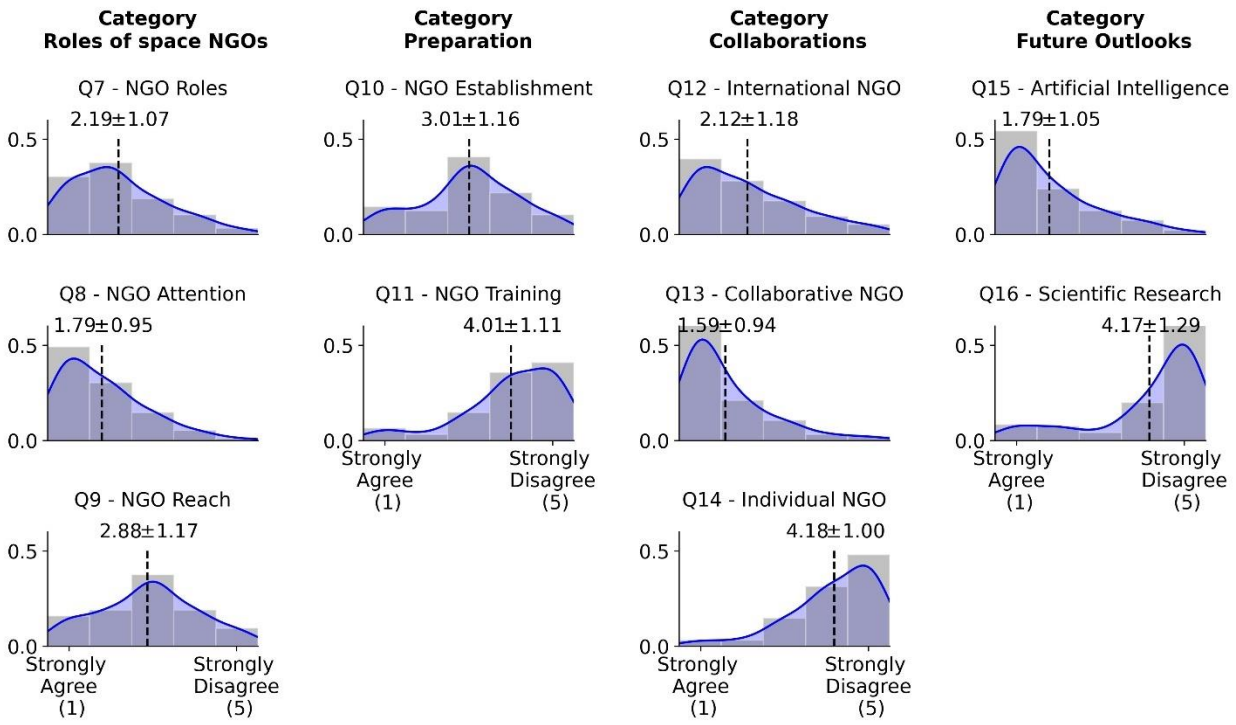

Figure 3 Probability density function (PDF) for the 96 survey responses from the main part of the survey (Q7-Q16) computed from kernel density estimation (KDE) using Gaussian kernel and a fixed bandwidth of 0.5. The mean and standard deviation of the score for each question is annotated on each individual plot.

with governmental agencies and private companies, the survey participants thought that they have similar reach and impact (Q9). This contradicts the recent case studies of disasters in Malawi (Kita 2017) and the Wenchuan earthquake in China (Lu and Xu 2014; Tang and Wang 2020), which argued that NGOs had a wider reach and larger impact during these disasters compared to governmental agencies and private companies.

Q10 and Q11 address the preparation phase in DRM. The survey participants generally perceived that the establishment and operation of space-related NGOs are equally challenging in developed and developing countries (Q10). While this opinion agrees with current quantitative data on the topic, a decade ago this would not have been the case. We now live in an era in which space-related and other NGOs are established daily in developing countries (Bromideh 2011; Ascher et al. 2016). Moreover, participants pointed out that training members of related NGOs with remote sensing knowledge is mandatory for successful DRM (Q11). Over the last decade, many NGOs have started to implement training for both their staff and potential volunteers for the purposes of supporting environmental policy in addition to effective disaster relief (Laituri and Kodrich 2008; Leeuw et al. 2010; Lechnter et al. 2017; Scholz et al. 2018).

Q12, Q13, and Q14 address the issue of collaboration between space-related NGOs and other public and private organizations in the DRM framework. Survey participants believed that international collaborations between space-related NGOs are slightly easier to arrange and

implement compared to collaborations between states (Q12). Lukaszczyk and Williamson (2010) argued that NGOs are not bounded by state policy and can avoid diplomacy issues that may arise when initiating international collaborations. When it came to collaborations between NGOs, space agencies, governmental agencies and the private sector, participants strongly believed that they are necessary for successful DRM (Q13 and Q14). Lu and Xu (2014) conducted a detailed analysis of different community post-disaster reconstruction projects and concluded that the most successful projects were those that involved NGOs, governments, and communities.

Q15 and Q16 explore the future outlooks in the field of DRM. There was a clear consensus from survey participants that artificial intelligence (AI) will be fundamental in the implementation of the next-generation DRM response (Q15) and that scientific research contributes considerably to the development of DRM strategies (Q16). AI was invented in the 1950s, but it is not until recently that it has matured considerably, enough for practical and widespread applications. In relation to DRM, AI has already revealed its multifaceted capabilities when it comes to disaster management. Examples of AI employed in disaster response include earthquake damage mapping (Syifa et al. 2019), flood susceptibility mapping (Chapi et al. 2019), storm surge prediction (Hashemi et al. 2016), heat wave hazard classification (Keramitsoglou et al. 2013), forest fire susceptibility mapping (Razavi-Termeh et al. 2020), and pandemic management (Bragazzi et al. 2020). In the upcoming years, academic research will be needed to underpin further development of AI.

3.2.2 Dependence of responses on demographic groups

The summary of the survey data provided in Section 3.2.1 represents perceptions that are generalized from the pool of survey participants. Since perceptions can be influenced by politics, economics, and culture, we explore the effects of participants' backgrounds on their responses to our questionnaire. We divided the responses into different demographic groups based on data collected in the first section of the survey (Q1- Q6). To our knowledge, there exist no other studies that quantitatively analyze such relationships. To ensure that our data and statistics are valid, we ignore any demographic group with less than 10 responses in this part of the analysis.

Examining the region based in (see Figure 4), participants based in Americas (including both North and South Americas), Europe, and Asia exhibited a similar response distribution. Africa was an outgroup with noticeable different perceptions of NGOs reach (Q9), establishment (Q10), and their ability to collaborate internationally outside official channels (Q12) compared to participants from any other regions. We reason that this is likely due to the fact that participants based in Africa have more opportunities to interact with NGOs. Resources from their governments are typically limited and a majority of the aids for DRM comes from NGOs (Kita 2017). Furthermore, participants based in Africa were slightly less advocate for scientific research (Q16). When poverty and hunger are more widespread, there is less attention available for science, technology, and innovation. Taking into consideration the small number of participants in Africa (N=10, see Figure 2), this interpretation can be highly biased. Another feature observed is that participants based in Asia tend to be less keen for international collaborations (Q12). This could be explained by the fact that Asia is the most disaster-prone continent, thus they focus their attention toward DRM within their own nations.

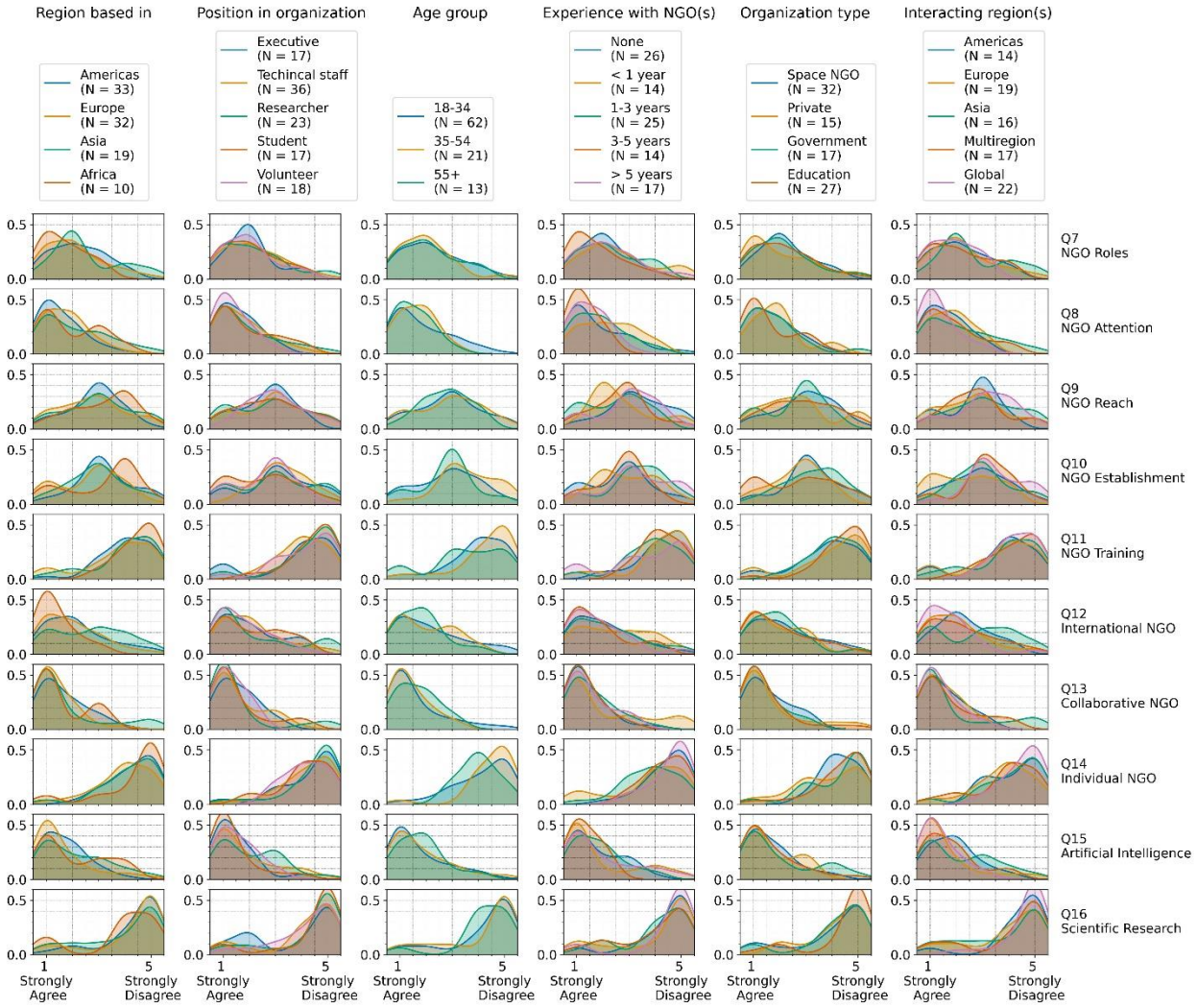

Figure 4 Probability density function (PDF) of survey responses from the main part of the survey (Q7-Q16) grouped based on demographic distribution. The estimation of PDF utilizes kernel density estimation (KDE) with Gaussian kernel and a fixed bandwidth of 0.5. Demographic groups with less than 10 responses are excluded.

Classifying by positions in the organization (see Figure 4), responses were similar across the different groups for most questions, except for Q15 and Q16 on future outlooks of DRM. Even though studies suggest that AI will be fundamental to DRM in the next era, almost half of the participants that identify themselves as researchers seem to be pessimistic about the prospects of future applications (Q15). This is likely because researchers are aware of limitations of AI. We can train machines to conduct a particular task and the machines can perform very well, but we are not able to understand what the machine has actually learned. Furthermore, the majority of survey participants in executive positions did not agree with the statement that scientific research conducted at universities and research institutes are useful to DRM (Q16). This could be because their position requires them to focus their attention to real-world disaster response events, while academia and research is occupied with theoretical work, although this has been changing recently.

When we categorize the responses by age groups (see Figure 4), responses to a few questions show correlation with the age groups such as Q15 and Q16. In these two questions, the older adults perceived AI and scientific research as less important to DRM than those perceived by the younger generations. This may stem from the fact that older adults are less likely to be familiar with new technologies compared to the younger generations. For questions regarding collaborations (Q13 and Q14), we can conclude that young and middle-aged adults similarly viewed the collaborations in the PPP framework. Older adults, however, appeared to be an outgroup with a more neutral opinion towards the effectiveness of collaborations between agencies. This can be explained by the transfer of both disaster response and relief efforts from governmental agencies to a more interorganizational PPP approach.

Based on the level of experience working with NGO(s) (see Figure 4), some correlations with the level of experience were observed for some questions (Q12, Q13, and Q14). Unfortunately, these correlations were not significant enough for us to make any useful interpretations. Surprisingly, participants with no experience working with NGO(s) were not an outgroup. In many cases (Q7-Q10, Q12-Q14), the outgroup was represented by participants with some experience working with NGO(s), but less than 1 year. These results show that participants can learn about NGOs and become involved in disaster relief efforts without needing to work for an NGO.

Inspecting the organization type (see Figure 4), we found that each group – space-related NGOs, private sector, government and academia – alternates to be an outgroup for different questions. Space-related NGOs were an outgroup for collaborations between different entities in DRM (Q13 and Q14). An unanticipated statistic was that space-related NGOs were the group with the least enthusiasm for collaborations. This is probably because they are generally the users and developers of satellite products, but they have limited experience with the disaster response work done in the field. Moreover, the private sector was an outgroup for questions related to the roles of space-related NGOs (Q7 and Q8). The survey participants in this group believed that space-related NGOs are more important than perceived by other groups, but they were less familiar with the fact that NGOs can be more efficient than state organizations. Educational institutions were an outgroup for Q10 and Q16; they have the most diverse responses when it comes to their opinion about the difficulties of establishing and operating NGOs in developed countries, but they were the strongest advocates for scientific research.

Based on the regions that organizations interact with (see Figure 4), the global organizations were an outgroup for a few instances (Q8, Q12, Q14, and Q16) with strong opinion toward the statements provided. Regarding the roles of space-related NGOs (Q8), they were the strongest advocates that NGOs can draw public attention to issues overlooked by state organizations. Regarding collaborations (Q12 and Q14), they were the strongest advocates for international collaborations. Regarding the future outlooks (Q16), they were also the strongest advocates for scientific research. These results infer that global organizations have visions for a science-supported collaborative society. No other groups besides the global organizations exhibited any clear trend.

We understand that our statistical analysis for this section can seem highly biased due to our small sample size, but there is value in demonstrating that this methodology can allow us to learn about the dependence of perceptions on political, economic, and cultural backgrounds. This lays a new

ground for studying implicit biases in perceptions and encourages future studies to adapt such quantitative methods.

3.2.3 Open-ended questions

The last section of the survey included open-ended questions (Q17 and Q18). Among the survey participants, 46.9% have some experience with using remote sensing data. The imagery experience ranges from optical images to thermal sensors and radar interferometry, and from raw images to derived products. Several participants are also experienced in using satellite imagery to detection of Near-Earth Object (NEO) and telecommunications.

Survey participants also identify several challenges when it comes to using remote sensing technologies for DRM including accessibility, deficiencies in technical training, and lack of public knowledge on the benefits of space-related technologies. The free remote sensing data and software currently available in the market are limited in their capabilities (e.g. low resolution, missing coordinates, etc.) and can be both complex and time consuming to use. To improve the technical operations of NGOs, potential solutions provided include rapid acquisition of satellite imagery, affordable technical support, technical training for staff, user control over satellite navigation and positioning to assist rescue teams, and telecommunications that are independent of ground-based infrastructure. However, in order to start implementing these solutions, we need an open source database in the form of a website or a mobile application where satellite data is near real-time, consistent, and easy to access. Another feature that would be beneficial is including a forum where members can network and share DRM strategies. An advancement to this would be to implement a system that automatically processes this data and sends alerts to emergency responders, as well as citizens nearby the critical sites. Moreover, NGOs encounter barriers in utilizing satellite data due to national cybersecurity concerns over access to high-resolution Earth observation data. A clearly defined relationship in the form of PPP between for-profit industry, government, and NGOs would help resolve this matter.

Besides these technical challenges, the participants also commented that they would like to see a better recognition for efforts from volunteers. For instance, the organizations can distribute a paper certificate of appreciation to acknowledge the work done by volunteers.

3.3 Correlation test

In addition to conducting statistical analysis of the survey responses to individual questions, we employed Spearman's rank correlation test to determine the relationship of responses to different questions. Figure 5 shows correlation coefficients calculated between all pairs of questions from the main part of the survey (Q7-Q16) using the quality-controlled dataset. Strong correlation between Q13 and Q14 was expected since these two questions were designed to ask about the same issue represented both in a positive statement and a negative statement. Moreover, Q9 seems to be an outgroup in which correlations with other questions are relatively low suggesting that the answer to this question is independent of others. We currently do not have a more insightful interpretation of other pairs of questions. Subsequent research can focus on exploring the possibility of causal relationships between pairs of questions with strong correlations.

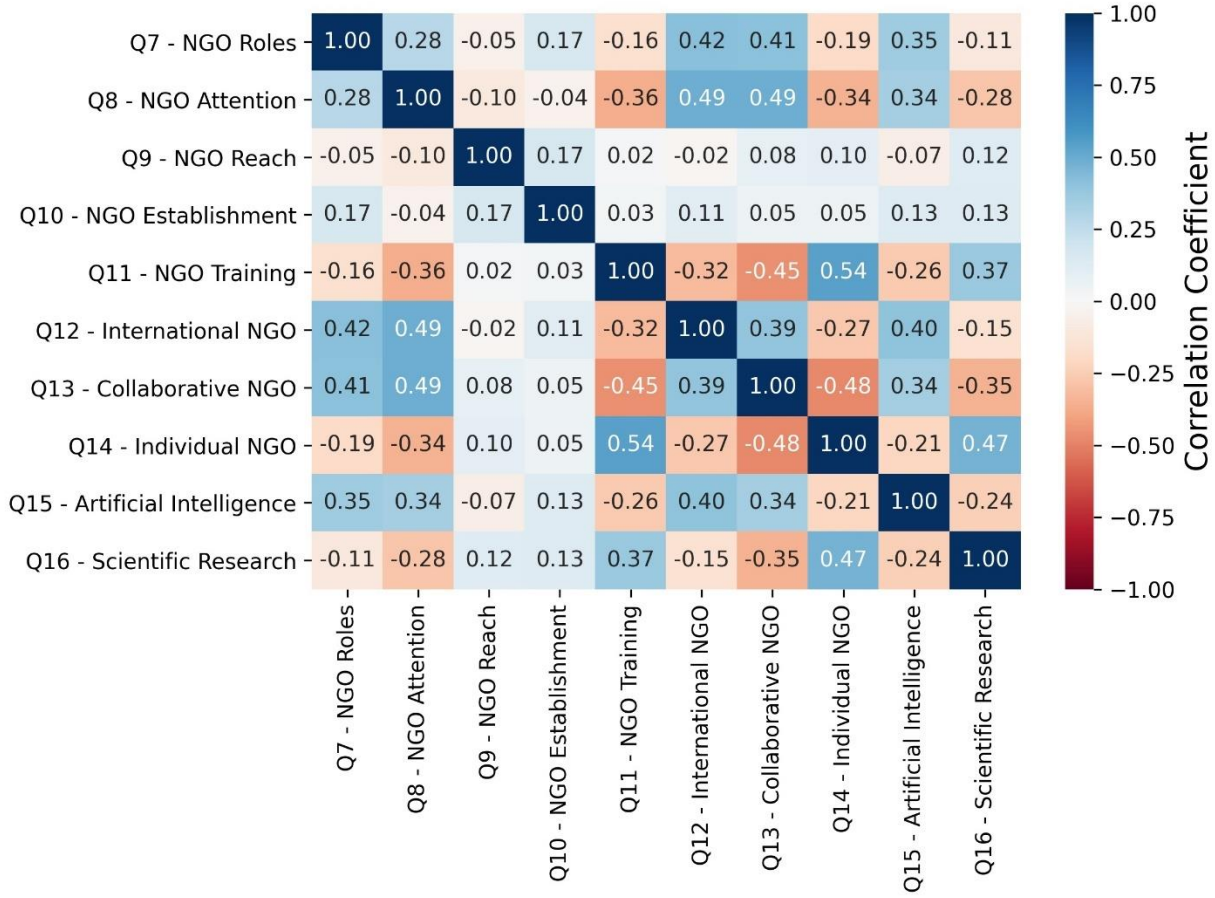

Figure 5 Spearman's rank correlation coefficients calculated between all pairs of questions from the main part of the survey (Q7-Q16) using the quality-controlled dataset (N=96) as an input.

4 Conclusions

In this study, we explored the roles of space-related NGOs in DRM, as perceived by individuals currently active in NGOs and institutions working with NGOs in the DRM framework. Since there are no other current studies that address the perceptions of space-related NGOs in the realm of disaster management, our questions were designed to cover a range of themes including: the roles of space-related NGOs, preparation for disaster management, collaborations between different sectors, and future outlooks of DRM. From 96 responses that passed the quality control test, we found that participants recognize the importance of space-related NGOs in the DRM framework owing to their ability to bridges the gap between scientific and non-scientific communities. Though the responses spread considerably over the whole range of our 5-point scale, related individuals in the field of DRM are generally aware that NGOs can work outside official channels allowing them effective established operations in developing countries promoting international and inter-sector collaborations. Many space-related NGOs are now starting a training program to train their members with knowledge about remote sensing technology for the purposes of both supporting environmental policy and effective disaster response. The future of DRM will be guided by the development of artificial intelligence in addition to human decision making. Using the

demographic information collected, we have demonstrated the ability to use a questionnaire-based survey study to investigate the influences of politics, economics, and culture on individuals' perceptions. This opens up a range of new possible projects adopting similar methods to study social implicit biases and prejudices in the DRM community. A better understanding of community awareness of different groups in the DRM framework will allow various agencies to tailor their outreach program to educate young professionals to be prepared for, and reduce risks from, future natural and man-made disasters.

Acknowledgements

We express our deepest gratitude to survey participants for their time and effort in completing our questionnaire. We acknowledge insightful comments on our work provided by Jim Volp, a former chair of Space Generation Advisory Council (SGAC), Emma Velterop, a former co-lead of Space Technology for Earth Applications (STEA) project group, SGAC, Vannel Feudjeu Medzepo from National High School of Public Works in Cameroon, Marco Romero from Angolan Office of Space Affairs and ISAE-SUPAERO, Dr. Mostafa M. K. Sayed from Thebes Higher Institute of Engineering in Egypt, and Dr. Peeranan Towashiraporn from Asian Disaster Preparedness Center (ADPC). This project is conducted under supervision of Swetha Kotichintala and Victor Hertel, the co-leads from STEA project group, SGAC.

References

Aitsi-Selmi, A., S. Egawa, H. Sasaki, C. Wannous, and V. Murray. 2015. The Sendai Framework for Disaster Risk Reduction: Renewing the Global Commitment to People's Resilience, Health, and Wellbeing. *International Journal of Disaster Risk Science* 6 (2): 3176. https://doi.org/10.1007/s13753-015-0050-9.

Ascher, W., G.D. Brewer, G.S. Cheema, and J.M. Heffron. 2016. *The Evolution of Development Thinking: Politics, Economics, and Inclusive Development*. New York: Palgrave Macmillan.

Auzzir, Z.A., R. Haigh, and D. Amaratunga. 2014. Public-private Partnerships (PPP) in Disaster Management in Developing Countries: A Conceptual Framework, *Procedia Economics and Finance* 18:807–814. https://doi.org/10.1016/S2*212*-5671(14)01006-5.

Bragazzi, N.L., H. Dai, G. Damiani, M. Behzadifar, M. Martini, and J. Wu. 2020. How Big Data and Artificial Intelligence Can Help Better Manage the COVID-19 Pandemic. *International Journal of Environmental Research and Public Health* 17 (9): 3176. https://doi.org/10.3390/ijerph17093176.

Bromideh, A.A. 2011. The widespread challenges of NGOs in developing countries: Case studies from Iran. *International NGO Journal* 6 (9): 197–202. https://doi.org/10.5897/NGOJ11.014.

Chapi, K., V.P. Singh, A. Shirzadi, H. Shahabi, D.T. Bui, B.T. Pham, and K. Khosravi. 2019. "A novel hybrid artificial intelligence approach for flood susceptibility assessment. *Environmental Modelling & Software* 95:229–245. https://doi.org/10.1016/j/envsoft.2017.06.012.

Decoopman, C., and A. Stark. 2020. SGAC: A Network for the Young Generation. In *Space Capacity Building in the XXI Century*, edited by S. Ferretti, 341–356. Cham, Switzerland: Springer.

Fat, M.J.L., E. Sell, N. Barrowman, and A. Doja. 2012. Public perception of Tourette syndrome on YouTube. *Journal of Child Neurology* 27 (8):1011–1016. https://doi.org/10.1177/0883073811432294.

Hashemi, M.R., M.L. Spaulding, A. Shaw, H. Farhadi, and M. Lewis. 2016. An efficient artificial intelligence model for prediction of tropical storm surge. *Natural Hazards* 82:471–491. https://doi.org/10.1007/s11069-016-2193-4.

Hicks, A., J. Barclay, J. Chilvers, M.T. Armijos, K.Oven, P. Simmons, and M. Haklay. 2019. Global Mapping of Citizen Science Projects for Disaster Risk Reduction. *Frontiers in Earth Science* 7:226. https://doi.org/10.3389/feart.2019.00226.

International Strategy for Disaster Reduction. 2004. *Living with Risk: A Global Review of Disaster Reduction Initiatives*. New York: United Nations.

Keramitsoglou, I., C.T. Kiranoudis, B. Maiheu, K.D. Ridder, J.A. Daglis, P. Manunta, and M. Paganini. 2013. Heat wave hazard classification and risk assessment using artificial intelligence fuzzy logic. *Environmental Monitoring and Assessment* 185:8239–8258. https://doi.org/10.1007/s10661-013-3170-y.

Kita, S. M. 2017. Government Doesn't Have the Muscle: State, NGOs, Local Politics, and Disaster Risk Governance in Malawi. *Risk, Hazards, and Crisis in Public Policy* 8 (3): 244–267. https://doi.org/10.1002/rhc3.12118.

Laituri, M., and K. Kodrich. 2008. On Line Disaster Response Community: People as Sensors of High Magnitude Disasters Using Internet GIS. *Sensors* 8 (5): 3037–3055. https://doi.org/10.3390/s8053037.

Lassa, J. A. 2018. Roles of Non-Government Organizations in Disaster Risk Reduction. *Oxford Research Encyclopedias: Natural Hazard Science*. https://doi.org/10.1093/acrefore/9780199389407.013.45.

Lechnter, K., M. Nolde, R. Kiefl, M. Enenkel, A. Papp, C. Scherkenbach, and S. Voigt. 2017. Earth Observation for SOS Children's Villages: Deployment of Cutting-Edge Technology to Support a Humanitarian NGO in Emergency Management. In *GI Forum*. https://doi.org/10.1533/giscience2017_01_s199.

Leeuw, J.D., Y. Georgiadou, N. Kerle, A.D. Gier, Y. Inoue, J. Ferwerda, M. Smies, and D. Narantuya. 2010. The Function of Remote Sensing in Support of Environmental Policy."*Remote Sensing* 2 (7): 1731–1750. https://doi.org/10.3390/rs2071731.

Liao, W., E.J. Hackathorn, and S. Wang. 2020. A Study of Applying a 3D Instructional Software of Popular Science (Science On a Sphere Explorer) in Earth Science Education of an Elementary School. In *22nd International Conference on Advanced Communication Technology (ICACT)*. https://doi.org/10.23919/ICACT48636.2020.9061378.

Lobo, M., and R.D. Guntur. 2018. Spearman's rank correlation analysis on public perception toward health partnership projects between Indonesia and Australia in East Nusa Tenggara Province. *Journal of Physics: Conference Series* 1116 (2): 022020. https://doi.org/10.1088/1742-6596/1116/2/022020.

Lu, Y., and J. Xu. 2014. NGO collaboration in community post-disaster reconstruction: field research following the 2008 Wenchuan earthquake in China. *Disasters* 39 (2): 258–278. https://doi.org/10.1111/disa.12098.

Lukaszczyk, A., and R. Williamson. 2010. The role of space related non-governmental organizations (NGOs) in capacity building. *Advances in Space Research* 45 (3): 468–472. https://doi.org/10.1016/j.asr.2009.10.004.

Novellino, A., C. Jordan, G. Ager, L. Bateson, C. Fleming, and P. Confuorto. 2019. Remote sensing for natural or man-made disasters and environmental changes. In *Geological Disaster Monitoring Based on Sensor Networks*, edited by T. Durrani, W. ang, and S. Forbes, 23–31. Singapore: Springer.

Parzen, E. 1962. On Estimation of a Probability Density Function and Mode, The Annals of Mathematical Statistics. *The Annals of Mathematical Statistics* 33 (3): 1065–1076. https://doi.org/10.1214/aoms/1177704472.

Razavi-Termeh, S.V., A. Sadeghi-Niaraki, and S.-M. Choi. 2020. Ubiquitous GIS-Based Forest Fire Susceptibility Mapping Using Artificial Intelligence Methods. *Remote Sensing* 12 (10): 1689. https://doi.org/10.3390/rs12101689.

Roeth, H. 2009. The development of a public private partnership framework and action plan for disaster risk reduction (DRR) in Asia. *United Nations Office for Disaster Risk Reduction*.

Rosenblatt, M. 1956. Remarks on Some Nonparametric Estimates of a Density Function. The *Annals of Mathematical Statistics* 27 (3): 832–837. https://doi.org/10.1214/aoms/1177728190.

Scholz, S., P. Knight, M. Eckle, S. Marx, and A. Zipf. 2018. Volunteered Geographic Information for Disaster Risk Reduction - The Missing Maps Approach and Its Potential within the Red Cross and Red Crescent Movement. *Remote Sensing* 10 (8): 1239. https://doi.org/10.3390/rs10081239.

Scott, D. W. 1979. On Optimal and Data-Based Histograms. *Biometrika* 66 (3): 605–610.

Silverman, B. W. 1986. Density Estimation for Statistics and Data Analysis. London: Chapman Hall. Syifa, M., P. R. Kadavi, and C.-W. Lee. 2019. An Artificial Intelligence Application

for Post-Earthquake Damage Mapping in Palu, Central Sulawesi, Indonesia. *Sensors* 19 (3): 542. https://doi.org/10.3390/s19030542.

Tang, G., and F.Wang. 2020. What factors contribute to nonprofit collaboration? An analysis of response and recovery efforts after the 2008 Wenchuan Earthquake, China. *Safety Science* 125:104624. https://doi.org/10.1016/j.ssci.2020.104624.

Teisman, G.R., and E.-H. Klijn. 2002. Partnership Arrangements: Governmental Rhetoric or Governance Scheme? *Public Administration Review* 62 (2): 197–205. https://doi.org/10.1111/0033-3352.00170.

Turner, E.A.L. 2010. Why Has the Number of International Non-Governmental Organizations Exploded since 1960? *Cliodynamics*. https://doi.org/10.21237/c7clio11196.

United States. 1978. The Belmont report: ethical principles and guidelines for the protection of human subjects of research. [Bethesda, Md.]: The Commission.

Velterop, E., K. Sirorattanakul, A. Novellino, D. Muhire, R. Amrutkar, S. Patial, D. Vargas-Sanabria, et al. 2019. Current and Near-Future State of Space Technology for Disaster Situations. In *Proceedings of the 70th International Astronautical Congress (IAC)*. IAC-19,B1,1,11,x50085.

Virtanen, P., R. Gommers, T.E. Oliphant, M. Haberland, T. Reddy, D. Cournapeau, E. Burovski, et al. In Press. SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. *Nature Methods*. https://doi.org/10.5281/zenodo.883859.

Waskom, M., O. Botvinnik, D. O'Kane, P. Hobson, S. Lukauskas, D. C. Gemperline, T. Augspurger, et al. 2017. *mwaskom/seaborn: v0.8.1* (September 2017). Zenodo. https://doi.org/10.5281/zenodo.883859.

World Medical Association. 2001. World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects. *Bulletin of the World Health Organization*, 79 (4): 373-374.

Zooniverse. 2017. Planetary Response Network and Rescue Global: Caribbean Storms 2017. https://www.zooniverse.org/projects/vrooje/planetary-response-network-and-rescue-global-caribbean-storms-2017/about/results.

Zwillinger, D., and S. Kokoska. 2000. *CRC Standard Probability and Statistics Tables and Formulae*. New York: Chapman Hall.