Pattern Analysis of Natural Disasters in the Philippines

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Abstract. The Philippines is one of the most vulnerable countries to natural disasters due to its geographical location. Natural disasters such as storms, floods, earthquakes, and droughts often occur which bring threat and disturbance to people. Its frequency and severity are probable to increase since there are many studies linking its relationship with climate change. This study analyzed the frequency of natural disasters occurred from the dataset provided by the CRED EM-DAT to identify the patterns from a specified period from 1980–2012. The Results revealed that there is a drastic increase in the frequency of storms that hit the Philippines for more than three (3) decades from 1980 to 2012. Storms, floods, and volcanic eruptions remain the top 3 natural disasters that affect the entire country. There is an increase of 147% from 1980–2012. Thus, the natural disasters are extensively aggravating several industries in the Philippines. The results also indicate that the frequency of natural disasters is more likely increase in the future.

Keywords: Data mining · Natural disasters · Clustering · Developing country

1 Introduction

The increasing number of occurrences of natural disasters has always been one of the main concerns of governments worldwide since its frequency and intensity are expected to rise even further shortly [1]. A natural disaster is defined as the actual happening of a natural event that causes significant disturbance and loss [2] such as alarm to the public [3], harm to people and damages to properties [4] It is caused by geophysical, meteorological, hydrological, climatological, extra-terrestrial and biological phenomena, which adversely impact the affected areas' environment [5]. Examples of natural disasters are storms, earthquakes, droughts, hurricanes, heat waves, thunderstorms and lightning [6].

Emergency Events Database or EM-DAT, which is governed by the Centre for Research on the Epidemiology of Disasters (CRED), provides that for hazard to qualify as a natural disaster it must fulfill at least one of the following criteria: (a) ten (10) or more people reported killed; (b) hundred (100) or more people reported affected; (c) declaration of a state of emergency and a; (d) call for international assistance [6].

J. J. Jung et al. (Eds.): BDTA 2017, LNICST 248, pp. 74–83, 2018.
https://doi.org/10.1007/978-3-319-98752-1_9

Natural disasters are also associated with climate change. According to many studies, climate change has a strong relationship to the occurrences of natural disasters since it increases the frequency and severity of the latter [7–9]. National Aeronautics and Space Administration (NASA) lay down all the probable consequences of the climate change which include, among others the increase in droughts and heat waves; changes in precipitation patterns and; stronger and more intense hurricanes. [10]

For the past few decades, many countries have experienced immense and distressing natural disasters [11]. The United Nations Office for Disaster Risk Reduction (UNISDR) in its report entitled, "The Human Cost of Weather-Related Disasters", provided that ninety percent (90%) of the disasters have been caused by floods, storms, heat waves and other weather-related events which claimed 606,000 lives, with additional 4.1 billion people injured, left homeless or in need of emergency assistance [12]. Some of the recorded major natural disasters in the planet are (1) Hurricane Katrina in 2005 which quickly moved to the city of New Orleans and resulted in massive flooding, loss of life and property. [13]; (2) Indian Ocean tsunami in 2004 which have received worldwide media coverage [14]; (3) the heavy monsoon that hit Pakistan in 2010 which also caused floods that affected the country, bringing immense damage to homes, schools, fields, and infrastructure. [7]; (4) the gigantic earthquake in Tohoku region, Northeast Japan with magnitude 9.0, followed by a giant tsunami. The tsunami was also historical as its run-up height reached over 39 m. As of early May 2011, over 24 thousand people were reported as dead or missing [15]; and (5) the 2010 earthquakes wrought in Haiti and Chile. The January 2010 earthquake that struck Haiti's densely populated capital, Port-au-Prince, caused significant loss of human life (between 200,000 and 250,000 fatalities), the displacement of hundreds of thousands more, and severe damage to the country's economic infrastructure [16].

In the Philippines, natural disasters such as floods, tropical storms, and droughts also occur frequently [17] due to its geographical setting and physical environment [18, 19]. For the last decade, tropical storms and cyclones often accompanied by storm surges, high winds, flooding, and landslides have caused tremendous disasters [20]. One of the most disastrous natural events ever recorded in the history of the Philippines is the typhoon Haiyan (Yolanda) in 2013 with maximum sustained winds reaching 315 kph with gusts up to 379 kph just before landfall [21]. Over a 16-hour period, the Category 5 super typhoon straightforwardly swept through six provinces in the central Philippines [22]. It was an enormous and extremely intense tropical cyclone that struck the Philippines causing catastrophic damage. According to statistics as of December 12, there were 5,982 fatalities, with an additional 1,799 missing and 27,022 injured [23]. In addition to the loss of life, Typhoon Haiyan also caused extreme economic losses; the damage to infrastructure; communication lines and; agriculture damages were estimated at US$802 million [22, 23].

As historical records show, the damages brought by natural disasters are threats to society claiming and affecting lives and environment. Many studies focus on social and natural sciences, even on economic perspectives with a fairly number of researches [14, 24–27]. There are also studies which map the real-time crisis of natural disasters using social media and public behavior during the occurrence of natural disasters [28, 29]. This research, in counterpart, analyses the patterns of natural disasters occurred in the Philippines using data mining techniques to determine the changes in the frequency

that happened over a specified period in the Philippines. It is organized as follows: Part II explains the overview of the Philippine geographical location and its natural disaster profile. It also explains the relationship between climate change and natural disasters; types of natural disasters and other studies that focus on pattern analysis using natural disaster events dataset. Part III presents the techniques used to form the pattern of natural disasters. These include among others, the basic statics, classifying and clustering. Part IV finally explains the conclusion as a result of the pattern analysis.

2 Literature Review

2.1 Overview of Philippine Geographical Location and Its Natural Disaster Profile

The Republic of the Philippines is a sovereign state in archipelagic Southeast Asia, with 7,107 islands spanning more than 300,000 square kilometers of territory. It is divided into three island groups: Luzon, Visayas, and Mindanao [30]. The archipelago has a total land area of 299,000 km 2 which makes it the 64th largest country in the world. It is part of western-Pacific "Ring of Fire" with a total 37 mountains, of which 18 are active. It also has a remarkably long coastline as regards its overall land size of which 67 out of 81 of its provinces have seashore [31].

Due to its exceptionally complex geographical location, the Philippines is vulnerable to natural disasters. Powerful typhoons develop many times per year accompanied by strong winds. The tectonic activity underlying the islands may trigger tsunamis and other deadly threat from the sea [31]. According to Guha-Sapir et al. (2012), the Philippines is one of the top 5 countries most frequently hit by natural disasters together with the United States, India, Indonesia and China [32]. This study is also supported by other researches which state that the Philippines is among the hardest hit by natural disasters, particularly typhoons, floods and droughts in Southeast Asia. [33, 34].

2.2 Climate Change and Natural Disasters

The Intergovernmental Panel on Climate Change (IPCC) which is the leading international body for the assessment of climate change defines climate change as a change in the state of the climate over time, whether due to natural variability or as a result of human activity. Another definition from the United Nations Framework Convention on Climate Change (UNFCCC) states that it refers to a change of climate which is directly or indirectly attributed to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods [35].

Climate change is considered as one of the many threats the world faces nowadays [36–38]. It is probable to lead to a continued increase in frequency and intensity of certain types of natural hazards in several regions of the world [39] despite efforts made to reduce greenhouse gases [30]. The influence of climate change to occurrences of natural disasters is deemed extremely complicated [40]. However, several pieces of evidence are formed to determine the link between these two topics [41]. It is predicted

that such climate change will increase the severity and frequency of climate-related disasters like flash floods, surges, cyclones and severe storms [7–9]. Anderson et al. [41] presented the evidence of the effects of climate change in the European setting, among others are; the more intense precipitation, hurricanes rainfall and increased number of occurrences of significant flooding and drought. On the other hand, Leng et al. [42] studied the climate change impacts on droughts in China. According to the study, droughts in some areas of the country for the next few years suggest that it will become more frequent, prolonged and severe.

In the Philippines, the Department of Interior and Local Government (DILG) analyzed the effects of climate change using the available data from 1951 to 2009. Results showed that an average of 20 tropical cyclones formed and cross the Philippines Area of Responsibility (PAR). There was also an increase in some hot days but the decrease of cold nights and the annual mean temperature increased by 0.57 °C [43]. Another study by Garcia et al. [44] states that climate change alters the geographic distribution of forest ecosystems. The study evaluated the effects of climate change on fourteen (14) threatened forest tree species in the Philippines. Out of the total number, 7 or 50% are threatened to decline in their suitable habitat.

Climate change has always been an important concern that the world needs to address since it has a definite relationship to the occurrences of natural disasters. Cases presented by Europe, China and the Philippines only point to one conclusion that is, the effects of climate change is becoming worse in certain parts of the world.

2.3 Pattern Analysis of Natural Disasters

At present, there are three worldwide and multi-peril loss databases such as the NatCatSERVICE (Munich Re), Sigma (Swiss Re) and EM-DAT (Centre for Research on the Epidemiology of Disasters). They focus on national or regional issues on specific hazards and specific sectors. The EM-DAT, in particular, provides for the criteria to be considered as a natural disaster as mentioned earlier [45].

Analysis of natural disasters patterns become very useful since it gives researchers better understanding of the big picture of what is happening. Several studies have analyzed the patterns of natural disasters to validate specific objectives mainly to identify the relationship with climate change [46], its effects on economy [47, 48] mitigation of risks associated with it [49] or merely to determine the annual disaster frequency together with its reported total deaths, affected people, and damages [50]. Most of these studies have determined that based on patterns from historical records, natural disasters can bring negative consequences in the future.

3 Methodology

The methodology used in the study is the Knowledge Discovery (KDD) in discovering the patterns in the dataset [51]. This method allowed the discovery of patterns and evaluated to draw appropriate conclusions. The following describes the dataset and the procedures used in the study: The data from EM-DAT regarding the natural disasters in the Philippines were used in this study. The available data covers the period from 1980

to 2012. This dataset contains, among others, the following: (1) the year the disasters occurred; the location of the disaster; the disaster subgroups and types; latitude and longitude; affected total affected people and; (6) the total damages per U.S. dollars. This study initially cleaned the dataset to eliminate noisy data. Noisy data found in the data set are those records that do not have given values such as dates, places and numbers or amounts. Moreover, sets of values in some columns were also eliminated and not considered to focus on the objective of the research. The attributes that were similar to each other were combined. The attributes selected were carefully assessed to explore on the possible relationships, and present them in an integrated approach. Only relevant data were selected in conjunction with the objective of the research. The cleaned dataset was then classified according to principal categories namely: year, location, disaster subgroup, disaster type and a total number of affected people and total damages per U.S. dollars. The relevant data were selected and transformed into a data set that can be mined. Basic statistics were applied through the use of RapidMiner to gather the number of the most and least observations per category.

4 Results and Discussion

The succeeding figures and tables show the graphical representation produced by RapidMiner and numerical values as provided in items 3.5 to 3.8:

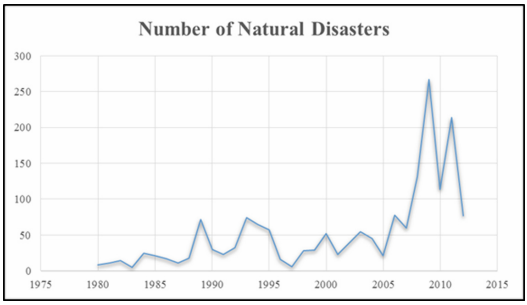

Fig. 1. Annual distribution of natural disasters

As presented in Fig. 1, natural disasters mostly occurred in 2009 followed by 2011. The top five (5) years with most number of natural disasters that occurred in the Philippines were presented in Table 1:

Table 1. Number of natural disasters per year

Year	Number of Natural Disasters
2009	267
2011	214
2008	132
2010	114
2006	78

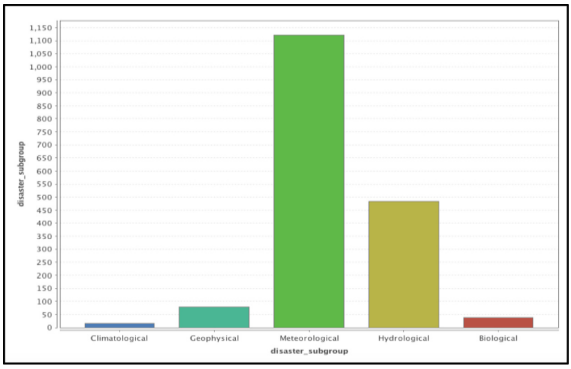

Fig. 2. Disaster subgroup

Figure 2 shows that natural disasters under the Meteorological subgroup represent the highest absolute count of 1,122 or 64.6% of the total recorded occurrences of natural disasters.

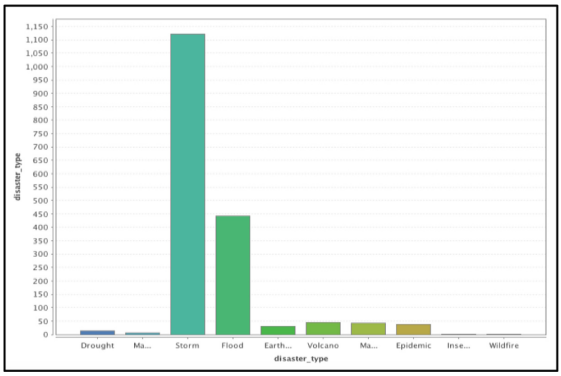

Fig. 3. Disaster types

Figure 3, storms are mostly experienced by the Philippines with an absolute count of 1,122 or 64.56% out of the total given values in the dataset. Further, numerical values of natural disaster types with corresponding percentages were also computed as presented in Table 2:

Table 3 shows that the decade 2001–2012 has a maximum number of days of natural disaster with 119 days. It is due to the bacterial infectious disease happened in Baguio City in 2004. Based on the World Health Organization (WHO), a total of 78 cases of meningococcal disease and 30 deaths were reported from Baguio City and Cordillera Region.

Table 2. Types of natural disasters

Index	Disaster type	Absolute count	Percentage
1	Storm	1,122	64.56%
2	Flood	442	25.43%
3	Volcano	44	2.53%
4	Mass movement wet	42	2.42%
5	Epidemic	37	2.13%
6	Earthquake (seismic activity)	30	1.73%
7	Drought	13	0.75%
8	Mass movement dry	5	0.29%
9	Wildfire	2	0.12%
10	Insect infestation	1	0.06%
Total		**1,738**	**100.00%**

Table 3. Min and max number of days of natural disasters

Decade	Number of days of natural disasters	
	Minimum	Maximum
1980–1990	0	7
1991–2000	0	41
2001–2012	0	119

5 Implications

This study contributes to the current pattern analysis of natural disasters events data. It also supplements and supports current studies in the field of data mining and evidence about the relationship between climate change and natural disasters. Moreover, this study focused on the trends of the natural disasters in the Philippines that may create significant influence in planning disaster risk and reduction management by the national or local government agencies concerned. The patterns produced by Rapid-Miner may be the basis of the national and local agencies and other concerned stakeholders in the formulation of policies and programs to deal with disasters in the Philippines. More importantly, may assist in making safer, adaptive and disaster resilient Filipino communities towards sustainable development.

6 Conclusions and Future Work

Natural disasters are considered one of the problems that the world faces today. Due to its increased frequency and severity, many studies have presented several pieces of evidence to determine the natural disasters' plausible relationship with climate change. As one of the most vulnerable countries in the world, Philippines is frequently hit by

natural disasters. Its geographical location is deemed one of the reasons of its explained vulnerability. Data mining techniques were applied to gather pertinent patterns on the dataset provided by the CRED EM-DAT. The results showed that natural disasters drastically increased from 1980 to 2012 by 147% which indicates that the increase of natural disasters experienced by the Philippines is aggravating. The results also suggest that the frequency of natural disasters is likely to increase in the future.

Despite the contributions of this work, the study also has some limitations. First, the study did not explore on the severity of effects of these natural disasters. Thus, it is also necessary to assess the extent of effects on the economy and financial funding provided by the government. Second, this study also did not include developing a predictive model based on the existing weather data attributes. Hence, this study recommends the development of a predictive model to further investigate the long-term effects of natural disasters regarding damages to property, natural resources, and human safety and prevention activities. Finally, this study could be further improved by applying climate analytics models to understand the underlying weather elements and its interactions fully.

Acknowledgments. The authors deeply appreciate the constructive comments and suggestions by the anonymous reviewers of the conference.

References

1. Hoffmann, R., Muttarak, R.: Learn from the past, prepare for the future: impacts of education and experience on disaster preparedness in the Philippines and Thailand. World Dev. **96**, 32–51 (2017)
2. Smith, K.: Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge, Abingdon (2003)
3. Hallegatte, S., Przyluski, V.: The economics of natural disasters: concepts and methods (2010)
4. Noy, I., duPont IV, W.: The long-term consequences of natural disasters—A summary of the literature (2016)
5. Mata-Lima, H., Alvino-Borba, A., Pinheiro, A., Mata-Lima, A., Almeida, J.A.: Impacts of natural disasters on environmental and socio-economic systems: what makes the difference? Ambiente Sociedade **16**(3), 45–64 (2013)
6. Emergency Events Database (EM-DAT)
7. Bergholt, D., Lujala, P.: Climate-related natural disasters, economic growth, and armed civil conflict. J. Peace Res. **49**(1), 147–162 (2012)
8. Visser, H., Petersen, A.C., Ligtvoet, W.: On the relation between weather-related disaster impacts, vulnerability and climate change. Clim. Change **125**(3–4), 461–477 (2014)
9. Miao, Q., Popp, D.: Necessity as the mother of invention: innovative responses to natural disasters. J. Environ. Econ. Manag. **68**(2), 280–295 (2014)
10. National Aeronautics and Space Administration (NASA). The consequences of climate change (2017)
11. Keller, E. A., DeVecchio, D. E.: Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes. Routledge, Abingdon (2016)
12. United Nations Office for Disaster Risk Reduction (UNISDR). The Human Cost of Weather Related Disasters

13. Gunderson, L.: Ecological and human community resilience in response to natural disasters. Ecol. soc. **15**(2) (2010)
14. Cavallo, E., Galiani, S., Noy, I., Pantano, J.: Catastrophic natural disasters and economic growth. Rev. Econ. Stat. **95**(5), 1549–1561 (2013)
15. Mimura, N., Yasuhara, K., Kawagoe, S., Yokoki, H., Kazama, S.: Damage from the great east japan earthquake and tsunami-a quick report. Mitig. Adapt. Strat. Glob. Change **16**(7), 803–818 (2011)
16. Cavallo, E., Noy, I.: Natural disasters and the economy–a survey. Int. Rev. Environ. Res. Econ. **5**(1), 63–102 (2011)
17. Orencio, P.M., Fujii, M.: A localized disaster-resilience index to assess coastal communities based on an analytic hierarchy process (AHP). Int. J. Disaster Risk Reduct. **3**, 62–75 (2013)
18. Pulhin, J.M., Tapia, M.A., Perez, R.T.: Integrating disaster risk reduction and climate change adaptation: Initiatives and challenges in the Philippines. In: Climate Change Adaptation and Disaster Risk Reduction: An Asian Perspective, pp. 217–235. Emerald Group Publishing Limited (2010)
19. Yumul, G.P., Cruz, N.A., Servando, N.T., Dimalanta, C.B.: Extreme weather events and related disasters in the Philippines, 2004–08: a sign of what climate change will mean? Disasters **35**(2), 362–382 (2011)
20. Franta, B., Roa-Quiaoit, H.A., Lo, D., Narisma, G.: Climate Disasters in the Philippines (2016)
21. Lagmay, A.M.F., et al.: Devastating storm surges of typhoon haiyan. Int. J. Disaster Risk Reduct. **11**(1–12) (2015)
22. Lum, T., Margesson, R.: Typhoon Haiyan (Yolanda): US and international response to Philippines disaster. Curr. Politics Econ. South Southeast. Central Asia **23**(2), 209 (2014)
23. National Disaster Risk Reduction and Management Council (2013)
24. Mori, N., Kato, M., Kim, S., Mase, H., Shibutani, Y., Takemi, T., Yasuda, T.: Local amplification of storm surge by Super Typhoon Haiyan in Leyte Gulf. Geophys. Res. Lett. **41**(14), 5106–5113 (2014)
25. Takahashi, B., Tandoc, E.C., Carmichael, C.: Communicating on Twitter during a disaster: an analysis of tweets during Typhoon Haiyan in the Philippines. Comput. Hum. Behav. **50**, 392–398 (2015)
26. Loayza, N.V., Olaberria, E., Rigolini, J., Christiaensen, L.: Natural disasters and growth: going beyond the averages. World Dev. **40**(7), 1317–1336 (2012)
27. Kousky, C.: Informing climate adaptation: a review of the economic costs of natural disasters. Energy Econ. **46**, 576–592 (2014)
28. Middleton, S.E., Middleton, L., Modafferi, S.: Real-time crisis mapping of natural disasters using social media. IEEE Intell. Syst. **29**(2), 9–17 (2014)
29. Chae, J., Thom, D., Jang, Y., Kim, S., Ertl, T., Ebert, D.S.: Public behavior response analysis in disaster events utilizing visual analytics of microblog data. Comput. Graph. **38**, 51–60 (2014)
30. Official Gazette, The Philippines
31. Boquet, Y.: The Philippine Archipelago (2017)
32. Guha-Sapir, D., Vos, F., Below, R., Ponserre, S.: Annual disaster statistical review 2011: the numbers and trends. Centre for Research on the Epidemiology of Disasters (CRED) (2012)
33. Israel, D.C., Briones, R.M.: Impacts of natural disasters on agriculture, food security, and natural resources and environment in the Philippines (No. 2012-36). PIDS discussion paper series (2012)
34. Benavidez, R., Jackson, B., Maxwell, D., Paringit, E.: Improving predictions of the effects of extreme events, land use, and climate change on the hydrology of watersheds in the Philippines. Proc. Int. Assoc. Hydrol. Sci. **373**, 147–151 (2016)

35. Intergovernmental Panel on Climate Change (IPCC)
36. Leichenko, R.: Climate change and urban resilience. Current opinion in environmental sustainability **3**(3), 164–168 (2011)
37. Solecki, W., Leichenko, R., O'Brien, K.: Climate change adaptation strategies and disaster risk reduction in cities: connections, contentions, and synergies. Curr. Opin. Environ. Sustain. **3**(3), 135–141 (2011)
38. Jones, H.P., Hole, D.G., Zavaleta, E.S.: Harnessing nature to help people adapt to climate change. Nat. Clim. Change **2**(7), 504–509 (2012)
39. Neumayer, E., Barthel, F.: Normalizing economic loss from natural disasters: a global analysis. Glob. Environ. Change **21**(1), 13–24 (2011)
40. Govind, P., Verchick, R.R.: Natural Disaster and Climate Change. International Environmental Law and the Global South: Comparative Perspectives (2015)
41. Anderson, J., Bausch, C.: Climate change and natural disasters: Scientific evidence of a possible relation between recent natural disasters and climate change. Policy Brief for the EP Environment Committee (IP/A/ENVI/FWC/2005-35) Brief Number 02a (2006)
42. Leng, G., Tang, Q., Rayburg, S.: Climate change impacts on meteorological, agricultural and hydrological droughts in China. Global Planet. Change **126**, 23–34 (2015)
43. Department of Interior and Local Government. Climate Change in the Philippines (2011)
44. Garcia, K., Lasco, R., Ines, A., Lyon, B., Pulhin, F.: Predicting geographic distribution and habitat suitability due to climate change of selected threatened forest tree species in the Philippines. Appl. Geogr. **44**, 12–22 (2013)
45. Wirtz, A., Kron, W., Löw, P., Steuer, M.: The need for data: natural disasters and the challenges of database management. Nat. Hazards **70**(1), 135–157 (2014)
46. Zhang, Z., Wang, P., Chen, Y., Zhang, S., Tao, F., Liu, X.: Spatial pattern and decadal change of agro-meteorological disasters in the main wheat production area of China during 1991–2009. J. Geogr. Sci. **24**(3), 387–396 (2014)
47. Alamgir, M., Shahid, S., Hazarika, M.K., Nashrrullah, S., Harun, S.B., Shamsudin, S.: Analysis of meteorological drought pattern during different climatic and cropping seasons in Bangladesh. JAWRA J. Am. Water Res. Assoc. **51**(3), 794–806 (2015)
48. Felbermayr, G., Gröschl, J.: Naturally negative: the growth effects of natural disasters. J. Dev. Econ. **111**, 92–106 (2014)
49. Parwanto, N.B., Oyama, T.: A statistical analysis and comparison of historical earthquake and tsunami disasters in Japan and Indonesia. Int. J. Disaster Risk Reduct. **7**, 122–141 (2014)
50. Li, C.J., Chai, Y.Q., Yang, L.S., Li, H.R.: Spatio-temporal distribution of flood disasters and analysis of influencing factors in Africa. Nat. Hazards **82**(1), 721–731 (2016)
51. Kamber, M., Han, J., Pei, J.: Data mining: Concepts and Techniques. Elsevier, Amsterdam (2012)