sustainability

MDPI

Article

An Open Data and Citizen Science Approach to Building Resilience to Natural Hazards in a Data-Scarce Remote Mountainous Part of Nepal

Binod Prasad Parajuli [1,*], Prakash Khadka [2], Preshika Baskota [1], Puja Shakya [1], Wei Liu [2], Uttam Pudasaini [3], Roniksh B.C. [3,4], Jonathan D. Paul [5], Wouter Buytaert [6] and Sumit Vij [7,8]

1 Climate and Resilience, Practical Action Consulting South Asia, Kathmandu 44600, Nepal; preshika.baskota@gmail.com (P.B.); puja.shakya@practicalaction.org.np (P.S.)
2 Risk and Resilience, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria; khadka@iiasa.ac.at (P.K.); liuw@iiasa.ac.at (W.L.)
3 Geomatics, Naxa Private Limited, Kathmandu 44600, Nepal; uttam@naxa.com.np (U.P.); ronikshbc@gmail.com (R.B.C.)
4 Department of Environmental Science, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu 44605, Nepal
5 Department of Earth Sciences, School of Life Sciences and the Environment, Royal Holloway, University of London, Egham TW20 0EX, UK; jonathan.paul@rhul.ac.uk
6 Department of Civil and Environmental Engineering, Imperial College London, London SW7 2AZ, UK; w.buytaert@imperial.ac.uk
7 Public Administration and Policy Group, Wageningen University & Research, 6706 KN Wageningen, The Netherlands; sumit.vij@wur.nl
8 Earth & Climate Cluster, Department of Earth Sciences, Faculty of Earth & Life Sciences, Vrije University Amsterdam, 1081 HV Amsterdam, The Netherlands
* Correspondence: binod.parajuli@practicalaction.org.np

Received: 13 October 2020; Accepted: 6 November 2020; Published: 13 November 2020

check for updates

Abstract: The citizen science approach has gained momentum in recent years. It can enable both experts and citizen scientists to co-create new knowledge. Better understanding of local environmental, social, and geographical contexts can help in designing appropriate plans for sustainable development. However, a lack of geospatial data, especially in the context of developing countries, often precludes context-specific development planning. This study therefore tests an innovative approach of volunteer citizen science and an open mapping platform to build resilience to natural hazards in the remote mountainous parts of western Nepal. In this study, citizen scientists and mapping experts jointly mapped two districts of Nepal (Bajhang and Bajura) using the OpenStreetMap (OSM) platform. Remote mapping based on satellite imagery, capacity building, and mobilization of citizen scientists was performed to collect the data. These data were then uploaded to OSM and later retrieved in ArcGIS to produce a usable map that could be exploited as a reference resource for evidence-based decision-making. The collected data are freely accessible to community members as well as government and humanitarian actors, and can be used for development planning and risk reduction. By piloting in two communities of western Nepal, we found that using open data platforms for collecting and analyzing location-based data has a mutual benefit for researchers and communities. Such data could be vital in understanding the local landscape, environmental risk, and distribution of resources. Furthermore, they enable both researchers and local people to transfer technical knowledge, collect location-specific data, and use them for better decision-making.

Keywords: citizen science; hazards; open data; remote mapping; sustainable development

1. Introduction

Nepal is exposed to a multitude of recurrent natural and human-induced hazards [1–3]. The steep slopes and fragile geology and landscapes, coupled with heavy monsoon rainfall patterns, lead to a wide range of hazards across the country [4,5], with landslides and floods claiming the majority of lives every year [5]. A total of 159 lives were lost in the year 2019 in Nepal from floods and landslides only [6]. Furthermore, low adaptive capacity exacerbated by poor governance plays a significant role in increasing vulnerability to these natural hazards [7]. Lack of adequate and scientific data is a major hindrance to effective decision-making and community-based resilience building [8].

Open data, in this context, are crucial to strengthening the impact of resilience-building efforts [9]. The availability and accessibility of open data can provide information on various climates as well as disaster-related information, helping communities to build awareness of pre-, during-, and post-disaster events [10]. In addition, open data help to expose risks and vulnerabilities, along with providing methods of applying these data to decision-making [11]. The United Nations Office for Disaster Risk Reduction (UNDRR) defines community resilience as an ability to "resist, absorb, accommodate, adapt, transform, and recover" after an exposure to hazards. They also emphasize the prevention of damage to the essential structure and quick recovery [12]. In this context, the use of open data in modeling hazards, as well as in assessing risks in data-scarce regions, can provide important information to potentially strengthen the disaster resilience of communities and individuals [13]. Hence, there has been increasing effort over the past few years to leverage open data and innovation to build climate and disaster resilience [9].

Citizen science is an approach that enables non-scientists from a diverse group of communities to leverage local knowledge and data in depicting a community through different interventions like monitoring or mapping in a locally understandable format [14]. It involves a wide range of stakeholders and citizens to co-produce knowledge more effectively and efficiently [15]. Citizen science involvement in participatory collaborative mapping has been growing as a practice in scaling up the conceptual common ground of communities and disseminating geographic information [16–18]. Volunteered Geographic Information (VGI) more broadly explains the concept of citizen-based geospatial mapping [19]. It is an approach of utilizing citizen scientists to generate geospatial content with participatory involvement using online platforms [20].

OpenStreetMap (OSM) is such an open platform used for VGI [21,22] to create and freely share geospatial information through mapping [21–23]. It consists of geographical data such as streets, buildings, and infrastructure, which can be added by any user with a ground-level knowledge to represent their community at varying spatial scales [24]. VGI enables individuals to capture local observations and make informed assessments of their communities through an increased awareness of local hazards, risks, and vulnerability [25]. The use of citizen science in mapping data in disaster situations is also vital for the acquisition of local and the most current information, the development of instant rescue plans, and monitoring of post-disaster influences on society and the environment [26,27]. Moreover, the shared knowledge and improved understanding of the broader community through community-based participatory mapping help to enhance disaster resilience building [15,28].

Hence, this study focuses on the use of open data and citizen science in a VGI approach in order to archive local knowledge and capture geospatial information at higher spatial resolution and accuracy. Most of the remote mountainous parts of Nepal lack geospatial data in digital platforms [29]. Thus, with remote mapping technology validated by a field-based mapping approach using citizen scientists, we demonstrate how essential geo-information can be generated and used in local-level planning and enhance resilience-building efforts of the community. This study also fills a sizeable data gap in remote mountainous communities by contributing to open data systems through geospatial data enrichment and providing the foundation for a wide range of actors to participate in resilience-building activities.

The remainder of the manuscript is as follows. In Section 2, we describe the materials and methods used for this study. Section 3 contains results, and is followed by a discussion in Section 4. Finally, Section 5 provides brief conclusions and a prospect for future activities.

2. Materials and Methods

2.1. Study Area

The study was carried out in the Bajhang and Bajura districts of the Sudur Paschim province in western Nepal. These districts are considered as the remotest districts of Nepal in terms of development, with the lowest human development index values as of 2014 [30], and are also among the most disaster-prone, affected by a wide range of disasters like landslides and floods [31]. The Bitthadchir Rural Municipality and Budhiganga Municipality, from their respective districts, were chosen as study sites. The latter covers elevations of 706–2449 m, having a total population of 21,677 and 4277 total households according to the 2011 national census. By contrast, Bitthadchir lies between 799–2747 m elevation and contains 17,154 inhabitants and 2739 households. Figure 1 is a map of the study area.

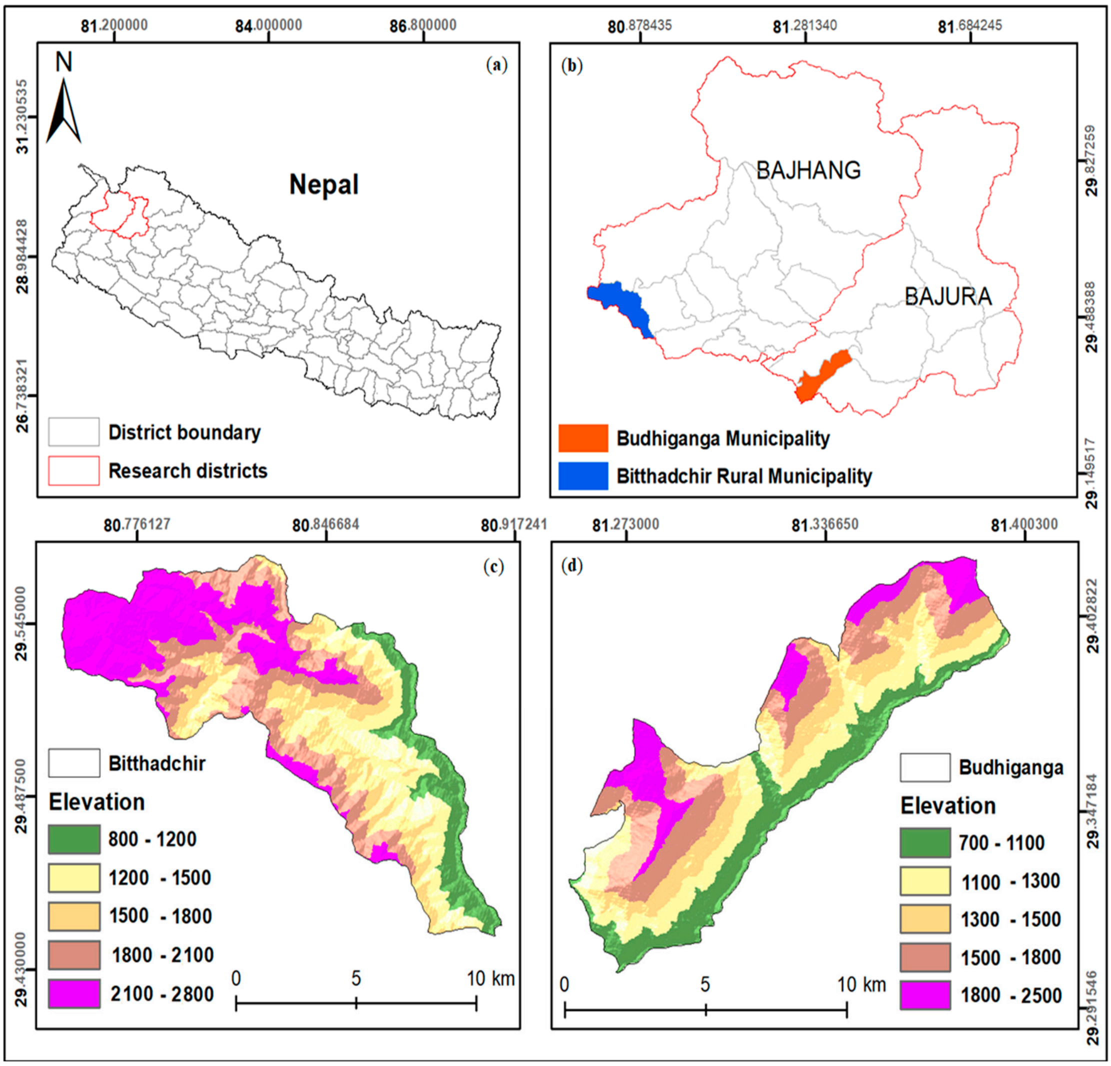


Figure 1. Maps showing Bitthadchir Rural Municipality and Budhiganga Municipality in the Bajhang and Bajura districts of western Nepal, respectively, as well as their elevation range. (**a**) Position of research districts, western Nepal; (**b**) Bajhang and Bajura districts; (**c**) Bitthadchir Rural Municipality elevation range; (**d**) Budhiganga Municipality elevation range.

2.2. Methods

2.2.1. Citizen Science for Collaborative Mapping

A collaborative mapping approach was used to enable citizen scientists to use ground-level knowledge in representing a community at varying spatial scales through mapping [32]. This process involved a wide range of stakeholders, including people from diverse backgrounds, such as students, government officials from municipal and ward offices, IT officers from the respective municipalities, representatives from Civil Society Organizations (CSOs), and those from the Nepal Police and the Nepal Army, to co-produce knowledge more effectively and efficiently. A preliminary study was made by remotely mapping the selected sites, followed by field training and data collection. First, intensive remote mapping was conducted by six volunteers. Then, a five-day training workshop was conducted in Budhiganga Municipality, Bajura, on 13–17 November, 2019 and in Bitthadchir Rural Municipality, Bajhang, on 19–23 November 2019 to further validate the data from the remote mapping. Figure 2 presents a summary of our workflow.

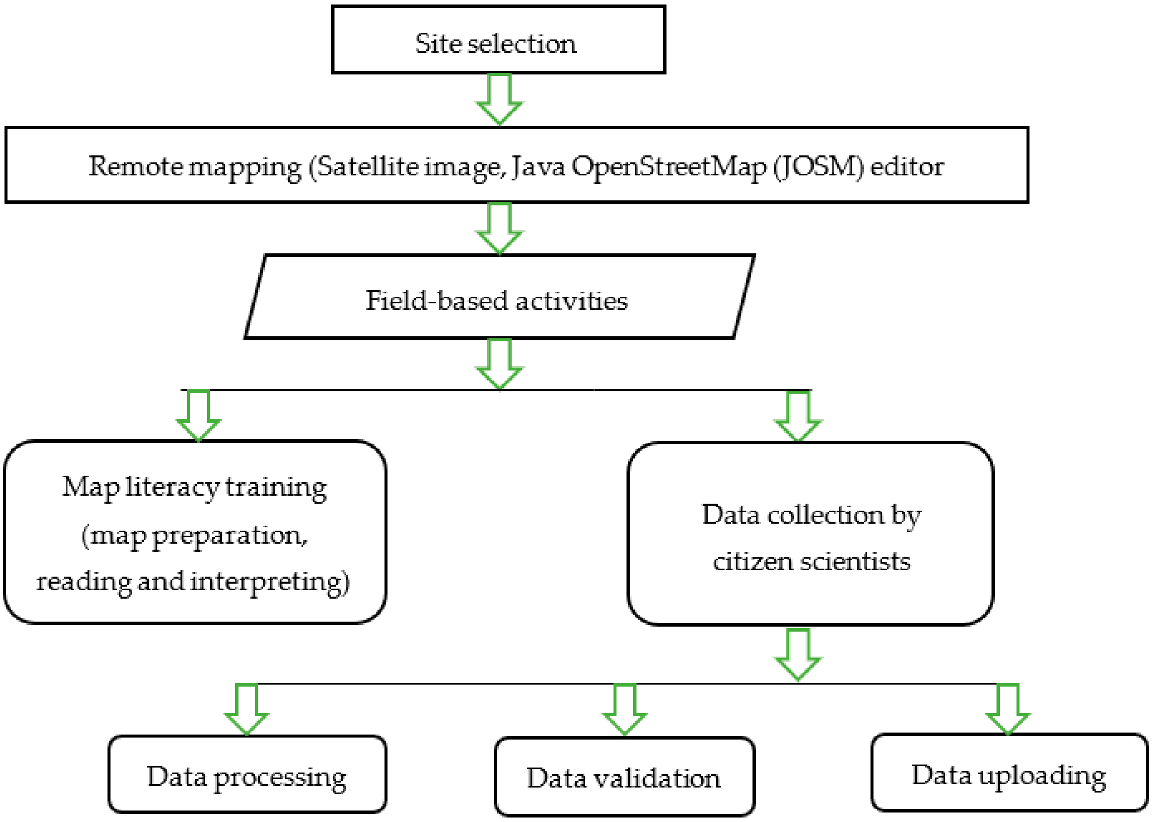


Figure 2. Flowchart of the methodological approach.

2.2.2. Remote Mapping

Remote mapping was carried out in order to digitize all possible objects on the ground before the field-level training and mapping exercises were undertaken. Digitization of the satellite image in OSM was carried out via a remote mapping event organized in Kathmandu, in which six mappers contributed over a span of two weeks. Preliminary remote mapping was carried out by experts who were familiar with remote mapping in OSM, and had an academic understanding of digital mapping. They consisted of a mix of people from geomatics, as well as students of environmental science and geography. Altogether, 110 h of remote mapping was performed using the JOSM software.

2.2.3. Map Literacy and OSM Training

A total of 49 participants, including six remote mappers, 21 citizen scientists from Bajhang, and 22 from Bajura, were involved in remote mapping, sensitization, and field training about the mapping. The sensitization session was planned to introduce the concept of data, open data, mapping at a local level, and data-driven planning, inter alia. Furthermore, participants were trained in preparing and interpreting maps with different practical sessions in order to assess their level of cartographic literacy and to teach them to prepare as well as read maps. The training session also included the concept and use of online and offline tools for mapping in OSM. The participants were instructed to create new data layers, to digitize the locations they knew, and to fill in attribute details. Similarly, a one-day data collection exercise was carried out in the field. Citizen scientists used GPS devices, mobile phones, and the OSMTracker app to collect geographical data, such as the locations of educational institutions, health facilities, road networks, and other community resources from the field.

2.2.4. Tools and Software Used

JOSM is a free software desktop editing tool for OSM geo-data created in Java, and it is helpful in remote mapping, editing, and exporting the data to the OSM platform [33]. It was used for digitizing field data, remote mapping, editing the collected data, and uploading to the OSM server. Likewise, OSMTracker, an offline smartphone app, was used to collect the points of interest to be added to the map with photos, recordings, and any geo-tagged information [34]. In addition, a GPS device was used for tracking and mapping local trails during field work. ArcGIS software was used to retrieve OSM data and visualize the maps.

2.2.5. Data Processing, Analysis, Validation, and Uploading

The data collected by participants were further analyzed, processed, and uploaded to OSM. The data processing, analysis, and validation steps were executed in two phases. First, the participants were divided into four groups, in which one trainer was assigned to assist. The data collected from the OSM tracker and GPS device were exported in JOSM software; each attribute and the nodes were checked carefully. Any errors in the name of the attribute, tag, and/or location were jointly discussed in a team and addressed accordingly. The trainer allocated to each group facilitated this process; each member of the group edited at least one of their known locations. This gave an opportunity to jointly learn and validate the collected information among both the trainers and citizen scientists. After data cleaning and validation, the data were uploaded to the OSM server. In the second phase, these data were again retrieved in JOSM, and were checked for inconsistencies and overlaps between the different nodes and attributes. Later, the shapefiles and tags were retrieved from the OSM server and visualized in ArcGIS to produce final usable and shareable maps.

3. Results

3.1. Remote Mapping of Two Districts

Two districts of the Sudurpaschim province were mapped by six volunteer citizen scientists using JOSM editor software with the help of freely available satellite imageries. During the remote mapping process, we mapped new features and updated already mapped areas, incorporating the changes seen in the latest satellite images. During two weeks of remote mapping, a total of 25,899 edits were made, including 24,704 buildings and 209.9 km of road, as listed in Table 1. Figure 3 shows the portion of the study area after the remote mapping.

Table 1. Total attributes edited in Java OpenStreetMap (JOSM) through remote mapping.

Attributes	Edits
Building (number)	24,704
Road (km)	209.9
Total (number)	25,899

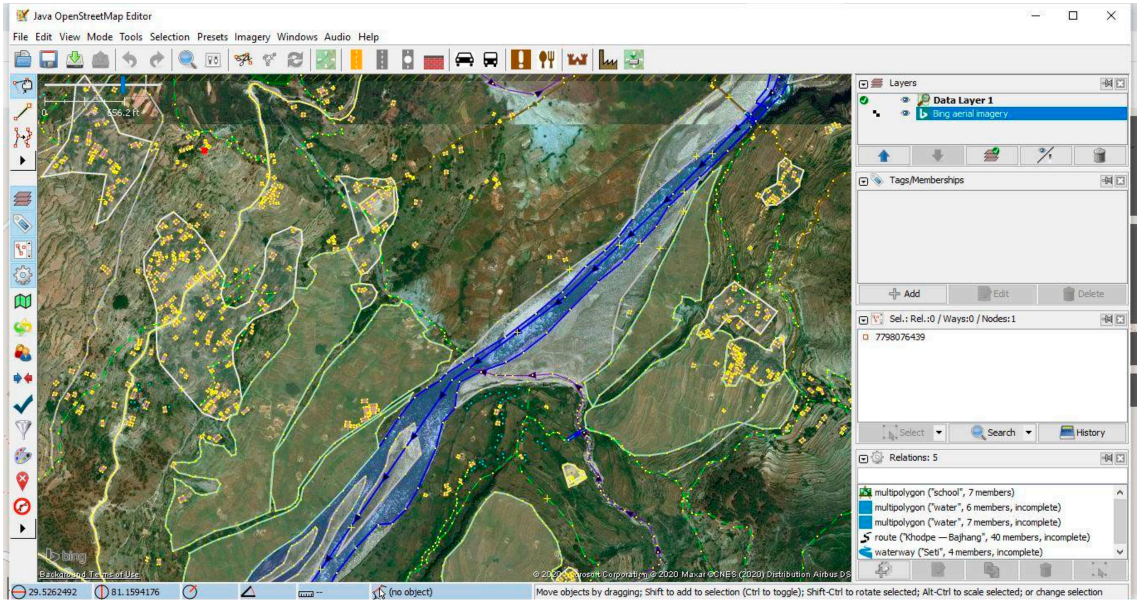


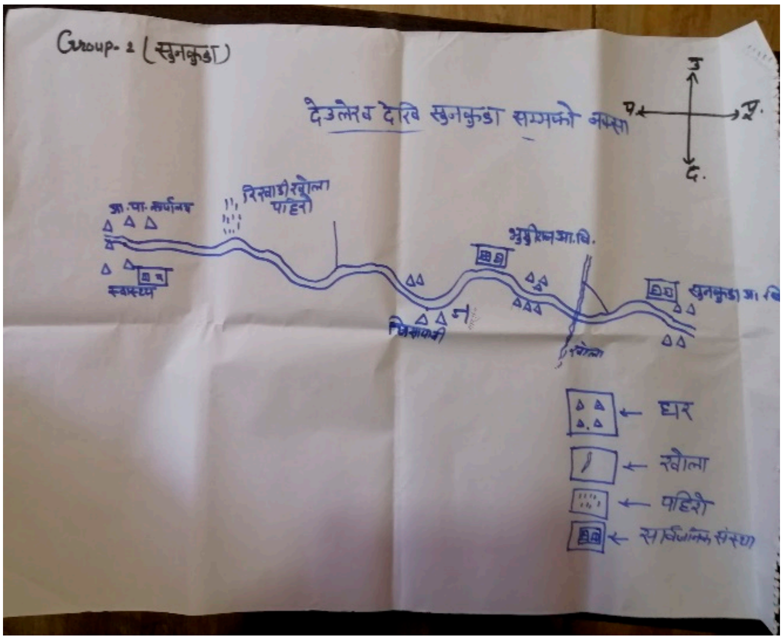
Figure 3. Portion of the study area remotely mapped in JOSM.

3.2. From Paper-Based Maps to Digital Maps

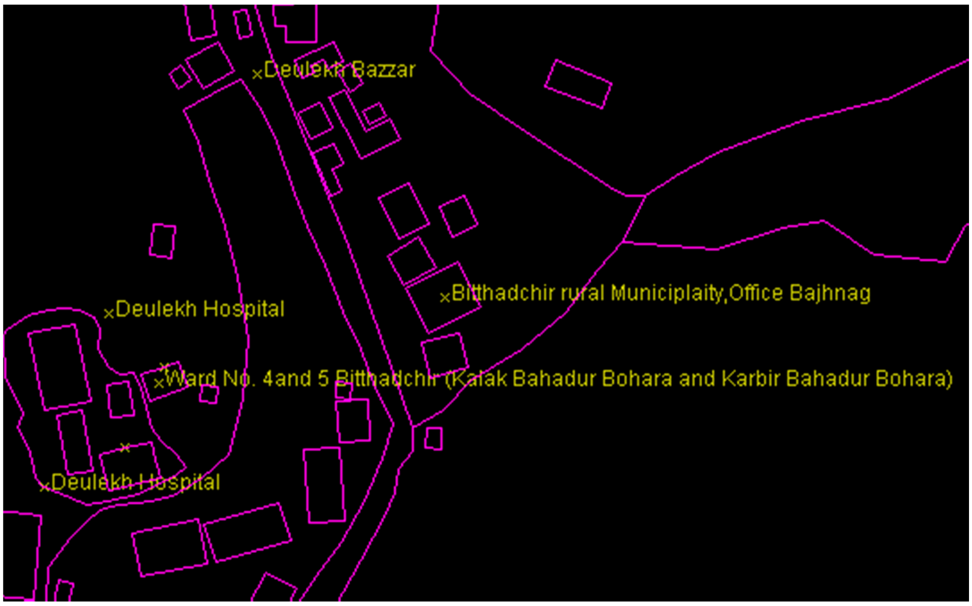
A schematic map was prepared by the citizen scientists using paper and markers, where they marked settlements, roads, agricultural lands, rivers, and key institutions, including local government offices. This exercise showed that the participants had at least a basic idea of their locality. Figure 4a shows the schematic map prepared by the local people. At the end of the three days' training, citizen scientists were divided into four groups, after which they walked approximately 48 km in total and mapped key landmarks, including buildings, roads, paths, water sources, hospitals, educational institutions, government offices, schools, open spaces, and financial institutions. All of these data were retrieved in a computer from OSM Tracker and a GPS. They were then further cleaned and verified in a group, before being finally uploaded to the server. Figure 4b shows the field-collected data uploaded to the OSM server.

After uploading all the collected data and remotely mapped data to the OSM server, the data were retrieved in ArcGIS to produce an easily understandable map showing key features, as shown in Figure 5. This map contains comprehensive information of the localities in an easily understandable format, with the help of text as well as legends.

The final map output produced for the Budhiganga and Bitthadchir rural municipalities using the data collected by the citizen scientists during field work and by the remote mapping volunteers is shown in Figure 6. The map shows key landmarks like buildings, paths, hospitals, temples, hotels, schools, and government offices.



(**a**)



(**b**)

Figure 4. (**a**) Schematic map prepared by local citizen scientists during the first day of mapping training; triangle = households, double line = roads, boxes = public health posts, schools, etc.; (**b**) data retrieval and upload to the OpenStreetMap (OSM) server using the JOSM editor.

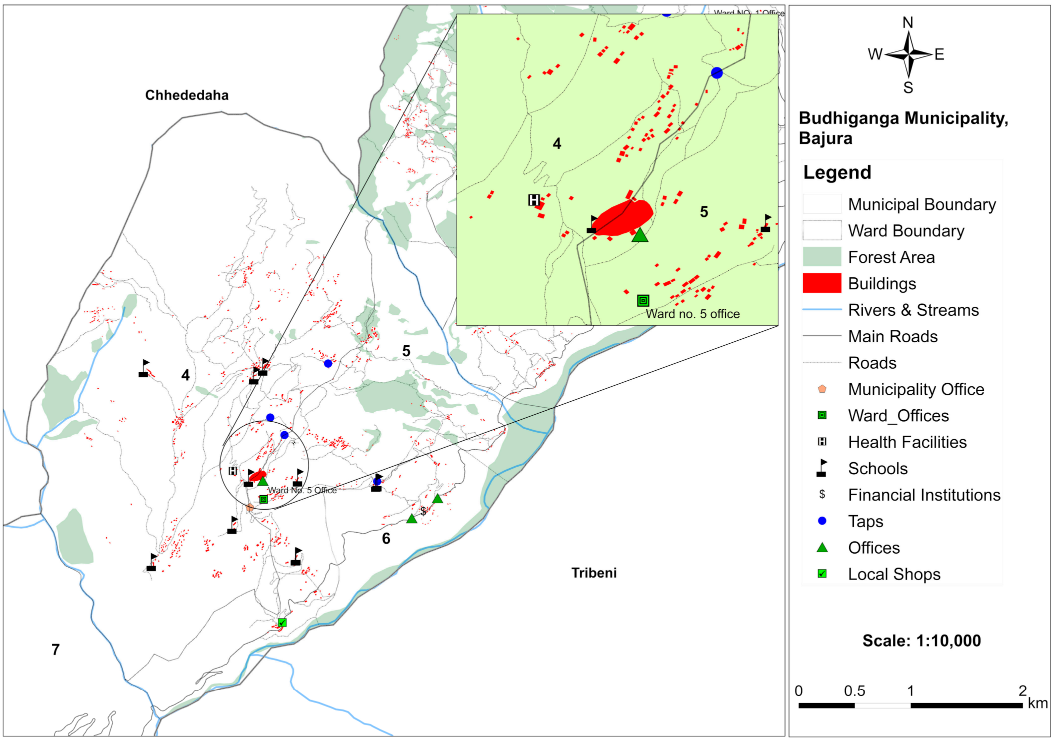
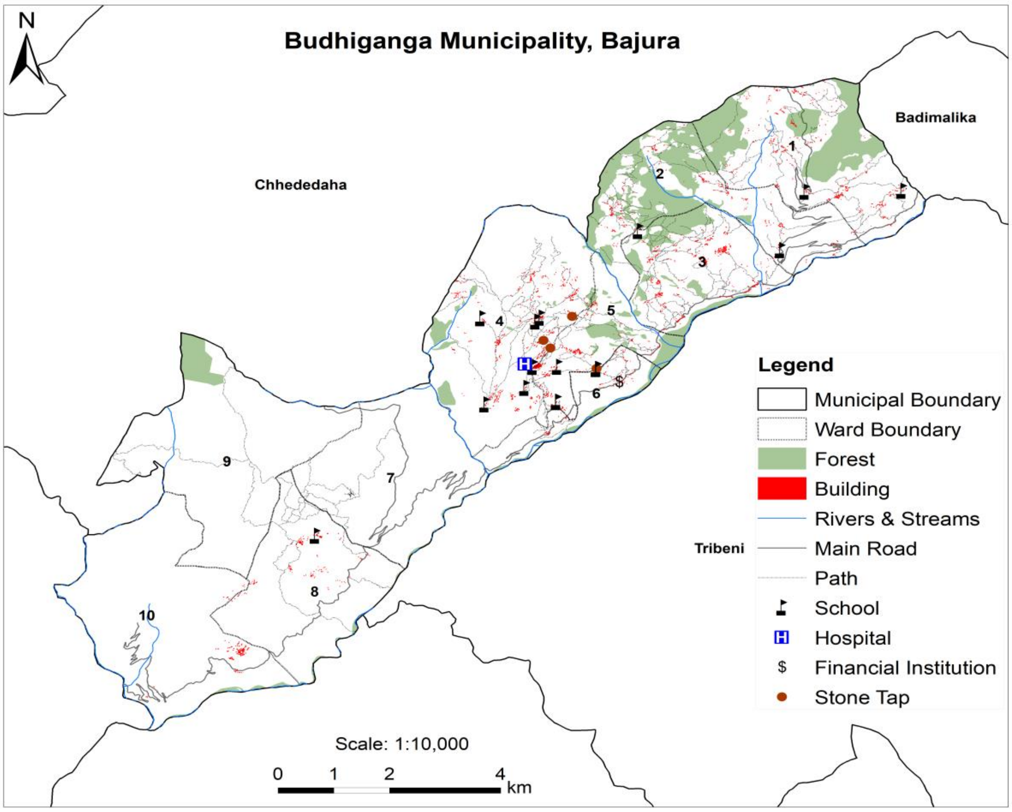
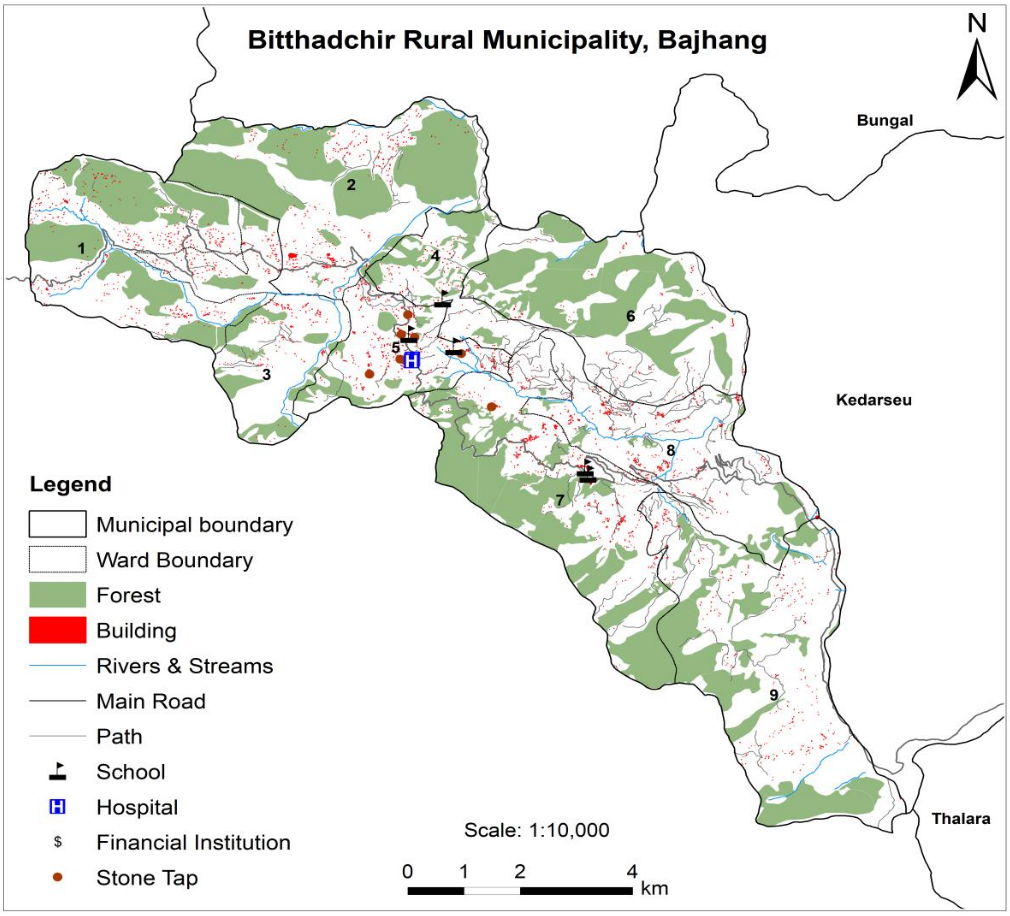


Figure 5. Initial map output produced for a portion of the study area using data collected by the participants during fieldwork. Key landmarks are highlighted.



(**a**)

Figure 6. *Cont.*



(**b**)

Figure 6. (**a**) Final map of Budhiganga municipality; (**b**) final map of Bitthadchir rural municipality. Salient features such as buildings, paths, hospitals, schools, and financial institutions are highlighted.

3.3. Map Literacy and Interest in Digital Mapping

The citizen scientists learned skills to collect both the location and attribute data of community resources, upload the data to open mapping platforms, and also retrieve those data to use for finding their local services and key institutions. This knowledge was also disseminated to a wider group of data users. The citizen scientists in the training were keen to learn about data collection tools and techniques. Since the mapping exercise had instantly visible outputs, the training was more engaging.

As a result of the training, 43 citizen scientists from the two districts worked in collaborative mapping activities and were able to understand and interpret the maps. After the training, 34 participants shared that they felt confident in reading maps and locating their areas on any map. During the first day of training, participants had difficulties in finding their houses and making sense of printed maps. However, after the training, they were able to identify their houses, agricultural land, and key institutions. This shows that the map literacy was demonstrably increased. Ten citizen scientists who were active during the group work and mapping created their own personal OSM accounts and shared a commitment to continue mapping their area in future.

3.4. Technology in Resilience Building

The output maps from this exercise reflected how remote mapping technologies, volunteers' knowledge, and the efforts of citizen scientists and technical mapping experts could successfully co-create crucial geospatial information in a data-sparse region. This joint effort resulted in open availability of base information accessible by different user groups, which could be used to better understand local resources, capacities, and vulnerabilities. The maps provide crucial information concerning key institutions, including government offices, health facilities, financial institutions, and public assets. In the future, these maps could be improved based on an explicit consultation with different stakeholders, revolving around their actual needs, with the help of the citizen scientists. The updated maps could then provide important information that could potentially be used as reference data while updating disaster-related policies and developmental plans. Most importantly, the trained citizen scientists could play an important future role in bringing new innovation to shape local-level planning and program implementation.

As a secondary output of the mapping exercise, a number of printable maps were prepared. These maps can be printed and be used by municipal offices and ward offices for wider dissemination. The mayor of the local municipalities mentioned these technologies as being crucial to building resilience to natural hazards by better understanding the localities; the newly trained citizen scientists are, therefore, useful resources to each municipality.

4. Discussion

We piloted a citizen science approach and remote mapping to co-create a geospatial knowledge openly available for further use in development planning. The results reflect that there is a clear possibility of producing new comprehensive datasets by combining the skills and knowledge of citizen scientists and mapping experts. As suggested by Rossi et al. [35], the discovery of new knowledge is dependent on the dedication and active participation of everyone with certain set purposes and interest in the issue, and is impacted by ongoing discussion. Another important factor is the ownership and collaboration between different institutions and stakeholders, which is vital for knowledge co-production [36]. As the co-creation of knowledge is a series of processes evolving though a similar series of discussions and implementation, the process should be flexible enough to learn from any errors while also producing knowledge in an integrated approach [37]. Enhancing the inclusiveness of such an integrated method could be crucial in minimizing barriers to collaborative learning and adopting new tools and approaches towards resilience building.

Our approach included flexibility to incorporate inputs from people of diverse backgrounds and disciplines, bringing valuable insights and understandings. The interest and enthusiasm shown by the citizen scientists and volunteer mappers resulted in the creation of base maps in places where very few digital mapping activities were hitherto implemented.

> *"Before this training, none of the ward offices in our municipality were mapped. but after going through this training, I was able to map all the ward offices of our municipality along with the respective contact details and upload the data to OSM platform"*—Feedback from the IT Officer at Budhiganga Municipality, Bajura.

Data quality is often a major issue in citizen-scientist-based approaches; we reflected on how these quality measures could be addressed through joint efforts during the designing, data collection, and analysis steps.

The production of new knowledge can only be sustainable if it incorporates the issues of all the disciplines that are cross-cutting with those discussed, including as many people as possible who are directly or indirectly concerned [38]. The design of this study gave us a better understanding of the specific roles of each stakeholder, resulting in integrative and collaborative results [39].

Incorporating and valuing the understanding of different groups of people with different realms of expertise could result in the creation of knowledge that could better support the planning process, as well as forming the basis for guiding knowledge-based decision-making [40]. We believe that these newly developed resources will be a useful resource material for decision-making and informing sustainable local development [41]. Ownership by the citizen scientists, local government, and mapping experts involved in the process will play a role in supporting the communities to improve adaptation strategies to natural hazards through evidence-based decision-making, and will be crucial to building resilience to natural hazards in general [42].

Furthermore, the open-platform geospatial information could be crucial during emergency situations, and could also greatly enhance disaster preparedness, quick responses, and early recovery [43]. The Government of Nepal has developed an integrated disaster information management portal; this method of co-producing knowledge could help collect ground data on hazards, risk, and locally available resources. As the information is openly available, the new contributors may make updates in a changing context [44]. Such a dynamic nature of this approach has a low cost: The volunteers can contribute their knowledge for the well-being of the society. Furthermore, as there is a global community of volunteer mappers, errors are regularly updated through multiple sources, making the process more robust. The least-developed countries have a number of barriers in accessing location-based data and in the availability of open geospatial data; our suggested method increases data access for academics, governments, and local community members to better understand their immediate local environment.

5. Conclusions

We conclude that local capacity building on digital mapping and emerging technologies through a citizen science approach holds rich potential to benefit both scientific researchers and citizen scientists by co-leveraging scientific expertise and local knowledge. This will considerably reduce the time and effort required by mapping experts, and also benefit citizen scientists through knowledge transfer. Most importantly, it helps to bring knowledge from different sources and experts in the volunteered contribution and allows them to corroborate each other. It also enables both researchers and local people to transfer technical knowledge, collect location-specific data, and use them for better decision-making. The data collected jointly by citizen scientists and mapping experts were used to produce a geo-database of the region that can be usefully leveraged in decision-making and information dissemination.

The collected information is available on an open platform and, as such, could play an important role in better understanding the local landscape, environmental risk, and locally available resources. These data could also be used in future geospatial and disaster risk research, as the data layer from OSM can be overlain with other datasets to better understand exposure and proximity to any particular hazard. Data accuracy and credibility remain an important concern around open geospatial data: future research could focus on improving data accuracy and correcting citizen scientist subjectivity to provide more robust information.

Author Contributions: Conceptualization and methodology: B.P.P., P.K., P.B., and W.L.; software: R.B.C. and U.P.; validation: P.K. and P.S.; formal analysis: J.D.P.; investigation: B.P.P., P.K., and U.P.; data curation: U.P. and R.B.C.; writing—original draft preparation: B.P.P. and P.B.; writing—review and editing: S.V., J.D.P., and W.B.; visualization: B.P.P., P.B., and U.P.; supervision: P.S., J.D.P., and W.B.; funding acquisition: W.B. All authors have read and agreed to the published version of the manuscript.

Funding: We acknowledge funding from the UK Natural Environment Research Council (NERC) and Department for International Development (DfID) (grant number: NE/P000452/1) under the UK SHEAR (Science for Humanitarian Emergencies and Resilience) programme.

Acknowledgments: We would like to acknowledge the effort of all the citizen scientists for their volunteered contributions in this study. In addition, we are thankful to the representatives of the Budhiganga and Bitthadchir municipalities of western Nepal for their cooperation and support during our capacity building and data collection work. We would also like to acknowledge the contributions from previous OSM mappers, who already mapped several landmarks in the study region.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ministry of Home Affairs. *Nepal Disaster Report 2017: The Road to Sendai*; Government of Nepal: Kathmandu, Nepal, 2017.
2. UNDRR. *Disaster Risk Reduction in Nepal: Status Report*; United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific: Bangkok, Thailand, 2019.
3. Aksha, S.K.; Emrich, C.T. Benchmarking Community Disaster Resilience in Nepal. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1985. [CrossRef]
4. Nepal Disaster Management Reference Handbook. Available online: https://reliefweb.int/report/nepal/nepal-disaster-management-reference-handbook-august-2017 (accessed on 15 September 2020).
5. Ministry of Home Affairs. *Nepal Disaster Report*; Government of Nepal: Kathmandu, Nepal, 2019; pp. 1–73.
6. Nepal Disaster Risk Reduction Portal. Available online: http://drrportal.gov.np/ (accessed on 10 September 2020).
7. Southasia Institute of Advanced Studies. *Post-Earthquake Disaster Governance in Nepal: Reflections from Practice and Policy*; Nepal South Asia Institute of Advanced Studies: Kathmandu, Nepal, 2016.
8. Chatterjee, R.; Shiwaku, K.; Das Gupta, R.; Nakano, G.; Shaw, R. Bangkok to Sendai and Beyond: Implications for Disaster Risk Reduction in Asia. *IJDRR* **2015**, *6*, 177–188. [CrossRef]
9. Ospina, A.V. *Big Data for Resilience Storybook: Experiences Integrating Big Data into Resilience Programming*; Canada International Institute for Sustainable Development: Winnipeg, MB, Canada, 2018.
10. GFDRR. *Open Data for Resilience Initiative: Policy Notes and Principles*; World Bank: Washington, DC, USA, 2016.
11. Nicoson, C.; Uexkull, N.V. *Overlapping Vulnerabilities: The Impacts of Climate Change on Humanitarian Needs*; Norwegian Red Cross: Oslo, Norway, 2019.
12. United Nations Office for Disaster Risk Reduction (UNDRR). Available online: https://www.undrr.org/terminology/resilience (accessed on 29 October 2020).
13. Data-Pop Alliance. Available online: https://datapopalliance.org/item/dfid-big-data-for-resilience-synthesis-report (accessed on 4 August 2020).
14. Corbett, J. *Good Practices in Participatory Mapping*; International Fund for Agricultural Development: Rome, Italy, 2009.
15. Liu, W.; Dugar, S.; McCallum, I.; Thapa, G.; See, L.; Khadka, P.; Budhathoki, N.; Brown, S.; Mechler, R.; Fritz, S.; et al. Integrated Participatory and Collaborative Risk Mapping for Enhancing Disaster Resilience. *Int. J. GeoInf.* **2018**, *7*, 68. [CrossRef]
16. Goodchild, M.F. Citizens as sensors: The world of volunteered geography. *GeoJournal* **2007**, *69*, 211–221. [CrossRef]
17. Moor, A.D. Common Agenda Setting through Participatory Collaboration Mapping: A Knowledge Base-Driven Approach. In Proceedings of the 16th CIRN Conference Monash Centre, Prato, Italy, 24–26 October 2018.
18. Panek, J.; Netek, R. Collaborative Mapping and Digital Participation: A Tool for Local Empowerment in Developing Countries. *Information* **2019**, *10*, 255. [CrossRef]
19. USGS. Available online: https://www.usgs.gov/core-science-systems/ngp/cegis/vgi (accessed on 22 September 2020).
20. Haklay, M. Citizen Science and Volunteered Geographic Information—Overview and typology of participation. In *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*; Sui, D.Z., Elwood, S., Goodchild, M.F., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 105–122.
21. Dorn, H.; Törnros, T.; Zipf, A. Quality Evaluation of VGI Using Authoritative Data—A Comparison with Land Use Data in Southern Germany. *ISPRS Int. J. GeoInf.* **2015**, *4*, 1657–1671. [CrossRef]
22. Lin, W. Volunteered Geographic Information constructions in a contested terrain: A case of OpenStreetMap in China. *Geoforum* **2018**, *89*, 73–82. [CrossRef]
23. Neis, P.; Zielstra, D. Recent Developments and Future Trends in Volunteered Geographic Information Research: The Case of OpenStreetMap. *Future Internet* **2014**, *6*, 76–106. [CrossRef]
24. Bégin, D.; Devillers, R.; Roche, S. Assessing Volunteered Geographic Information (VGI) Quality Based on Contributors' Mapping Behaviours. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2013**, 149–154. [CrossRef]

25. Haworth, B.T.; Bruce, E.; Whittaker, J.; Read, R. The Good, the Bad, and the Uncertain: Contributions of Volunteered Geographic Information to Community Disaster Resilience. *Front. Earth Sci.* **2018**, *6*, 183. [CrossRef]
26. Kocaman, S.; Anbaroglu, B.; Gokceoglu, C.; Altan, O. A Review on Citizen Science (CITSCI) Applications for Disaster Management. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2018**, 301–306. [CrossRef]
27. Yalcin, I.; Kocaman, S.; Gokceoglu, C. A CitSci Approach for Rapid Earthquake Intensity Mapping: A Case Study from Istanbul (Turkey). *ISPRS Int. J. GeoInf.* **2020**, *9*, 266. [CrossRef]
28. Haworth, B. Emergency Management Perspectives on Volunteered Geographic Information: Opportunities, Challenges and Change. *Comput. Environ. Urban Syst.* **2016**, *57*, 189–198. [CrossRef]
29. Aksha, S.K.; Resler, L.M.; Juran, L.; Carstensen, L.W. A geospatial analysis of multi-hazard risk in Dharan, Nepal. *Geomat. Nat. Hazards Risk* **2020**, *11*, 88–111. [CrossRef]
30. Sharma, P.; Guha-Khasnobis, B.; Khanal, D.R. *Nepal Human Development Report 2014, Beyond Geography, Unlocking Human Potential*; National Planning Commission, Government of Nepal, United Nations Development Programme: Kathmandu, Nepal, 2014.
31. Ministry of Home Affairs. *Nepal Disaster Report 2015*; Government of Nepal, Disaster Preparedness Network-Nepal (DPNet-Nepal): Kathmandu, Nepal, 2017.
32. Weyer, D.; Bezerra, J.C.; Vos, A.D. Participatory Mapping in a Developing Country Context: Lessons from South Africa. *Land* **2020**, *8*, 134. [CrossRef]
33. Java OpenStreetMap. Available online: https://josm.openstreetmap.de/ (accessed on 9 September 2020).
34. OSM Tracker. Available online: https://play.google.com/store/apps/details?id=net.osmtracker&hl=en (accessed on 9 September 2020).
35. Rossi, F.; Rosli, A.; Yip, N. Academic engagement as knowledge co-production and implications for impact: Evidence from Knowledge Transfer Partnerships. *J. Bus. Res.* **2017**, *80*, 1–9. [CrossRef]
36. Wamsler, C. Stakeholder involvement in strategic adaptation planning: Transdisciplinarity and Co-production at Stake? *Environ. Sci. Policy* **2017**, *75*, 148–157. [CrossRef]
37. Hegger, D.; Lamers, M.; Van Zeijl-Rozema, A.; Dieperink, C. Conceptualising joint knowledge production in regional climate change adaptation projects: Success conditions and levers for action. *Environ. Sci. Policy* **2012**, *18*, 52–65. [CrossRef]
38. Lemos, M.C.; Morehouse, B.J. The co-production of science and policy in integrated climate assessments. *Glob. Environ. Chang.* **2005**, *15*, 57–68. [CrossRef]
39. Groot, A.M.E.; Bosch, P.R.; Buijs, S.; Jacobs, C.M.J.; Moors, E.J. Integration in urban climate adaptation: Lessons from Rotterdam on integration between scientific disciplines and integration between scientific and stakeholder knowledge. *Build. Environ.* **2015**, *83*, 177–188. [CrossRef]
40. Edelenbos, J.; van Buuren, A.; van Schie, N. Co-producing knowledge: Joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environ. Sci. Policy* **2011**, *14*, 675–684. [CrossRef]
41. Moreno, J. The role of communities in coping with natural disasters: Lessons from the 2010 Chile Earthquake and Tsunami. *Proc. Eng.* **2018**, *212*, 1040–1045. [CrossRef]
42. Gorddard, R.; Colloff, M.J.; Wise, R.M.; Ware, D.; Dunlop, M. Environmental Science & Policy Values, rules and knowledge: Adaptation as change in the decision context. *Environ. Sci. Policy* **2016**, *57*, 60–69. [CrossRef]
43. Bhanumurthy, V.; Ram Mohan Rao, K.; Jai Sankar, G.; Nagamani, P.V. Spatial data integration for disaster/emergency management: An Indian experience. *Spat. Inf. Res.* **2017**, *25*, 303–314. [CrossRef]
44. Coetzee, S.; Ivánová, I.; Mitasova, H.; Brovelli, M.A. Open geospatial software and data: A review of the current state and a perspective into the future. *ISPRS Int. J. GeoInf.* **2020**, *9*, 90. [CrossRef]