"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.200
DOI: https://doi.org/10.3846/enviro.2017.200

Sensitivity Analysis of the Index of a Rural Municipality's Vulnerability to Losses Resulting from Extreme Weather Events

Katarzyna Kocur-Bera

Department of Geoinformation Analysis and Cadastre, University of Warmia and Mazury in Olsztyn, Poland
E-mail: katarzyna.kocur@uwm.edu.pl

Abstract: Vulnerability index describes, in the form of a numerical indicator, the vulnerability of rural areas to financial losses resulting from extreme weather events. The index can also be used for the management, planning and administration of a space. A sensitivity analysis is a technique used to determine the response of the index under study to a change to either the value or the number of variables. This technique is used within specified boundaries which depend on one or more input variables. The main aim of the study was to conduct a sensitivity analysis of the vulnerability index depending on the number of variables making up this index. Results show that the excess of features under consideration results in the distortion of the level of the index of vulnerability to financial losses resulting from extreme weather events, while the determination of vulnerability on the sole basis of the arising financial losses may lead to erroneous conclusions.

Keywords: shaping the safe space, vulnerability index, sensitivity analysis, rural areas.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

Many countries of the world are aware of the growing problem of climate change and the resulting extreme weather events, and commence cooperation in order to reduce this impact. In 1988, the United Nations set up the Intergovernmental Panel on Climate Change (IPCC) which consists of thousands of scientists from all over the world. The main task of the Panel is to assess the current state of research as well as to increase knowledge of climate change and its consequences (IPCC 2016).

In 1997, in Kyoto, Japan, governments of numerous states made another step and adopted the Kyoto Protocol. The treaty commits State Parties to reduce or limit greenhouse gas emissions. The Kyoto protocol came into force in 2005. To date, the treaty has been formally adopted by 183 states and the European Union. The Kyoto Protocol specifies the levels of greenhouse gas emissions for 37 industrialised countries. Most of these objectives assumed a decrease in greenhouse gas emissions by 5–8% in relation to the level of emissions in 1990. As regards most of the industrialised countries, only the United States refused to ratify the Protocol. The Kyoto Protocol is focused on industrialised countries which are responsible for most of the past and present greenhouse gas emissions. These countries should have the necessary knowledge and funds required to reduce greenhouse gas emissions which, according to estimates, are ten times higher than those in developing countries to which Poland should be included (Clima 2016).

It should be stressed that at the forum of the United Nations Framework Convention on Climate Change (UNFCCC), governments of over 190 countries debate how to reduce greenhouse gas emissions and adapt to climate change, and recognise that these activities need to be carried out in parallel (UNFCCC 1992). The need to develop adaptation programmes, and the tasks of the Convention Parties arise from both Article 4 of the above-mentioned Convention and the "*Nairobi work programme on impacts, vulnerability and adaptation to climate change*" of 2006, adopted at its forum, which provides for, *inter alia*, the necessity for countries to get involved in an assessment of the possible impact of climate change on various areas of life, and devise a strategy aimed at limiting this impact by adapting to this change (UNFCCC 2007).

On 1 April 2009, the European Commission, with a view to the implementation of the Nairobi Programme, published the White Paper: *Adapting to climate change: Towards a European framework for action*, COM(2009)147, which specifies the scope of the European Union's actions for the years 2009–2012 (White Paper 2009). The White Paper is of strategic nature, and directs the preparation to a more effective response to the consequences of climate change at the EU and Member States' level. The EU's adaptation system will respect the principle of subsidiarity and supporting the main EU's objectives of sustainable development. The four pillars of the EU's White Paper include: building a knowledge base on the impact and consequences of climate change; integrating adaptation into EU key policy areas; employing a combination of policy instruments to ensure effective delivery of adaptation; and stepping up international cooperation on adaptation. The European Union is the main leader in the global struggle against climate change. The EU, as one of the major economic powers, has undertaken to continuously reduce greenhouse gas emissions, while being only responsible for 14% of global emissions. The European Union's activities are focused on:

- a requirement for the Member States, concerning an assessment of the existent flood risk and its management;
- the adaptation as regards the cultivation of crops which require less water or tolerate the drought better;
- the construction of buildings in a manner assuming energy saving, protected against storms, floods, and heat waves;
- planning of industrial facilities, taking into account the adaptation to new conditions;
- an order for main services dealing with health and social issues, which should be prepared for heat waves and other unusual weather conditions;
- the introduction of innovative technologies which, by reducing wastewater, will reduce water consumption by approx. 40%;
- the creation of the Natura 2000 network covering areas of protected nature, which aim at supporting the nature in the adaptation to environmental changes (White Paper 2009; Kocur-Bera 2016a).

The government of the Republic of Poland adopted a position on the White Paper in 2010, and decided that it was necessary to develop an adaptation strategy for sectors and areas sensitive to climate change. Hence, a document entitled "*Strategic Adaptation Plan for sectors and areas sensitive to climate change until the year 2020, with a perspective until 2030*", called in short SPA 2020, was drawn up. According to the document, the preparation of a set of directional adaptation measures until the year 2020 for sectors and areas sensitive to climate change should take place in relation to national integrated development strategies in order to improve the resilience of the economy and society to climate change, and reduce the associated losses. The sectors to which attention should be paid due to the sensitivity to climate change include: water management, biological diversity, forestry, energy, transport, agriculture, land management and planning, construction, and health. For these sectors, measures were indicated that needed to be taken in order to tackle climate change. Climate change scenarios for Poland until 2030 indicate an increased risk as regards extreme weather and climatic events (rainstorms, floods, flooding, landslides, heat waves, droughts, hurricanes, etc.). These events will occur with an increasing frequency and intensity, and will affect increasing areas of the country (SPA 2020).

Human activities in respect of climate change are generally focused on two areas: mitigation (the elimination of the causes of global warming, combating it through the reduction in greenhouse gas emissions to the atmosphere, the reduction in burning of fossil fuels, improving energy efficiency, and energy saving) and adaptation (adapting to new climatic conditions in such a manner so as to minimise the risk of their adverse effect on the way of functioning of the society and economy) (Kocur-Bera 2016b; Kocur-Bera, Dudzińska 2015).

Adaptation measures in rural areas should be taken beginning from the local level. At that level, it is necessary to take into account all possibilities for defining the space, which will make it possible to minimise the impact of climate change on everyday life and, at the same time, improve the current living and farming conditions. The measures being introduced should not only prevent or eliminate the changes taking place but also solve the problems and conflicts occurring at a local level (Kocur-Bera 2015; Kocur-Bera 2016b).

The main aim of the activities towards combating climate change in agricultural areas of Poland is to minimise the soil erosion, reduce the degradation of organic substances in the soil, prevent changes to the soil structure, seek to manage water resources rationally, and protect the environment. The article focuses on the calculation of an aggregate synthetic measure (Sokołowski 2014; Dziekański 2015; Zeliaś, Malina 1997) which, using a set of features, enabled the construction of the so-called index of a municipality's vulnerability to financial losses resulting from the occurrence of extreme weather events. Moreover, a sensitivity analysis was also carried out based on the choice of a number of variables making up the constructed index (Krawczyk, Wrzesińska 2009). This helped indicate the optimum number of features describing a space in terms of spatial, environmental, agro-climatic, and economic factors which enabled the calculation of the proposed index of a municipality's vulnerability.

The synthetic vulnerability index (measure) of the municipality is expressed as a mean value of all standardised and reduced attributes describing space (Sokołowski 2014; Zeliaś 2006; Kocur-Bera 2016b). It is expressed by a general formula (1).

$$IP = \left(\frac{\sum_{n}^{i} W_{iu}}{n} \right) * 100, \tag{1}$$

where: w_{iu} – an unitarised value of the variable with the use of formulas (1) and (2); n – number of features.

The unitarisation was performed according to formulas (1) and (2):

For stimulants $\Longrightarrow$

$$x_{ij} = \frac{xij - \min\{xij\}}{\max\{xij\} - \min\{xij\}}. \tag{2}$$

For destimulants ⟹ $$x_{ij} = \frac{\max\{xij\} - xij}{\max\{xij\} - \min\{xij\}}, \quad (3)$$

where: i – number of the entity; j – number of the feature.

Methods

The principal aim of the study is to determine the degree of vulnerability of the investigated taxonomic units to the occurrence of financial losses due to the occurrence of extreme weather events. To this end, the method for linear ordering of objects which is a model-free method based on the aggregate synthetic measure of an object's vulnerability to extraordinary weather events. This measure enabled the determination, based on a single indicator, of an aggregate measure, namely the so-called index of a municipality's vulnerability to financial losses resulting from the occurrence of extreme weather events. The measure was constructed on the basis of the following: (a) 20 features describing a space – *Ranking A*; (b) 10 features describing a space, reduced using the method of information capacity analysis – *Ranking B*; (c) 11 features describing a space, reduced on the basis of an expert's choice – *Ranking C*; (d) 1 feature describing financial losses in the investigated municipalities, resulting from the occurrence of extreme weather events in the years 2010–2014 – *Ranking D*. Then, the positioning was performed of municipalities' vulnerability to financial losses resulting from extreme weather events, they were compared, and the correlation was determined. The performed sensitivity analysis enabled the indication of the optimum number of variables making up the vulnerability index.

For the verification of the method in question, empirical data were used which concerned 59 municipalities of Warmińsko-Mazurskie Voivodeship, in which extraordinary weather events resulting in losses in rural areas occurred in the years 2010–2014. The study took into account effects of such events as torrential rains, hurricanes, spring ground frosts, floods, adverse effects of over-wintering, hailstorms, lightning strikes, and drought. The values of the output set of diagnostic variables were chosen based on merit. Table 1 lists all diagnostic features which were used for the calculation of the vulnerability index.

Table 1. List of variables
Source: own study

Name of the variable	Description of the variable
X_1	The value of finacial losses due to extrema weather events in the municipality (PLN)
X_2	The area injured by extrema events in the municipality (ha)
X_3	The area of municipality (ha)
X_4	The area of water reservoirs in the municipality (ha)
X_5	The area of wetlands ad wastelands (ha)
X_6	The area of land used for agriculture (ha)
X_7	The area of meadows and pastures (ha)
X_8	The area of forests and wooded areas (ha)
X_9	The indicator of quality and agricultural suitability of soils (by Witek *et al.*1981)
X_{10}	The indicator of agroclimate (by Witek *et al.* 1981)
X_{11}	The indicator of relief (by Witek *et al.* 1981)
X_{12}	The indicator of water conditions (by Witek *et al.* 1981)
X_{13}	The general indicator of agricultural production space (by IUNiG)*
X_{14}	The indicator of bonitation of arable land (by Witek *et al.* 1981)
X_{15}	The indicator of bonitation of grassland (by Witek *et al.* 1981)
X_{16}	The indicator of land use of arable land (by Witek *et al.* 1981)
X_{17}	The indicator of land use of grassland (by Witek *et al.* 1981)
X_{18}	The synthetic index of arable land (by Witek *et al.* 1981)
X_{19}	The synthetic index of grassland (by Witek *et al.* 1981)
X_{20}	Location of the municipality in areas with natural handicaps LFS (by Annex D 1999)

*IUNiG – Institute of Soil Science and Plant Cultivation in Puławy, Poland

Results and discussion

Table 2 lists results of the examination of the correlation between all the gathered variables making up the index of municipalities' vulnerability to financial losses resulting from extreme events (see: Table 1). Calculation of the index of a municipality's vulnerability. *Ranking A* takes into account all spatial, environmental, agro-climatic, and economic features listed in Table 1. *Ranking B* was constructed based on the method of information capacity analysis. The method involves calculating the correlation matrix (the Pearson product-moment coefficients), finding the feature which is most strongly correlated with the other ones, and finding all features for which the correlation strength exceeds a certain threshold value. The threshold value was set at a level of 0.70 as a "strong" correlation according to J. Guilford. The feature which are most correlated with the remaining ones is referred to as a central variable (where it has satellite features) or an isolated variable (where no satellite features have been found for it). The satellite features are temporarily excluded, and the procedure is followed again until each of the features has been attached its status. The satellite features are excluded from the set of diagnostic features, while the central and isolated features remain for further analyses. Table 2 lists coefficients of correlation between 20 variables, and Table 3 presents results of the performed exclusion of diagnostic features.

Table 2. The Pearson product-moment coefficients of correlation for 20 variables
Source: own study

variable	Corellation (20 variables)																			
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
X1	1.000	0.955	0.151	-0.123	00040	0.261	-0.014	0.018	0.0101	0.083	0.099	-0.053	0.090	00.079	0.019	-0.008	0.012	0.025	-0.008	-0.005
X2	0.955	1.000	0.134	-0.101	0.060	0.201	-0.012	0.054	0.008	0.055	0.063	-0.155	-0.000	0.029	-0.009	-0.056	-0.056	0.024	-0.050	0.075
X3	0.151	0.134	1.000	0.275	0.296	0.840	0.778	0.765	0.045	-0.119	-0.185	0.086	0.024	-0.024	0.127	-0.059	-0.059	-0.045	-0.103	0.107
X4	-0.123	-0.101	0.275	1.000	0.123	0.055	0.209	0.162	0.061	0.096	-0.174	0.038	0.058	-0.021	0.125	0.034	-0.131	0.013	-0.068	0.068
X5	0.040	0.060	0.296	0.123	1.000	0.262	0.252	0.043	-0.113	-0.037	0.047	-0.043	-0.101	-0.111	-0.045	-0.080	-0.074	-0.096	-0.064	-0.081
X6	0.261	0.201	0.840	0.055	0.262	1.000	0.777	0.489	0.291	-0.163	-0.037	0.273	0.258	0.217	0.045	0.166	0.36	0.188	0.124	0.001
X7	-0.014	-0.012	0.778	0.209	0.252	0.777	1.000	0.602	0.272	-0.208	-0.069	0.351	0.249	0.170	0.154	0.182	0.173	0.186	0.146	-0.076
X8	0.018	0.054	0.765	0.162	0.043	0.489	0.602	1.000	-0.178	-0.133	-0.243	-0.131	-0.190	-0.210	-0.255	-0.229	-0.144	-0.220	-0.233	0.127
X9	0.101	0.008	0.045	0.061	-0.113	0.291	0.272	-0.178	1.000	0.358	0.206	0.911	0.992	0.854	0.759	0.312	0.718	0.850	0.798	-0.580
X10	0.083	0.055	-0.119	0.096	-0.037	-0.163	-0.208	-0.113	0.358	1.000	0.315	0.274	0.441	0.302	0.331	0.284	0.306	0.304	0.315	-0.497
X11	0.099	0.063	-0.185	-0.174	0.047	-0.037	-0.069	-0.243	0.206	0.315	1.000	0.315	0.282	0.303	0.437	0.290	0.493	0.308	0.457	-0.305
X12	-0.053	-0.155	0.086	0.038	-0.043	0.273	0.351	-0.131	0.911	0.274	0.315	1.000	0.921	0.805	0.743	0.842	0.749	0.849	0.803	-0.560
X13	0.090	-0.000	0.024	0.058	-0.101	0.258	0.249	-0.190	0.992	0.441	0.282	0.921	1.000	0.856	0.776	0.821	0.737	0.857	0.813	-0.610
X14	0.079	0.029	-0.024	-0.021	-0.111	0.217	0.170	-0.210	0.854	0.302	0.303	0.805	0.856	1.000	0.840	0.905	0.753	0.964	0.852	-0.450
X15	0.019	-0.009	-0.127	0.125	-0.045	0.045	0.154	-0.255	0.759	0.331	0.437	0.743	0.776	0.840	1.000	0.780	0.752	0.827	0.835	-0.454
X16	-0.008	-0.056	-0.059	0.034	-0.080	0.166	0.182	-0.229	0.312	0.284	0.290	0.842	0.821	0.905	0.780	1.000	0.694	0.985	0.817	-0.430
X17	0.012	-0.056	-0.059	-0.131	-0.074	0.136	0.173	-0.144	0.718	0.306	0.493	0.749	0.737	0.753	0.752	0.694	1.000	0.742	0.876	-0.484
X18	0.025	-0.024	-0.045	0.013	-0.096	0.188	0.186	-0.220	0.850	0.304	0.308	0.849	0.857	0.964	0.827	0.985	0.742	1.000	0.854	-0.452
X19	-0.009	-0.050	-0.103	-0.068	-0.064	0.124	0.146	-0.233	0.798	0.315	0.457	0.803	0.813	0.852	0.835	0.817	0.876	0.854	1.000	-0.512
X20	-0.005	0.075	0.107	0.068	-0.081	0.001	-0.076	0.127	-0.580	-0.497	-0.305	-0.560	-0.610	-0.450	-0.454	-0.430	-0.484	-0.452	-0.512	1.000

The exclusion of 10 variables from the model changed the ranking of municipalities' vulnerability to extreme events in relation to the ranking conducted using all obtained geoinformation (features).

Table 3. Results of the application of information capacity analysis
Source: own study

Item	Variable	Status of the variable	Recommendation
1	*X13*	Central	Remains
2	*X14*	Satellite	Excluded
3	*X15*	Satellite	Excluded
4	*X16*	Satellite	Excluded
5	*X17*	Satellite	Excluded
6	*X18*	Satellite	Excluded
7	*X19*	Satellite	Excluded
8	*X12*	Satellite	Excluded
9	*X9*	Satellite	Excluded
10	*X20*	Isolated	Remains
10	*X7*	Central	Remains
11	*X3*	Satellite	Excluded
12	*X6*	Satellite	Excluded
13	*X11*	Isolated	Remains
14	*X10*	Isolated	Remains
15	*X8*	Central	Remains
16	*X3*	Satellite	Excluded
17	*X1*	Isolated	Remains
18	*X2*	Isolated	Remains
19	*X4*	Isolated	Remains
20	*X5*	Isolated	Remains

In the next step of the study, features were selected by intuitive method, and a synthetic indicator of taxonomic units' vulnerability to extreme events was determined again. *Ranking C* was based on 11 diagnostic variables selected by the expert method, while *Ranking D* was based on the amount of financial losses caused by extreme weather events in the period under study. Table 4 lists all successive conducted rankings.

Table 4. A list of all developed rankings
Source: own study

Name of the Community	*Ranking A*	*Ranking B*	*Ranking C*	*Ranking D*
Biskupiec pomorski	21	7	1	1
Bartoszyce	10	24	2	3
Sępopol	18	20	3	16
Korsze	1	1	4	4
Braniewo	5	4	5	5
Kisielice	24	22	6	24
Bisztynek	3	2	7	2
Wiczęta	2	3	8	22
Lubawa	31	31	9	8
Kolno	20	29	10	38
Reszel	23	25	11	20
Działdowo	38	18	12	26
Płośnica	34	23	13	30
Iłowo osada	43	21	14	28
Milejewo	12	5	15	35
Grodziczno	49	27	16	9
Dobre miasto	26	38	17	45
Rychliki	7	8	18	39
Barciany	4	14	19	17
Markusy	6	10	20	51
Lubomino	9	6	21	29
Zalewo	28	43	22	43
Frombork	16	11	23	59
Pasym	42	30	24	40
Budry	29	33	25	19
Kiwity	8	9	26	33
Wieliczki	40	34	27	54
Godkowo	14	15	28	34
Kalinowo	25	45	29	55
Rybno	58	28	30	31
Ełk	48	47	31	10
Kętrzyn	11	17	32	18
Janowiec kościelny	45	35	33	57
Dźwierzuty	39	39	34	49
Świątki	15	16	35	44
Jonkowo	50	41	36	52
Kurzętnik	52	37	37	14
Lidzbark warmiński	30	55	38	13
Prostki	41	48	39	15
Świętajno (olecko)	51	36	40	41
Biskupiec	36	53	41	39
Srokowo	13	12	42	27
Wydminy	37	46	43	58
Barczewo	47	52	44	6
Olecko	35	49	45	48
Nowe miasto lubawskie	56	40	46	12
Olsztyn	32	13	47	25
Młynary	19	19	48	23
Górowo iławeckie	33	56	49	36
Lidzbark welski	59	44	50	11
Sorkwity	46	50	51	32
Pasłęk	17	26	52	47
Purda	53	54	53	46
Banie mazurskie	44	51	54	50
Węgorzewo	27	58	55	21
Piecki	54	59	56	56
Ostróda	22	42	57	53
Mrągowo	57	32	58	7
Biała piska	55	57	59	42

The performed analyses show that six objects in all conducted rankings are at a similar position, therefore they exhibit similar vulnerability to extreme events regardless of the geoinformation taken into account during the study. These include the following municipalities: Banie Mazurskie, Bisztynek, Braniewo, Korsze, Piecki, and Purda. The greatest differences in rankings (in the levels of the synthetic measure of vulnerability) were noted in three objects: Barczewo, Frombork, and Mrągowo. Figure 1 presents the classification of the presented rankings, and Table 4 lists the correlations between the presented rankings.

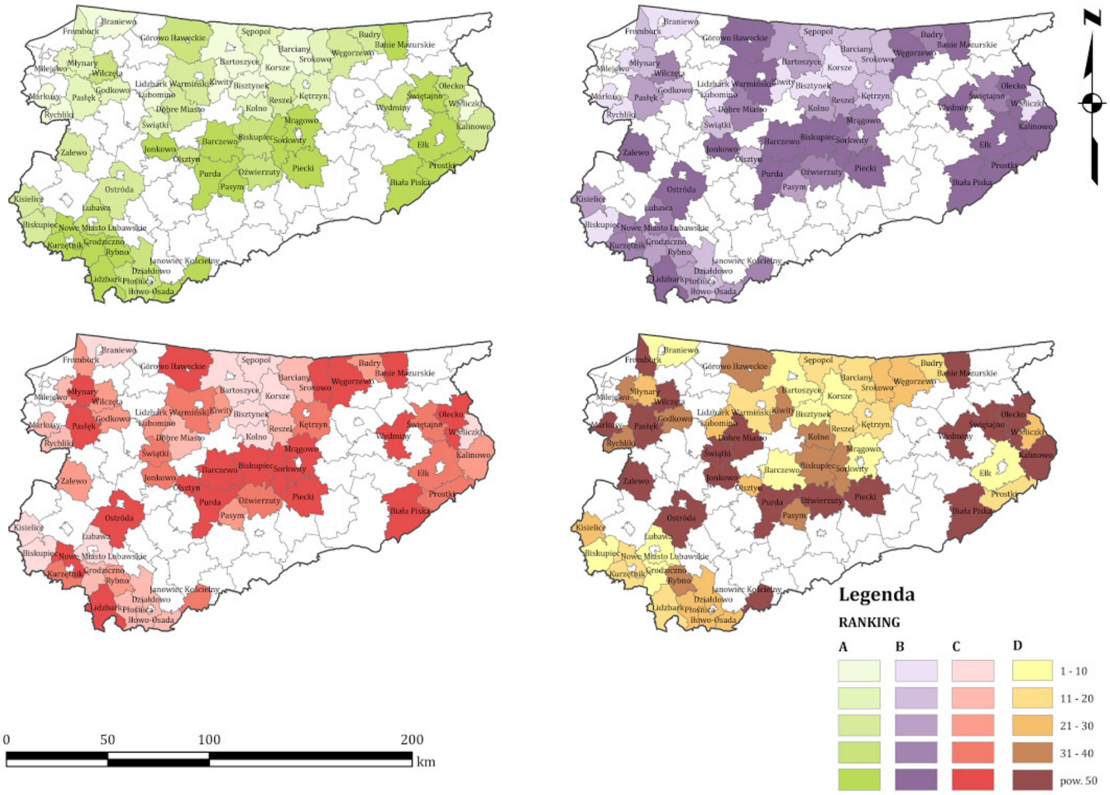

Fig. 1. Graphic representation of the ranking of municipalities vulnerable to extraordinary weather events in an arrangement of every 10th class
Source: own study

Table 5. Correlations for particular rankings
Source: own study

	Correlations			
Variable	*A*	*B*	*C*	*D*
A	1.000000	0.722034	0.551666	0.124197
B	0.722034	1.00000	0.676856	0.278174
C	0.551666	0.676856	1.000000	0.347017
D	0.124197	0.278174	0.347017	1.00000

It is difficult to clearly state which ranking is the best. Therefore, the degree of their consistency was examined, and the Pearson product-moment coefficients were calculated for them (see: Table 5). The following rankings have a statistically significant consistency ($p < 0.05$): A with B, A with C, B with D, C with D, D with B, and D with C. Rankings A with B have the highest consistency, where *Ranking A* is based on the vulnerability index using 20 features, and *Ranking B* is based on the vulnerability index based on 10 features (10 features were excluded using the information capacity analysis). When the absolute values of correlation coefficients are added up, it turns out that *Ranking B* exhibits the highest connectivity with other rankings, and it appears most reliable. *Ranking D* clearly exhibits the lowest correlation coefficient.

Conclusions

The aim of the study was to perform sensitivity analysis of the index of a municipality's vulnerability to extreme events depending on the number of variables. The vulnerability index is an aggregate synthetic measure which, thanks to the inclusion of many spatial, environmental, agro-climatic, and economic factors, describes, in a form of a single index, a municipality's vulnerability to financial losses resulting from the occurrence of extreme weather events. The sensitivity analysis was carried out based on the choice of a number of variables used to form this index. Ranking A was constructed based on all (20) the gathered pieces of information on the space and the environment. The constructed vulnerability index, with the help of 20 variables, enabled the development of a ranking of municipalities, from those most vulnerable to such events to the safest ones. *Ranking B* was based on the vulnerability index constructed on the basis of 10 variables. The exclusion of excess variables was based on the information capacity method. *Ranking C* was constructed using the vulnerability index constructed on the basis of 11 pieces of information. The variables were selected using the expert method. Finally, *Ranking D* was constructed on the basis of financial losses noted in agricultural crops within the area under study in the years 2010–2014. Results of the analysis of correlations between the presented methods for the calculation of the vulnerability index demonstrated that a single variable describing financial losses is not a sufficient measure for the determination of the vulnerability. This is due to the fact that the determinants occurring within the municipality under study may have a soothing effect on the results of the occurrence of extreme events. The inclusion of many (20) characteristics describing a space in the study is not advised either as variables strongly correlated with each other are included in the vulnerability index. It is therefore necessary to introduce reduction methods e.g. information capacity analysis which enables the exclusion of features that are dependent on each other and exhibit a similar range of variation from the investigated set of data. The conducted sensitivity analysis demonstrated that the reduction in the number of variables should be performed using mathematical methods.

References

Annex, D. 1999. *Uzasadnienie dla delimitacji i poziomu wsparcia finansowego dla działania pt. Wsparcie działalności rolniczej na obszarach o niekorzystnych warunkach gospodarowania (ONW)*. Ministry of Agriculture and Rural Development, Warszawa.

Clima. 2016. *Climate action* [online], [cited 25 October 2016]. European Comission. Available from Internet: http://ec.europa.eu/clima

Dziekański, P. 2015. Wykorzystanie wskaźnika syntetycznego do oceny poziomu rozwoju samorządu na przykładzie gmin wiejskich województwa świętokrzyskiego, *Determinanty rozwoju Polski. Finanse publiczne.* IX Kongres Ekonomistów Polskich.

IPCC. 2016. *Intergovernmental panel on climate change* [online], [cited 13 October 2016]. World Meteorological Organization. Available from Internet: https://www.ipcc.ch/news_and_events/docs/factsheets/FS_what_ipcc.pdf

Krawczyk, E.; Wrzesińska, J. 2009. The use of sensitiveness analysis to the effectiveness' risk of building and implementation of the cadastre communications system, *Zeszyty Naukowe SGGW w Warszawie. Ekonomika i Organizacja Gospo-darki Zywnościowej* 74: 111–121.

Kocur-Bera, K. 2015. Identyfikacja subpolpulacji o podobnych charakterystykach w aspekcie ekstremalnych zjawisk pogodowych, *Acta Scientarum Polonorum, Administratio Locorum* 14(3): 745–89.

Kocur-Bera, K. 2016a. Climate change and its importance for agricultural production, *Geomatics, Landmanagement and Landscape* 3: 77–87. https://dx.doi.org/10.15576/GLL/2016.3.77

Kocur-Bera, K. 2016b. *Kształtowanie bezpiecznej przestrzeni obszarów wiejskich w aspekcie wystepowania ekstremalnych Zjawisk pogodowych*. UWM Olsztyn.

Kocur-Bera, K.; Dudzińska, M. 2015. Economic and spatial aspects of occurrence of extreme events in rural areas, in *Proceedings of the 2015 International Conference „Economic Science For Rural Development"*, Jelgava, LLU ESAF, 23–24 April 2015. ESDR 2015: 15–24.

NAS 2020. 2013. *Polish national strategy for adaptation to climate change (NAS 2020).* Ministry of the Environment Republic of Poland, Warsaw, October 2013.

Sokołowski, A. 2014. *Analizy wielowymiarowe*. Training materials, StatSoft Polska.

UNFCCC. 1992. *United nations framework convention on climate change* [online], [cited 20 November 2016]. FCCC/INFORMAL/84 GE.05-62220 (E) 200705. Available from Internet: https://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC. 2007. *The nairobi work programme on impacts, vulnerability and adaptation to climate change* [online], [cited 12 October 2016]. Druck Center Meckenheim. Available from Internet: https://unfccc.int/files/adaptation/sbsta_agenda_item_adaptation/application/pdf/nwp_brochure.pdf

White Paper. 2009. *Adapting to climate change: towards a European framework for action*. COM (2009) 147.

Witek, T.; Górski, T.; Kern, H.; Bartoszewski, Z.; Biesiacki, A.; Budzyńska, K.; Demidowicz, G.; Deputat, T.; Flaczyk, Z.; Gałecki, Z.; Ganowicz, M.; Gondek, W.; Huczyński, B.; Ochalska, L.; Jarubas, M.; Jastrzebski, M.; Kuczaj, W.; Kwiecień, L.; Mrozowski, J.; Olejniczak, E.; Ostrowski, K.; Partyka, A.; Sotniczuk, M.; Zbysław, B.; Langhmer, L. 1981. *Waloryzacja Rolniczej Przestrzeni Produkcyjnej Polski Według Gmin*. IUNiG Puławy.

Zeliaś, A.; Malina, A. 1997. O budowie taksonomicznej miary jakości życia, *Taksonomia* 4: 238–262.

Zeliaś, A. 2006. *Kilka uwag na temat metod doboru zmiennych występujących na rynku nieruchomości*. Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 450. Publications of the Department of Econometrics and Statistics, 17: 985–696.