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Invited Commentary

Socio-Environmental Vulnerability Mapping for Environmental and Flood Resilience Assessment: The Case of Ageing and Poverty in the City of Wrocław, Poland

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ABSTRACT

The phenomena of urbanization and climate change interact with the growing number of older people living in cities. One of the effects of climate change is an increased riverine flooding hazard, and when floods occur this has a severe impact on human lives and comes with vast economic losses. Flood resilience management procedures should be supported by a combination of complex social and environmental vulnerability assessments. Therefore, new methodologies and tools should be developed for this purpose. One way to achieve such inclusive procedures is by incorporating a social vulnerability evaluation methodology for environmental and flood resilience assessment. These are illustrated for application in the Polish city of Wrocław. Socio-environmental vulnerability mapping, based on spatial analyses using the poverty risk index, data on the ageing population, as well as the distribution of the areas vulnerable to floods, was conducted with use of a location intelligence system combining Geographic Information System (GIS) and Business Intelligence (BI) tools. The new methodology allows for the identification of areas populated by social groups that are particularly vulnerable to the negative effects of flooding. *Integr Environ Assess Manag* 2018;14:592–597. © 2018 SETAC

Keywords: Socio-environmental vulnerability   Resilience   Climate change   Riverine flood   Location intelligence systems

INTRODUCTION

The urban areas in the world are witnessing a number of trends that occur simultaneously, namely the growing number of inhabitants (Hammond et al. 2015); increased urban sprawl and soil sealing (Recanatesi et al. 2017); extreme weather patterns and climate change, which impacts the pluvial patterns in water catchment areas (Apel et al. 2016; Chen et al. 2016); and consequently, a faster runoff generation and higher flow rates (Qin et al. 2013; Zhou et al. 2015; Sperotto et al. 2016). The increased rates of urbanization and the projected climatic transformations will cause more climate changes that are expected to lead to more frequent and extreme urban flooding, and these floods are both of the fluvial and pluvial kind. In addition, societies all over the world observe a growing population of older people in cities (OECD 2015; van Hoof and Kazak 2018). The potential risks that environmental hazards pose to older people in relation to emergency preparedness are large (Gusmano and Rodwin 2010). Due to an increased concentration of property, higher flood hazards lead to potentially higher rates of economic losses (Olsen et al. 2015; Hattarai et al. 2016). If our cities are to be more resilient and better able to cope with the consequences of urban floods, they are expected to adopt sustainable strategies for adaption to new climatic and socioeconomic conditions (Serre et al. 2010). The planning of resilient cities needs to be based on the best available knowledge of flood hazards (Fritsch et al. 2016), on probable economic impacts understood as the total cost of a disaster to the community and the environment (Carrera et al. 2015), and on the risk to human lives and safety. Flood resilience management should ideally be supported by risk assessment tools that allow making decisions in conditions with a certain degree of uncertainty. Such an analytical and decision-making tool should include hazard assessment and risk mapping, and should help understand the impacts of floods on human lives, the infrastructure, the transport system, and the property damage (Fritsch et al. 2016). Nowadays, some of the most widely used tools for environmental protection available to the wider

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environmental community are Environmental Assessments (EA) (Morgan 2012; Noworyta 2018). According to Polish legislation, EA should include, among others, the assessment of risks associated with climate change, the characteristics of planned investments in relation to areas vulnerable to floods, and an assessment of the impact on human health and safety. Or, as one specific regulation states, "as the impact on the environment shall be understood as well as impact on human health" (Dz.U. 2008). Recently, flood risk management plans were adopted in Poland. The assessment of the exposure of the designed investment to flood hazard is an integrated part of the process of programming.

BACKGROUND AND APPROACH DEVELOPMENT

Concepts of both resilience and vulnerability have their origins in social and ecological theories (Miller et al. 2010). Nowadays, there are numerous definitions of the concept of resilience. The most important defines it as the ability of a socio-ecological system to absorb disturbances, to withstand natural and anthropogenic hazards, and to reconfigure after a crucial disturbance (Slootweg and Jones 2011). Vulnerability is defined as the state of sensitivity for hazards connected with social and environmental changes linked to resilience (Adger 2006). Therefore, in the present paper, we used a combined approach of socio-environmental vulnerability.

Numerous researchers and practitioners conducted analysis and studies in the context of a potential risk in order to understand the concepts of resilience and vulnerability. Therefore, one major focus is the development of indices to quantify resilience and vulnerability using environmental indicators (Bakkensen et al. 2017). This study assesses socio-environmental vulnerability using data and indicators of flood vulnerability, poverty, and ageing. According to the theory of urban vulnerability assessment presented by Salas and Yepes (2018), such an assessment can be based on a biophysical approach, a social approach, or a comprehensive approach. In each case, different factors are considered as driving forces, and one of them is the flood. In order to ensure the safety of citizens in the case of floods, the concept of equal egressibility should be of concern (Proulx and Pineau 1996). "Egressibility" means that in case of an emergency, people have the ability to leave a building or to reach an area of safety. Different drivers may influence the egressibility situation in a city. For instance, economic or health conditions may reduce the ability of self-evacuation, which requires support and assistance. As Wilk et al. (2017) concluded, vulnerability is highly correlated with poverty, age, and neighborhood residence. Furthermore, Thiault et al. (2018) highlighted the need of mapping social–ecological dependencies in order to provide communities and decision makers with the information required to identify and prioritize management interventions.

Therefore, the goal of the present study is to develop a socio-environmental vulnerability mapping method, which can be used within the framework of EA. Current practice in Poland implements the impact assessment on human beings in EA; however, it does not recognize the vulnerable groups. The methodology we propose allowed for assessment of resilience of specific social groups with regard to flood hazard. Socio-environmental vulnerability mapping is based on the superimposition of the spatial distribution of the original design of the poverty risk index (see more in Supplemental Data), the ageing society's spatial pattern, as well as the distribution of the areas vulnerable to floods.

MATERIALS AND METHODS

Study area

The case study was carried out in the city of Wrocław in Poland. This city has a surface area of 293 km^2 and 637 683 inhabitants (according to data of the Local Data Bank, stated as of 31 December 2017). The population density in residential areas at risk of floods varied from just 18 to 16 470 inhabitants per square kilometer. The most densely settled districts were located mainly in an old part of the city. A high population density was also observed in neighborhoods developed after World War II, which are located 5 to 6 km to the west of the center. Village districts located in the eastern and southern parts of the city were characterized by a density of 3800 to 6330 inhabitants per square kilometer.

Wrocław is a rapidly developing city with spreading residential zones and suburban areas (Szewrański et al. 2015). In 1997, the city was flooded by water from the River Odra. The city's flood protection system was designed for a discharge of 2400 m^3/s, whereas the mean annual discharge was 145 m^3/s. In July 1997, the peak flow rate was 50% higher, and floodwaters inundated one-third of the city's area (Kundzewicz et al. 1999).

MATERIALS

Data used for calculating the poverty risk index, distribution of the areas vulnerable to floods, and demographic information allowed us to map socio-environmental vulnerability.

The statistics about the reasons for relative poverty (corresponding to causes of social benefits granting) were obtained from the annual reports by the Municipal Social Welfare Center (Municipal Social Welfare Center in Wrocław, 2012). Up to 2012, data were created for 10 Social Assistance Terrain Units (SATU) within the city of Wrocław. Therefore, features that represent the most common causes of social benefits granting were the basis for the calculation of the poverty risk index. The following diagnostic features were chosen: (x1) the number of single households granted permanent benefits, (x2) the number of persons in households granted permanent benefits, (x3) the number of people in households granted temporary benefits due to unemployment, (x4) the number of people in households granted temporary benefits due to disability, and (x5) the number of people in households granted meals for children (Świąder et al. 2017).

The data for the distribution mapping of the areas vulnerable to riverine floods were obtained from "IT System of the Country's protection against extreme hazards" (ISOK

2018). Flood hazard maps covered the areas in which the probability of flood occurrence ranges from once every 500 y (Q 0.2%), to once every 100 y (Q 1%), and to once every 10 y (Q 10%). The extreme event of a complete destruction of a river embankment is also mapped in Informatyczny System Osłony Kraju [Country's Protection Against Extreme Hazards] (ISOK). This most severe scenario is used in the present study. The flood hazard maps include geoinformation about the extent of a flood, the water depth, and the speed and directions of water flow (http://www.isok.gov.pl/pl/). The flood hazard maps were prepared based on hydraulic modeling with the use of a digital elevation model obtained from light detection and ranging (LiDAR) scanning (Wesołowski 2017). Location-oriented demographic data were retrieved from the Wrocław Spatial Information System. The age structure of the population, aggregated by census blocks, was available for years 1998 to 2017. In the present study, the age structure of inhabitants was gained from an external data set (https://geoportal.wroclaw.pl/zasoby/). Studies indicate 2 kinds of socially vulnerable groups: age related and poverty related. According to Ashley and Ashley (2008), people who are older than 60 y have a higher vulnerability to flooding. Similarly, Salvati et al. (2018) noticed that older adults (over 70 y of age) had a higher mortality level than did the other age categories, proportionally, in the case of floods. On the other hand, based on fluvial floods and drought data for 52 countries, Winsemius et al. (2018), concluded that people living in poverty are particularly vulnerable to the negative impacts of natural disasters such as floods. The ageing population group was represented by people aged 65 and over, although the vulnerability of older people does not depend just on age. It depends on someone's physical or mental frailty, for which several indices exist (Gobbens et al. 2010; Phillips and Feng 2018). Someone who is not very mobile, for instance, because he or she is seated in a wheelchair, has greater challenges in terms of egressibility, than does someone who still walks around without mobility aids or assistive devices. If people live in multistory houses, being able to move to higher floors on a temporary basis can also be a way to protect oneself against the effects of floods. Overall, older adults form a very heterogeneous group of people in terms of health status, financial resources, accessibility to help and assistance from professional and informal carers (including nursing aides and relatives), and education level (as a potential measure for preparedness), etc. Therefore, it is difficult to generalize for the group as a whole, but such an assumption had to be established for the present study.

METHODS

An analytical workflow was carried out using a location intelligence system that combined Geographic Information System (GIS) and Business Intelligence (BI) software (Szewrański et al. 2017). The first step in the analysis was the intersection of all input data (distribution of the areas vulnerable to floods, poverty risk index, and demographic data), which was conducted using ArcGIS 10.6. The GIS was used as a data-blending tool. A personal geodatabase was built that was connected to a BI system called "Tableau." Secondly, a multidimensional spatial data exploration was conducted, as well as a clustering analysis according to the relationship of the number of older people (65 y and over) per 100 inhabitants, the value of poverty risk index, and the extent of floods. Demographic data were spatially aggregated into 32 urban districts, which were projected to be flooded in the case of a complete destruction of the river's embankments.

The analysis was conducted using a nonhierarchical clustering method, namely the k-means method (Steinbach et al. 2000). The clustering allows for the distinction of homogeneous groups in the population. The universal algorithm allows for the avoidance of the incorrect supposition of decision makers. All visualizations and the final mapping were made using Tableau (http://www.tableau.com, Seattle, Washington, USA).

RESULTS

An original poverty risk index methodology was proposed to quantify the spatiosocial segregation in the city. The poverty risk index ranges from 0.1505 to 0.6480. The highest poverty rate was observed in the older parts of Wroclaw, located in the south of the city center. A relationship between high population density and higher poverty level was observed in these areas. The analysis was enriched by the information concerning the population of older people. The number of people older than 65 y per 100 inhabitants ranged from 12 to 33 in specific districts. The majority of older people lived in village districts, multiflat housing areas in the west and in the areas with the highest poverty index. Thus, a multidimensional clustering of poverty and society ageing was provided. By using the k-means methodology, 3 cluster groups of social vulnerability to flood event were identified. Two groups, the poorest and the oldest people, were assumed to be the most vulnerable groups (Figure 1, red color). Two other clusters (blue and orange) present the lower poverty risk index (Figure 1).

It was assumed that the presence of fewer older people means a lower rate of social vulnerability. The most vulnerable social groups are located in southeastern part of the city. In these areas, an interaction of the high poverty level, high settlement density, and higher number of older people in the population was observed. The spatial distribution analyses can be enriched by a more detailed flood vulnerability assessment. The flood water level is commonly recognized as an indicator of potential economic and civil losses (Hammond et al. 2015). It was assumed that higher levels of flood inundation implicate greater threats to vulnerable groups in society. As a consequence, more attention and direct actions should be focused toward these people.

DISCUSSION AND CONCLUSIONS

In general the EAs performed in Poland most often use descriptive and/or comparative methods (Kazak et al. 2017). Practice shows that environmental and human exposure analyses should be conducted in order to build an effective risk management system. Rarely, specialists use spatial

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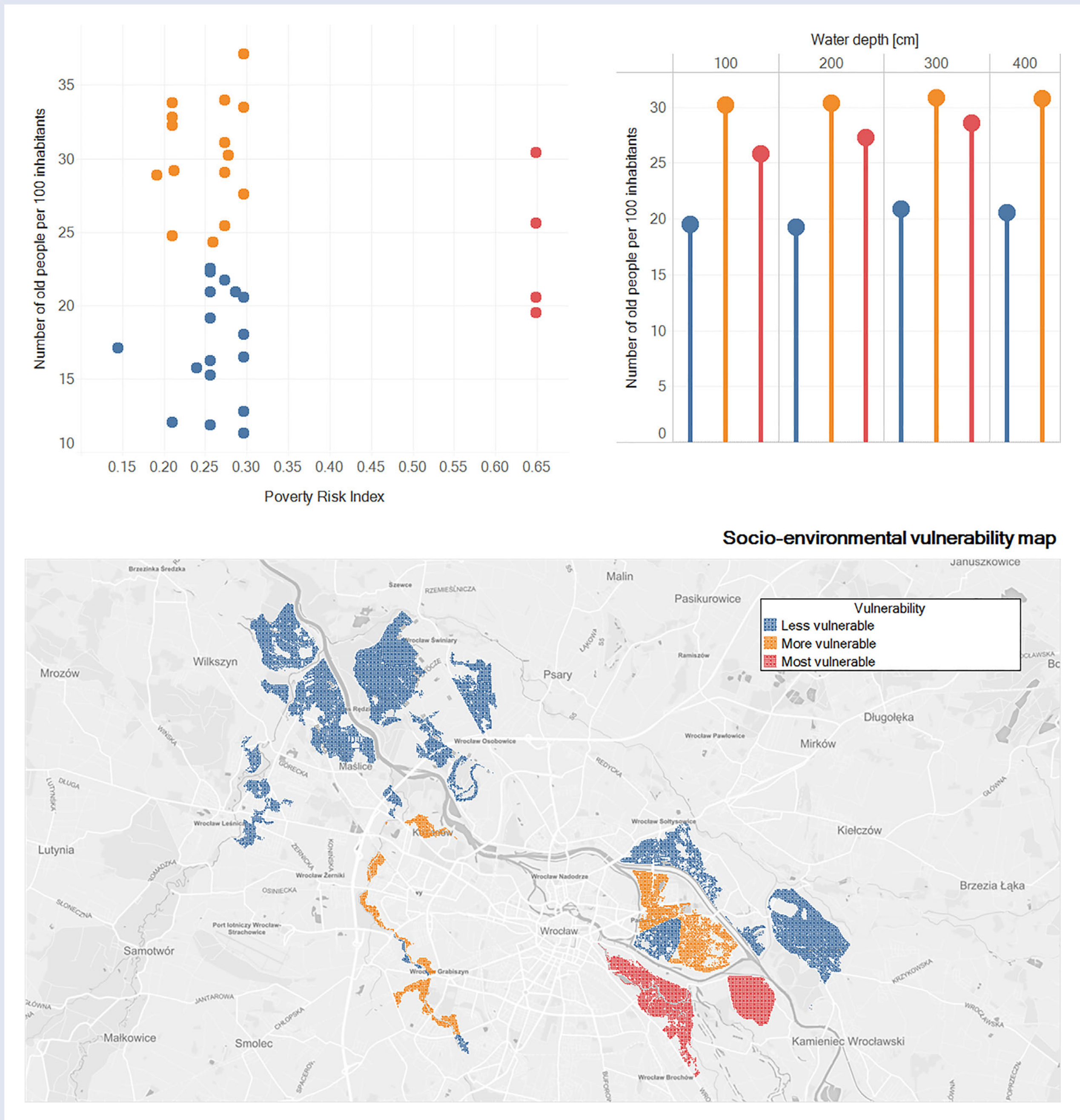

Figure 1. The location intelligence dashboard with a visualization of the socio-environmental vulnerability map.

analysis and GIS as a support for conducting EA procedures (Gajos and Sierka 2012; Pyszny and Przybyła 2016). The need to increase the effectiveness of the impact assessment system is acknowledged by practitioners and researchers around the world (Antunes et al. 2001; Gonzalez et al. 2010).

The proposed methodology allows for the identification of areas inhabited by social groups particularly vulnerable to the negative effects of flooding, in this case, older people who may have great difficulty in fleeing to safe areas in case of high waters. The implementation of socio-environmental vulnerability mapping could provide a more complex assessment of planned flood control investments. As a consequence, such mapping can be an important element of a multicriteria decision-making process. Practitioners are encouraged to use the presented method in the assessment of specific investments such as transport infrastructure. A similar approach should also be developed with respect to other components of the environment (such as air pollution or noise), and it should be implemented into strategies for urban adaptation to climate change (Tokarczyk-Dorociak et al. 2017; Kiełkowska et al. 2018). In addition, the proposed methodology could also be expanded in terms of its applicability to areas that are prone to the occurrence or risk of floods, most noticeably cities built on the banks of large rivers, low-lying countries in deltas such as the Netherlands and Bangladesh, and cities built in river valleys.

The applicability of the methodology depends on the availability of demographic and geographical data that can be used as input for the model.

The methodology presented in the present paper is universal and can be applied in any case in which the specific data needed for the simulations are available. Multidimensional clustering and social-environmental vulnerability mapping with the use of the location intelligence tool could be widely used in flood resilience management and emergency action planning, EA, urban designing, and climate adaptation programming.

Disclaimer—The authors declare no conflicts of interest.

Data Accessibility—The spatial data on demographic patterns in the city of Wrocław is freely available online: https://geoportal.wroclaw.pl/mapy/demografia/. The poverty risk index was originally developed and calculated by authors, and the underlying data are not publicly available. The flood hazard map can be obtained online from a geoportal, which can be accessed via http://mapy.isok.gov.pl/imap/.

SUPPLEMENTAL DATA

Description of the poverty risk index was calculated using a multidimensional comparative analysis (MCA) in accordance with the concept of development pattern (Wawrzyniak 2016).

REFERENCES

Adger WN. 2006. Vulnerability. *Global Environ Chang* 16:268–281.

Antunes P, Santos R, Jordão L. 2001. The application of Geographical Information Systems to determine environmental impact significance. *Environ Impact Assess Rev* 21:511–535.

Apel H, Trepat OM, Hung NN, Chinh DT, Merz B, Dung NV. 2016. Combined fluvial and pluvial urban flood hazard analysis: Concept development and application to Can Tho city, Mekong Delta, Vietnam. *Nat Hazards Earth Syst Sci* 16:941–961.

Ashley ST, Ashley WS. 2008. Flood fatalities in the United States. *J Appl Meteorol Climatol* 47:805–818.

Bakkensen LA, Fox-Lent C, Read LK, Linkov I. 2017. Validating resilience and vulnerability indices in the context of natural disasters. *Risk Anal* 37:982–1004.

Bank Danych Lokalnych [Local Data Bank] Ludność [Population]. [cited 2018 February 14]. https://bdl.stat.gov.pl/BDL/metadane/grupy/3?back=True#

Carrera L, Standardi G, Bosello F, Mysiak J. 2015. Assessing direct and indirect economic impacts of a flood event through the integration of spatial and computable general equilibrium modelling. *Environ Model Softw* 63:109–122.

Chen Y, Samuelson HW, Tong Z. 2016. Integrated design workflow and a new tool for urban rainwater management. *J Environ Manage* 180:45–51.

Dz.U. 2008 nr 199 poz. 1227. Ustawa z dnia 3 października 2008 r. o udostępnianiu informacji o środowisku i jego ochronie, udziale społeczeństwa w ochronie środowiska oraz o ocenach oddziaływania na środowisko [Polish Act on the Provision of Information on the Environment and its Protection, Public Participation in Environmental Protection and Environmental Impact Assessments of 3 October 2008].

Fritsch K, Assmann A, Tyrna B. 2016. Long-term experiences with pluvial flood risk management. In: Lang M, Klijn F, Samuels P, editors. Vol 7. 3rd European Conference on Flood Risk Management; 2016 Oct 17–21; Lyon, France. Les Ulis (FR): EDP Sciences.

Gajos M, Sierka E. 2012. GIS technology in environmental protection: Research directions based on literature review. *POLISH J Environ Stud* 21:241–248.

Gobbens RJJ, van Assen MALM, Luijkx KG, Wijnen-Sponselee MT, Schols JMGA. 2010. The Tilburg frailty indicator: Psychometric properties. *J Am Med Dir Assoc* 11:344–355.

Gonzalez A, Gilmer A, Foley R, Sweeney J, Fry J, González A. 2010. Applying geographic information systems to support strategic environmental assessment: Opportunities and limitations in the context of Irish land-use plans. *Environ Impact Assess Rev* 31(3):368–381.

Gusmano MK, Rodwin VG. 2010. Urban aging, social isolation, and emergency preparedness. *IFA Glob Aging* 6:39–50.

Hammond MJ, Chen AS, Djordjević S, Butler D, Mark O. 2015. Urban flood impact assessment: A state-of-the-art review. *Urban Water J* 12:14–29.

Hattarai R, Yoshimura K, Seto S, Nakamura S, Oki T. 2016. Statistical model for economic damage from pluvial floods in Japan using rainfall data and socioeconomic parameters. *Nat Hazards Earth Syst Sci* 16:1063–1077.

Informatyczny System Osłony Kraju – ISOK [Country's Protection Against Extreme Harazds - ISOK]. Hydroportal Publikujący Mapy Zagrożenia Powodziowego I Mapy Ryzyka Powodziowego w formacie pdf [Hydroportal Publishing flood hazard maps and flood risk maps in pdf format]. [cited 2018 February 12]. http://mapy.isok.gov.pl/imap/

Kazak J, Świąder M, Szewrański S, Żmuda R. 2017. Geo-environmental indicators in Strategic Environmental Assessment. *Acta Sci Pol Form Circumiectus* 16:123–135.

Kiełkowska J, Tokarczyk-Dorociak K, Kazak J, Szewrański S, van Hoof J. 2018. Urban adaptation to climate change plans and policies - The conceptual framework of a methodological approach. *J Ecol Eng* 19:50–62.

Kundzewicz ZW, Szamalek K, Kowalczak P. 1999. The great flood of 1997 in Poland. *Hydrol Sci J* 44:855–870.

Miller F, Osbahr H, Boyd E, Thomalla F, Bharwani S, Ziervogel G, Walker B, Birkmann J, Van der Leeuw S, Rockström J, et al. 2010. Resilience and vulnerability: Complementary or conflicting concepts? *Ecol Soc* 15(3):11.

Morgan RK. 2012. Environmental impact assessment: The state of the art. *Impact Assess Proj Apprais* 30:5–14.

Municipal Social Welfare Center in Wrocław. 2012. Semi-annual and annual report of granted social assistance benefits – monetary, in nature and services for I-XII 2012 [translated from Polish].

Noworyta W. 2018. Kilka krytycznych refleksji na temat raportów oddziaływania na środowisko [A few critical reflections on environmental impact reports]. In: Dobrowoski G, editor. Rozważania o... [The consideration of...]. Katowice (PL): Group INFOMAX. p 251–262.

[OECD] Organisation for Economic Co-operation and Development. 2015. Ageing in cities. Paris (FR). [cited 2018 May 2]. http://www.oecd-ilibrary.org/urban-rural-and-regional-development/ageing-in-cities/brno-czech-republic_9789264231160-12-en

Olsen AS, Zhou Q, Linde JJ, Arnbjerg-Nielsen K. 2015. Comparing methods of calculating expected annual damage in urban pluvial flood risk assessments. *Water* 7:255–270.

Phillips DR, Feng Z. 2018. Global ageing. In: Skinner MW, Andrews GJ, Cutchin M, editors. Geographical gerontology: Perspectives, concepts, approaches. Abingdon (UK): Routledge. p 93–109.

Proulx G, Pineau J. 1996. Review of evacuation strategies for occupants with disabilities. Ottawa (ON): Natl Research Council Canada. Internal Report, Institute for Research in Construction. IRC IR712.

Pyszny K, Przybyła C. 2016. Systemy informacji przestrzennej w strategicznych ocenach oddziaływania na środowisko [Polish]. Spatial information systems in strategic environmental assessment. Poznań (PL): Regionalna Dyrekcja Ochrony Środowiska w Poznaniu.

Qin H, Li Z, Fu G. 2013. The effects of low impact development on urban flooding under different rainfall characteristics. *J Environ Manage* 129:577–585.

Recanatesi F, Petroselli A, Ripa MN, Leone A. 2017. Assessment of stormwater runoff management practices and BMPs under soil sealing: A study case in a peri-urban watershed of the metropolitan area of Rome (Italy). *J Environ Manage* 201:6–18.

Salas J, Yepes V. 2018. Urban vulnerability assessment: Advances from the strategic planning outlook. *J Clean Prod* 179:544–558.

Salvati P, Petrucci O, Rossi M, Bianchi C, Pasqua AA, Guzzetti F. 2018. Gender, age and circumstances analysis of flood and landslide fatalities in Italy. *Sci Total Environ* 610–611:867–879.

Serre D, Barroca B, Diab Y. 2010. Urban flood mitigation: Sustainable options. In: Brebbia CA, Hernandez S, Tiezzi E, editors. Sustainable city VI: Urban regeneration and sustainability. Vol 129. Southhampton (UK): WIT. p 299–309.

Slootweg R, Jones M. 2011. Resilience thinking improves SEA: A discussion paper. *Impact Assess Proj Apprais* 29:263–276.

Sperotto A, Torresan S, Gallina V, Coppola E, Critto A, Marcomini A. 2016. A multi-disciplinary approach to evaluate pluvial floods risk under changing climate: The case study of the municipality of Venice (Italy). *Sci Total Environ* 562:1031–1043.

Steinbach M, Karypis G, Kumar V. 2000. A comparison of document clustering techniques. In: KDD Workshop on Text Mining. Vol. 400, No. 1, p. 525–526.

Świąder M, Szewrański S, Kazak J. 2017. Poverty risk index as a new methodology for social inequality distribution assessment. *IOP Conf Ser Mater Sci Eng* 245:72021. DOI: 10.1088/1757-899X/245/7/072021.

Szewrański S, Kazak J, Sylla M, Świąder M. 2017. Spatial data analysis with the use of ArcGIS and Tableau systems. In: Ivan I, Singleton A, Horák J, Inspektor T, editors. The rise of big spatial data. Lecture notes in geoinformation and cartography. Cham (CH): Springer. p 337–349.

Szewrański S, Kazak J, Szkaradkiewicz M, Sasik J. 2015. Flood risk factors in suburban area in the context of climate change adaptation policies - Case study of Wroclaw, Poland. *J Ecol Eng* 16:13–18.

Thiault L, Marshall P, Gelcich S, Collin A, Chlous F, Claudet J. 2018. Mapping social–ecological vulnerability to inform local decision making. *Conserv Biol* 32:447–456.

Tokarczyk-Dorociak K, Walter E, Kobierska K, Kołodynski R. 2017. Rainwater management in the urban landscape of Wroclaw in terms of adaptation to climate changes. *J Ecol Eng* 18:171–184.

van Hoof J, Kazak JK. 2018. Urban ageing. *Indoor Built Environ* 27(5): 583–586.

Wawrzyniak D. 2016. Standard of living in the European Union. *Comp Econ Res* 19:141–155.

Wesołowski D. 2017. Building on firm foundations. *GEO:connexions* 16: 44–46.

Wilk J, Jonsson AC, Rydhagen B, Rani A, Kumar A. 2017 Aug 25. The perspectives of the urban poor in climate vulnerability assessments - The case of Kota, India. *Urban Clim* 24:633–642.

Winsemius HC, Jongman B, Veldkamp TIE, Hallegatte S, Bangalore M, Ward PJ. 2018 Mar 2. Disaster risk, climate change, and poverty: Assessing the global exposure of poor people to floods and droughts. *Environ Dev Econ* 23(3):328–348.

Zhou ZN, Qu L, Zou T. 2015. Quantitative analysis of urban pluvial flood alleviation by open surface water systems in new towns: Comparing Almere and Tianjin Eco-City. *Sustainability* 7:13378–13398.

