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# Geospatial Methods and Tools for Natural Risk Management and Communications

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**Abstract:** In the last decade, real-time access to data and the use of high-resolution spatial information have provided scientists and engineers with valuable information to help them understand risk. At the same time, there has been a rapid growth of novel and cutting-edge information and communication technologies for the collection, analysis and dissemination of data, re-inventing the way in which risk management is carried out throughout its cycle (risk identification and reduction, preparedness, disaster relief and recovery). The applications of those geospatial technologies are expected to enable better mitigation of, and adaptation to, the disastrous impact of natural hazards. The description of risks may particularly benefit from the integrated use of new algorithms and monitoring techniques. The ability of new tools to carry out intensive analyses over huge datasets makes it possible to perform future risk assessments, keeping abreast of temporal and spatial changes in hazard, exposure, and vulnerability. The present special issue aims to describe the state-of-the-art of natural risk assessment, management, and communication using new geospatial models and Earth Observation (EO)architecture. More specifically, we have collected a number of contributions dealing with: (1) applications of EO data and machine learning techniques for hazard, vulnerability and risk mapping; (2) natural hazards monitoring and forecasting geospatial systems; (3) modeling of spatiotemporal resource optimization for emergency management in the post-disaster phase; and (4) development of tools and platforms for risk projection assessment and communication of inherent uncertainties.

**Keywords:** risk management; risk communication; earth observation system; big-data analysis; geographic information system; natural hazards; climate change; monitoring and early warning; landslide inventory; decision making

## 1. Introduction

Time and again, natural hazards (e.g., floods, landslides, earthquakes, and so on) heavily impact land and society throughout the world [1,2]. Economic losses from natural disasters grew from US$50 billion per year in the 1980s to just under $200 billion per year in the last decade [3]. Moreover, in light of the projected increase of risk in many regions from the effects of climate change, augmented exposure, and social growth in risk-prone areas [4,5], improved understanding of the fundamental causes of disasters, identification of the main risk drivers, and analysis of their spatiotemporal changes are key to effective disaster risk management [6]. This covers the provision of accurate and useful risk information (risk identification, analysis and reduction) and coping capacities before or during the event related to preparedness (in terms e.g., of early warning system, forecasting), emergency response and disaster relief but, also, recovery and reconstruction during post-event phase.

Thus, disaster risk management should be based on an understanding of risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Moreover, consideration of historical changes in risk consequences (also via collecting and analyzing post-event data, i.e., damage and loss from previous disasters) and underlying mechanisms provide insights into what can be expected, and thereby open up the discussion on how to tackle such situations. From this perspective, risk assessment should not be limited to representing risk features at a single point in the past, but rather what is needed in the risk management process is proper inclusion of projections of all dimensions. Implementation of risk forecasting systems may become fundamental products for the delineation of risk scenarios to support international or national agencies involved in Disaster Risk Reduction (DRR) and, in general, for emergency managers making decisions [7].

However, the risk management cycle, as described by Kreibich et al. [8], can be completed only if the hazard and risk information, provided by sophisticated and cutting-edge models and technologies, is integrated with institutional processes and adequately and effectively communicated to the different end-users such as engineers, decision makers, governmental authorities, community representatives and, last but not least, the general public [9]. The damage and losses caused by historical disasters are often not widely known, and those that could arise from future disasters (including infrequent but high-impact events) may not be known at all. Therefore, communication of risk is usually given low priority. Instead appropriate communication prior to and during events, especially at the right time, is crucial to limiting impacts and ensuring the well-being of at-risk communities by raising awareness and triggering action. Once risk information is produced, all users need to be aware of and knowledgeable about the limitations and uncertainties that can arise from uncertainties in exposure data, as well as about the hazard itself and fragility and vulnerability functions [10]. Failure to consider these factors can lead to flawed decision-making and, inadvertently, to increased risk.

Monitoring events on various levels, which reflect complex interactions among human activities, technical installations and infrastructures as well as societal institutions and capacities, is a prerequisite to gaining additional insights and knowledge about natural risk. Novel ways of making use of (big-)data and new geo-information technologies are interesting points of departure for environmental monitoring. Having a good understanding of the hazard event is always a priority, but methodological developments, embedding insights in operational tools, and finding ways to support decisions about adaptation and risk mitigation are also required. Nowadays there is a recognized need for and developing of Information and Communication Technology (ICT)-based strategies and tools to support decision-makers in preparedness and response to disaster-related emergencies.

As result, the last decades have seen a growing demand in technologies for Earth observation (EO) and environmental monitoring, which provide scientists and engineers with valuable geo-spatial information to study risk assessment and mitigation processes. At the same time, the power of computers and newly developed algorithms have grown sharply (e.g., machine learning, agent-based and system dynamic models, etc.). Such advances have extended the range of possibilities for geo-scientists, whose interest in exploiting their potentials is greatest, updating and re-inventing the way risk management and communication, highly resource- and data-intensive processes, are carried out.

A number of research fields have progressed significantly, ranging from modeling natural hazards and identification of their magnitude, to the monitoring of extreme events, and the identification and analysis of risk, its uncertainties and future projections. Indeed, recent studies have offered a number of innovative strategies based on bigdata, EO infrastructures and (geospatial) modeling to improve knowledge about natural hazard phenomena through new remote sensing algorithms, such as landslide detection and quantification [11,12] and delineation of flood-prone areas over large territories and/or with a growing level of detail [13]. These strategies are aimed at quantitatively assessing risk projections and weighing a portfolio of future scenarios [14], and supporting risk and emergency management into the broader context of related governance (multi-institutional) arrangements [15,16]. These are crucial topics to advance our capacity to cope with natural hazards in a changing environment.

This present special issue provides an overview of experiences that researchers from different parts of the world (i.e., Europe, Asia-China, Japan; Korea, Iran-USA, North Africa) have acquired on geo-information, geospatial methods and technologies for natural hazard monitoring, risk management and communications. The selected collection of papers introduces several of these aspects, presenting novel techniques, architectures and case studies.

In the following section, we summarize the contents of each specific manuscript and its contribution to the topic. Finally, we present concluding remarks.

## 2. Overview of the Special Issue

Geospatial information and related tools and technologies, applied to data interpretation and information dissemination, can provide insights and support for decisions in all aspects of integrated disaster risk and crisis management: estimating and mapping hazard and risk, determining damage scenarios and impacted areas, early-warning planning, resource distribution during recovery, and risk communication. Geospatial information is critical for all phases of the disaster management cycle, from supporting risk identification and reduction, and developing preparedness solutions, to prioritizing response and recovery efforts.

In this context, this special issue of the *ISPRS International Journal of Geo-Information* entitled "Geospatial Methods and Tools for Natural Risk Management and Communications" contains eight research papers that present new strategies and approaches to tackling the above aspects of integrated risk management.

During the pre-event phase, authorities need to have at their disposal appropriate maps describing hazardous areas. It is also important for them to be aware of the different steps within a coherent approach that lead to the identification of hazardous areas, the evaluation of the corresponding hazards, and, finally, the estimation of the risks these assessments imply.

With the objective of mapping landslide susceptibility, Capitani et al. [17] apply and evaluate the performance of the Main Scarp Upper Edge (MSUE) method, proposed by Clerici et al. [18], in two case studies in Italy to predict translational slide-type landslides with high spatial resolution. The authors of the contribution employed MSUE, a statistical method that uses a conditional analysis, in order to test all possible combinations of six geomorphologic and geological landslide predisposing factors (i.e., lithology, slope angle, slope aspect, distance to hydrographic elements, distance to tectonic lineaments) to estimate the values of these factors, presumed to be good candidates as susceptibility indicators for landslide susceptibility model calibration and validation. They performed the surveys in two different basins by means of two landslide inventories related to a period before and after a fixed date, taken respectively as calibration and validation dataset. The performance of model validation was evaluated comparing the landslide susceptibility classifiers using the Receiver Operating Characteristics (ROC) curves and the Area Under the ROC Curve [19]; the value of AUC range from 0.5 (completely random classifier) to 1.0 (perfectly discriminating classifier). Moreover, the reduced chi-square method was used to determine the maximum likelihood of predisposing indicators with an acceptable statistical significance ($p \leq 0.05$). In conclusion, the results of the proposed validation show that translational slide-type landslides can be predicted with good accuracies utilizing the MSUE model in the proposed case study. However, MSUE applicability to other landslide typologies and/or in different geomorphological contexts is still unverified and should be studied in future work.

Large datasets from satellite remote sensing techniques are necessary for large scale, continuous and up-to-date landslide inventories to assess landslide susceptibility, hazard, and risk. In this context, Liu et al. [20] investigated the influence of shadows on the landslide susceptibility model utilizing a timeseries of high-resolution optical images available from the FORMOSAT-2 satellite sensor to develop a landslide inventory in a case study in Taiwan. Based on the assumption that shadows are inevitability found in optical imagery of mountainous areas, the authors state that long-term and large-coverage landslide inventories, using only shadow- and cloud-free optical imagery, are not practical in terms of time and costs.

The research question that guided the work was "how can the shadow inventory, achieved using remote sensing technique improve the accuracy of a landslide susceptibly model?" After the shadow and landslide inventories for a delimited area in Taiwan were simultaneously prepared using a semi-automatic expert system proposed and validated by Liu in [21], the authors evaluated a landslide susceptibility index in order to predict landslides by weighting (using the geometric mean) the various predisposing factors (i.e., slope, aspect, lithology, total flux of water in the stream as described in [22]) according to their contributions. The landslide susceptibility model was then corrected considering the contribution of the shadow-corrected area, revealing an increase of model performance evaluated by of a novel statistical indicator (proposed by the authors in [22]) that combines the percentage of landslide occurrence and its cumulative occurrence. In conclusion, this work is a first attempt to employ the evidence of shadow in the detection of landslide-prone areas and to prepare landslide susceptibility maps that are the basis for land use and emergency response planning for risk prevention, public safety and the realization of safe engineering projects.

The extraction of meaningful information on a large scale from heterogeneous, geo-referenced data is a hot research topic and there is increasing interest on the part of technicians in the field of risk management. At the same time, interpretation of big geo-data calls for highly automated approaches that rely on new machine learning and data mining. Merghadi et al. [23] assessed and compared the prediction capability of five machine learning methods (Random Forest (RF), Gradient Boosting Machine (GBM), Logistic Regression(LR), Artificial Neural Network (NNET), and Support Vector Machine (SVM)) for landslide susceptibility mapping in a case study area in Algeria historically affected by landslides. The landslide inventory was organized in a geo-database, containing the geologic, lithologic, and geomorphologic characteristics of the study area as well as indirect landslide occurrence factors (i.e., altitude, slope, aspects, Topographic Wetness Index (TWI), landforms, rainfall, lithology, stratigraphy, soil type, soil texture, land-use, depth to bedrock, bulk density, distance to faults, distance to hydrographic network, distance to roads network), and, after, this dataset was resampling in calibration and validation dataset. The input data was processed using a GIS Free and Open-Source Software (FOSS) couple with R statistical computing programming language. (The algorithms source code is available on GitHub at https://github.com/aminevsaziz/lsm_in_Mila_basin). Model hyperparameters were tuned and configured using Sequential Model-Based Optimization (SMBO) [24] in order to predict and generate landslide occurrence areas in the form of probability grids and, subsequently, reclassifying them into five susceptibility classes (from very low to very high). Model calibration and validation was performed using Receiver Operating Characteristics (ROC) curves based on the highest value of the Area Under the ROC Curve (AUC) [19]. Even if the ensemble tree models (i.e., GBM and RF) have the highest AUC values for the proposed case study, the similar satisfactory performance of all the machine learning methods used cannot justify, a priori, selection of a specific machine learning approach in other territorial contexts. However, apart from transferability to other contexts in terms of comparing machine learning methods, the main contribution of the work relates to demonstrating the effectiveness of the these methodologies for assessing landslide susceptibility on a large scale.

Landslide hazard maps are essential instruments for disaster prevention and control. For example, they can be integrated in monitoring and forecasting systems. In this regard, the use of modern information technology for comprehensive data handling, along with data visualization, can improve the level of information and end-user understanding, thus providing assistance in disaster prevention, early warning and relief decision-making. In this context, Leng et al. [25] presents the implementation for a case study in China of a three-dimensional geological disaster monitoring and early warning GIS platform based on Representational state transfer (REST) service; this service can abstract data and services as resources and accesses them through a unique Uniform Resource Identifier (URI) [26]. The proposed architecture is composed of three main components: (i) a REST Web service integrated in the 3D GIS platform that builds the platform client; this client communicates with (ii) the working engine composed of three main background services (geo-information, monitoring and warning modules), managed by the REST APIs on the server (Apache Torncat Server and Geo-Server); these services are able to analyze (iii) the information and spatial data stored in a MYSQL DataBase.

The latter data organization management module is able to handle real-time data, vector layers, Digital Elevation Model (DEM), and image layers to query its related attributes by using tags and realizing a 3D rendering based on the 3D Earth Model. The real-time observations, collected by observation equipment (e.g., GPS, rain gauges, inclinometers, and video surveillance), are managed in the working core in order to obtain information on surface deformation, deep deformation, groundwater, and weather monitoring that feed the warning modules based on thresholding methods described in [27]. Finally, the client presentation layer can initiate REST service requests to the service layer for relevant geographic data and can use the underlying graphical engine to render the acquired data on a 3D globe. The primary aim of the proposed operative tool is to support disaster prevention and relief.

Indeed, novel ITC techniques and EO-based methods for prompt assessment of hazards and loss in the early-recovery response stages of a disaster risk reduction (DRR) cycle can be decisive for coping with residual risk, particularly for the organization of rescue and relief efforts. For example, during a flood emergency, the most urgent demands of civil protection operators regard indications on the timing of the flood recession stage, which suggests, for instance, which areas will be accessible first and which roads should be restored in a short time. Scarpino at al. [7] investigated the integration of multi-temporal Synthetic Aperture Radar (SAR) images and DEM data with a 2D hydrodynamic model to forecast and monitor spatiotemporal flood dynamics in terms of flood extent and water depth maps. By processing a time series of SAR images before and during two recent calamitous events in an Italian coastal area, variant-in-time binary maps of flood extent were produced using the method proposed by Giustarini et al. [28], which, combined with information extracted by a high resolution Digital Elevation Model (DEM), were used to produce flood-water-depth maps. These multi-temporal SAR-based hazard maps were used as calibration and validation set in simulating, through a bi-dimensional hydrodynamic model [29], the above mentioned flood events. Once the best fit among flood predictions of hydraulic models was identified by Manning coefficients calibration, the efficacy of SAR data in correcting hydrodynamic inconsistencies was shown with regard to reliable assessment of flood extent and water-depth maps during the validation process. Validation performances were estimated using several statistical performance measurements such as root square mean errors (RSME), the Nash and Sutcliffe efficiency (NSE) coefficients, and the minimized sum of under- or over-predicting errors. Taking advantage of the day, night, and cloud-penetrating capacity and high spatial resolution of SAR, and exploiting the short revisit time of SAR images provided by the Cosmo-SkyMed constellation of four satellites, the study demonstrated that the combination of direct observation of flooding from SAR remote sources and flood inundation models can archive rapid and accurate flood predictions in what are usually complex topographies of flat terrain, such as urbanized areas located at a river delta. In particular, this contribution illustrates the usefulness of multi-temporal SAR observations in ungauged basins, and in light of a continuing decline in the number of operational gauging stations or inaccessible ground measurement.

Hazard and risk assessment prediction can play a critical role in impact modeling before an event strikes and during it, or it can provide initial and rapid loss estimates in an event's immediate aftermath and critical information for emergency and reconstruction. Moreover, risk information to coordinate emergency services, plan evacuation routes, create shelters, and run preparedness drills needs to be available before an event occurs, since after the event there is rarely time to collect the information needed to inform relief operations. Hooshangi et al. [30] proposes a GIS- and MultiAgent-based model to optimize dynamic task allocation, considering inherent uncertainties in urban search and rescue (USAR) operations during the post-event phase of a simulated earthquake event in Iran. Agent-Based (AB) modeling is a bottom-up approach that starts with the 'parts' of a system, i.e., individuals/agents (whose behavior is dictated by algorithmic rules), and then tries to understand the system properties that can emerge from their interactions. AB modeling is particularly useful for spatial problems because individuals/agents are considered as simple entities thatcan interact dynamically in multidimensional space [31]. The proposed multi-agent system consists of five groups (independent agents, injured agent, central agent, search agent, rescue agent and medical team) distributed over a geo-referenced environment, using in each stage the assignment of tasks or collaborations for decision-making weights calculated on the basis of the experts' opinions by an analytic hierarchy process (AHP). The latter process defines a set of criteria and sub-criteria arranged in a hierarchy in order to make pair-wise comparisons and find the weights of the criteria or decision alternatives. The proposed method is compared with a traditional approach, developed by authors during this study, for task allocation combining the contract net protocol (CNP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The CNP is an auction-based coordination technique composed of four steps: task(s) recognition, task(s) announcement, receiving offers, and allocating task(s). The fuzzy genetic TOPSIS method was used to determine the weight of decisions in the modeling. The results showed that the Multi-Agent System (MAS) was more accurate than the CNP model in terms of USAR operational time and the number of human fatalities and, therefore, confirms MAS as a promising approach to support decision-making in natural hazard emergency management.

Anticipating risk consequences and comparing a set of simulated scenarios, keeping abreast of evolving risk, is urgent and critical, allowing risk management specialists to demonstrate how policy actions taken now and in the near future can affect at-risk environments in the mid- to long-term future. Hence, risk assessment needs to account for temporal and spatial changes in hazard, exposure, and vulnerability, particularly in rapidly urbanizing areas or where climate change impacts will be felt the most. Kefi et al. [32] propose a GIS-based method to estimate future flood loss scenarios and compare the effect of a portfolio of mitigation alternatives in a case study in Vietnam, taking into account the potential effects of climate change and land-use changes estimated for 2030. A commercial 2D hydrodynamic model, calibrated on a past event, was used to estimate total direct tangible flood damage at regional scale (i.e., that due to the physical impacts of the hazard itself). Climatic variables, calculated from Global Climate Models (GCMs) [33], were applied to the flood model to predict the change in flood hazards from global warming. For the direct economic damage assessment, the hazard maps were overlaid with land use maps extracted by the land change modeler (LCM), developed by Clark Labs (Clark University, Worcester, MA, USA) [34], based on multi-temporal Landsat remote sensing images and geomorphological characteristics of the study area (e.g., DEM and slope). Moreover, the vulnerability of land-use was assessed by establishing flood-depth damage function [35] estimated by collected data from surveys. Comparison of current and future risk scenarios shows that that climate change, combined with the expansion of built-up areas, increases the vulnerability of urban areas to flooding and economic damage. Moreover, two scenarios based on the implementation of flood control measures were analyzed to demonstrate the effect of adaptation strategies: (i) the protection and restoration of lakes and ponds, and (ii) the setup of water sensitive urban design (WSUD) combined with lake preservation. The results show that the WSUD alternative produce the highest benefits for the selected case study in terms of economic damage reduction (approximately 29% respect to the base case scenario). The achieved results highlight the importance of using cost–benefit analysis to propose mitigation action to support stakeholders in making better informed decisions.

Demonstrated success is one of the best ways to illustrate the benefits associated with risk assessment and show how emerging efforts can contribute to further success. Cross-discipline studies make it possible to obtain lessons from different kinds of hazards or multi-hazards that could be used to advance risk assessments in multiple fields. Lee and Lee [36] applied risk management concepts and practices that are well proven in the industrial sector to reduce natural risk, showing their applications to landslide risk assessment in South Korea. In particular, the authors investigated the advantages and weaknesses in the transferability of industrial risk management methods to natural hazards: Hazard and Operability (HAZOP) is a semi-quantitative method helpful for identifying cause-and-effect scenarios following changes in the guidewords for each physical parameter [37]; Safety Integrated Level (SIL) provides probability measurements of performance required for a safety-related system to achieve targeted risk reduction [38]; Quantitative Risk Analysis (QRA) is a systematic quantitative approach used to estimate and evaluate the risk to which a study area is exposed [39]. The analysis presented in this study may help improve risk management of natural hazards by establishing a more systematic context and facilitating risk communication.

## 3. Concluding Remarks

The contributions of the special issue "Geospatial Methods and Tools for Natural Risk Management and Communications" offer novel insights into diverse geo-information aspects dealing with all features of natural risk management such as preparation, protection and prevention, and comprising the flood forecasting and warning system phases of emergency management. The aim of the present special issue is to shed light on the potential gains in knowledge on different aspects of geo-information and possibilities of applying these insights to enhance current approaches to risk management and communication. The power of computers is constantly increasing and new EO data at higher resolution are now available. A number of the papers in this special issue exploit these new data through novel and cutting-edge geospatial models and technologies to provide new insights into risk management and communication-process understanding. However, further progress in risk understanding, analysis, forecasting, and warning is still needed to disentangle the complex interactions between hazards, exposure, and vulnerability and to increase resilience. This special issue is a valuable contribution toward that effort and provides a direction for future research. In this regard, the proposed contributions demonstrate the complexities that arise from the multi-faceted aspects involved in understanding and managing disaster risk in all its dimensions for different types of natural hazards in heterogeneous territorial and socioeconomic contexts. Furthermore, they show that communication strategies are a key element to strengthening resilience and cope better with future extreme events. By providing novel insights and novel techniques to tackle these complexities, this special issue contributes to advancements in the field of geospatial research for natural risk management and communication.

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## References

1. IPCC. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; IPCC: New York, NY, USA, 2012.
2. UNISDR. *Sendai Framework for Disaster Risk Reduction 2015–2013*; UNISDR: Geneva, Switzerland, 2015.
3. World Bank. Understanding Risk in An Evolving World—Emerging Best Practices in Natural Disaster Risk Assessment. Available online: https://openknowledge.worldbank.org/handle/10986/20682 (accessed on 25 November 2017).
4. Mechler, R.; Bouwer, L.M. Understanding trends and projections of disaster losses and climate change: Is vulnerability the missing link? *Clim. Chang.* **2014**, *133*, 23–35. [CrossRef]
5. IPPC; Stocker, T.F.; Qin, D.; Plattner, G.-K.; Tignor, M.; Allen, S.K.; Boschung, J.; Nauels, A.; Xia, Y.; Bex, V.; et al. (Eds.) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
6. *IRDR—Integrated Research on Disaster Risk: Forensic investigation of Disasters: The FORIN Project*; Integrated Research on Disaster Risk: Beijing, China, 2011.
7. Scarpino, S.; Albano, R.; Cantisani, A.; Mancusi, L.; Sole, A.; Milillo, G. Multitemporal SAR Data and 2D Hydrodynamic Model Flood Scenario Dynamics Assessment. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 105. [CrossRef]
8. Kreibich, H.; van den Bergh, J.C.J.M.; Bouwer, L.M.; Bubeck, P.; Ciavola, P.; Green, C.; Hallegatte, S.; Logar, I.; Meyer, V.; Schwarze, R.; et al. Costing natural hazard. *Nat. Clim. Chang.* **2014**, *4*, 303–306. [CrossRef]

9. Albano, R.; Sole, A.; Adamowski, J. READY: A web-based geographical information system for enhanced flood resilience through raising awareness in citizens. *Nat. Hazards Earth Syst. Sci.* **2015**, *15*, 1645–1658. [CrossRef]
10. Albano, R.; Sole, A.; Adamowski, J.; Perrone, A.; Inam, A. Using FloodRisk GIS freeware for uncertainty analysis of direct economic flood damages in Italy. *Int. J. Appl. Earth Obs. Geoinf.* **2018**, *73*, 220–229. [CrossRef]
11. Pawluszek, K.; Borkwoski, A.; Tarolli, P. Sensitivity analysis of automatic landslide mapping: Numerical experiments towards the best solution. *Landslides* **2018**, *15*, 1851–1865. [CrossRef]
12. Kavzoglu, T.; Shain, E.K.; Colkesen, I. Landslide susceptibility mapping using GIS-based multi-criteria decision analysis, support vector machines, and logistic regression. *Landslides* **2014**, *3*, 425–439. [CrossRef]
13. Samela, C.; Albano, R.; Sole, A.; Manfreda, S. An open source GIS software tool for cost effective delineation of flood prone areas, Computers. *Environ. Urban Syst.* **2018**, *70*, 43–52. [CrossRef]
14. Muis, S.; Guneralp, B.; Jongman, B.; Aerts, J.C.J.H.; Ward, P.J. Flood risk and adaptation under climate change and urban expansion: A probabilistic analysis using global data. *Sci. Total Environ.* **2015**, *538*, 445–457. [CrossRef]
15. Inam, A.; Adamowski, J.; Prasher, O.; Halbe, J.; Malard, J.; Albano, R. Coupling of a Distributed Stakeholder-Built System Dynamics Socio-Economic Model with SAHYSMOD for Sustainable Soil Salinity Management. Part 1: Model Development. *J. Hydrol.* **2017**, *551*, 596–618. [CrossRef]
16. Inam, A.; Adamowski, J.; Prasher, O.; Halbe, J.; Malard, J.; Albano, R. Coupling of a Distributed Stakeholder-Built System Dynamics Socio-Economic Model with SAHYSMOD for Sustainable Soil Salinity Management. Part 2: Model Coupling and Application. *J. Hydrol.* **2017**, *551*, 278–299. [CrossRef]
17. Capitani, M.; Ribolini, A.; Bini, M. Susceptibility to Translational Slide-Type Landslides: Applicability of the Main Scarp Upper Edge as a Dependent Variable Representation by Reduced Chi-Square Analysis. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 336. [CrossRef]
18. Clerici, A.; Perego, S.; Tellini, C.; Vescovi, P. A GIS-based automated procedure for landslide susceptibility mapping by the conditional analysis method: The Baganza valley case study (Italian Northern Apennines). *Envrion. Geol.* **2006**, *50*, 941–961. [CrossRef]
19. Fawcett, T. An introduction to ROC analysis Pattern. *Recogn. Lett.* **2006**, *27*, 861–874. [CrossRef]
20. Liu, C.-C.; Luo, W.; Chung, H.-W.; Yin, H.-Y.; Yan, K.-W. Influences of the Shadow Inventory on a Landslide Susceptibility Model. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 374. [CrossRef]
21. Liu, C. Preparing a landslide and shadow inventory map from high-spatial-resolution imagery facilitated by an expert system. *J. Appl. Remote Sens.* **2015**, *9*. [CrossRef]
22. Liu, C.; Luo, W.; Chen, M.; Lin, Y.; Wen, H. A new region-based preparatory factor for landslide susceptibility models: The total flux. *Landslides* **2016**, *13*, 1049–1056. [CrossRef]
23. Merghadi, A.; Abderrahmane, B.; Tien Bui, D. Landslide Susceptibility Assessment at Mila Basin (Algeria): A Comparative Assessment of Prediction Capability of Advanced Machine Learning Methods. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 268. [CrossRef]
24. Bischl, B.; Richter, J.; Bossek, J.; Horn, D.; Thomas, J.; Lang, M. Mlrmbo: A modular framework for model-based optimization of expensive black-box functions. *arXiv*, **2017**, arXiv:1703.03373.
25. Leng, X.; Liu, D.; Luo, J.; Mei, Z. Research on a 3D Geological Disaster Monitoring Platform Based on REST Service. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 226. [CrossRef]
26. Trilles, S.; Belmonte, O.; Díaz, L.; Huerta, J. Mobile Access to Sensor Networks by Using GIS Standards and RESTful Services. *IEEE Sens. J.* **2014**, *14*, 4143–4153. [CrossRef]
27. Jiang, R.G.; Xie, J.C.; Li, J.-X. Research and application of 3D Early Warning Monitoring Platform for flood prevention. *J. Hydraul. Eng.* **2012**, *134*, 280–287.
28. Giustarini, L.; Hostache, R.; Matgen, P.; Schumann, G.J.P.; Bates, P.D.; Mason, C. A Change Detection Approach to Flood Mapping in Urban Areas Using TerraSAR-X. *IEEE Trans. Geosci. Remote Sens.* **2013**, *51*, 2417–2430. [CrossRef]
29. Sole, A.; Giosa, L.; Albano, R.; Cantisani, A. The laser scan data as a key element in the hydraulic flood modelling in urban areas. In Proceedings of the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences—ISPRS Archive 2013, London, UK, 29–31 May 2013.

30. Hooshangi, N.; Alesheikh, A.A. Developing an Agent-Based Simulation System for Post-Earthquake Operations in Uncertainty Conditions: A Proposed Method for Collaboration among Agents. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 27. [CrossRef]
31. Grimm, V. Ten years of Individual-Based modelling in ecology: What have we learned and what could we learn in the future? *Ecol. Model.* **1999**, *115*, 129–148. [CrossRef]
32. Kefi, M.; Mishra, B.K.; Kumar, P.; Masago, Y.; Fukushi, K. Assessment of Tangible Direct Flood Damage Using a Spatial Analysis Approach under the Effects of Climate Change: Case Study in an Urban Watershed in Hanoi, Vietnam. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 29. [CrossRef]
33. Samadi, S.Z.; Sagareswar, G.; Tajiki, M. Comparison of general circulation models: Methodology for selecting the best GCM in Kermanshah Synoptic Station, Iran. *Int. J. Global Warm.* **2010**, *2*, 347–365. [CrossRef]
34. Clark Labs. Land Change Modeller for ArcGIS (Brochure). Available online: https://clarklabs.org/landchange-modeler-for-arcgis/ (accessed on 25 November 2017).
35. Albano, R.; Mancusi, L.; Sole, A.; Adamowski, J. FloodRisk: A collaborative free and open-source software for flood risk analysis. *Geomatic Natural Hazad Risk* **2017**, *8*, 1812–1832. [CrossRef]
36. Lee, J.; Lee, D.K. Application of Industrial Risk Management Practices to Control Natural Hazards, Facilitating Risk Communication. *ISPRS Int. J. Geo-Inf.* **2018**, *7*, 377. [CrossRef]
37. Dunjo, J.; Fthenakis, V.; Vilchez, J.A.; Arnaldos, J. Hazard and operability (HAZOP) analysis. A literature review. *J. Hazard Mater.* **2010**, *173*, 19–32. [CrossRef]
38. International Electrotechnical Commission. *Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*; IEC 61508; International Electrotechnical Commission: Geneva, Switzerland, 1998.
39. Freeman, R.A. Ccps guidelines for chemical process quantitative risk analysis. *Plant Oper. Prog.* **1990**, *9*, 231–235. [CrossRef]