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MULTIFACTORIAL METHODOLOGY FOR NATURAL HAZARDS RISK ASSESSMENT

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Abstract

During the last years new methodologies are developed for the natural hazards risk assessment. The presented work deals with the methodology firstly developed by several bodies at global and regional level (United Nations programs – ISDR, UNDP; Inter-American Development Bank and Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (GTZ); ESPON 3.1.3 Hazards Project; Joint Research Centre (JRC), EC. Our goal is to further improve these methodologies including some new elements such as: building risk profiles, introduction of the qualitative and quantitative risk levels, combination of several hazards and the influencing factors, and application of the developed methodology to some selected objects in Bulgaria (forest fires around Etropole town surroundings). Presented methodology shows reasonable results and could be explored and exploited by the local authorities, civil defense and risk managers.

Key words: factor analysis, forest fires application, risk assessment.

Introduction

Recent disasters dramatically affected millions of people, with hundreds of thousands of lives and USD 1.5 trillion lost between 2005 and 2014. Global economic loss from disasters varies on average from USD 250 to 300 billion each year. Changing climate, rapid urbanization, ongoing violence and conflicts in many parts of the world, changing demographics, technological innovations, increasing inequality and many other known and emerging changes with their inherent uncertainties have created an unprecedented context for disaster impact. The risk assessment (analysis) of natural hazards is a disaster preparedness activity including pre-disaster risk reduction phase of the risk management process. Risk analysis is a base for decision making and the main tool for the risk management and scenarios development about the risk reduction. UN terms and definition are accepted and approved among risk management specialists. According that, risk assessment includes three main activities: vulnerability, hazard and coping capacity assessment.

The initial definition is given by Blaikie et al. (1994): Risk = Hazard potential × Vulnerability or Risk = Hazard × Vulnerability/Coping capacity (UNISDR 2002). It must be mentioned that these are not algebraic equations and only show the interactions between risk, hazard and vulnerability.

The aim of this study is to present the complex methodology for risk assessment generated by different natural hazards, to improve the approach introducing correct weighting coefficients, to include risk perception as an important factor for the risk assessment.

A holistic risk assessment that considers all relevant hazards and vulnerabilities, both direct and indirect impacts, and a diagnosis of the sources of risk will support the design of policies and investments that are efficient and effective in reducing risk (UNDRR 2019).

Methodology for risk and multi-risk assessment

There are many models and methods for disaster and damage assessment caused by particular natural hazards. The methods used own specific features and the differences in models often lead to some disadvantages like: different results, different scenarios with various initial and final data, incompatibility, inappropriateness, etc. That is why during the last years the efforts are directed to holistic approach including all factors and parameters concerning risk assessment and analysis.

Basic methods and methodologies about the risk and multi-risk assessment are developed by: United Nations programs (UN) – ISDR, UNDP; Inter-American Development Bank and Deutsche Gesellschaft für Technische Zusammenarbeit (IADB 2003, IADB 2005); ESPON 3.1.3 Hazards Project (2004); Joint Research Centre (JRC), EC.

We accepted the following parameters modifying them from the original methodology. For the risk assessment – all components (hazards, exposure, vulnerability and coping capacity) are expressed by the equations (1–4).

$$H=w(H_1)\cdot H_1+w(H_2)\cdot H_2+w(H_3)\cdot H_3+\ldots+w(Hn)\cdot Hn, \quad (1)$$

$$E=w(E_1)\cdot E_1+w(E_2)\cdot E_2+w(E_3)\cdot E_3+\ldots+w(En)\cdot En, \quad (2)$$

$$V=w(V_1)\cdot V_1+w(V_2)\cdot V_2+w(V_3)\cdot V_3+\ldots+w(Vn)\cdot Vn, \quad (3)$$

$$C=w(C_1)\cdot C_1+w(C_2)\cdot C_2+w(C_3)\cdot C_3+\ldots+w(Cn)\cdot Cn, \quad (4)$$

where: H, E, V and C are the values of the Hazard, Exposure, Vulnerability, and Capacity and Measures, respectively; H_1, H_2, Hw, E_1, E_2, Ew, V_1, V_2, Vn, C_1, C_2, Cn refer to the scaled values of the indicators; and w_i are the weights. A total sum of the weighting coefficients must be equal to 100. Our approach to introduce normalized weights is accepted to be able to create compatible values of all 4 components.

The risk profile for the given selected area is expressed by formula (5).

$$R = w\cdot H+w\cdot E+w\cdot V-w\cdot C, \quad (5)$$

where: R is the overall risk index, H, E, V and C are the values of the hazard, exposure, vulnerability and coping capacity, respectively, and w is the weighting coefficient.

Multifactorial methodology

The developed and adapted methodology for risk and multi-risk assessment includes:

• Risk perception as a part of the risk assessment

Considering the models and research, risk perception can be accepted as a root foundation related to the risk management. Therefore, the inclusion in the risk assessment is imperative. The psychological judgement ‘It won’t happen to me’ is associated with the personality. But the analogous psychological factors are the base of human behavior and decisions. Risk perception as a key factor may be becomes the main reason for maximize vulnerability or respectively its reduction.

The study of risk perception arose out of the observation that experts and people often disagreed about the risky various technologies and natural hazards. Three major families of theory have been developed: psychology approaches (heuristics and cognitive), anthropology/sociology approaches (cultural theory) and interdisciplinary approaches (social amplification of risk framework). The earliest psychometric research was done by psychologists Daniel Kahneman and Amos Tversky (Kahneman et al. 1982, Kahneman and et al. 2000).

Research within the psychometric paradigm turned to focus on the roles of affect, emotion, believes, etc, in influencing risk perception. Melissa Finucane and Paul Slovic have been the key researchers here.

On the basis of the knowledge of non-physical dimensions and contextual risk properties we can understand the human behavior against natural events and threats. What a society defines or professes to perceive as risk is thus not necessarily in any direct relation to the magnitude of risk as defined by the two components of probability of occurrence and extent of damage. It is very important for several reasons that a proactive and rationally structured risk policy addresses the issue of risk perception – the behavior of people is guided by their perceptions and not by scientific risk models (Pidgeon et al. 1992, Renn 1998, Fischoff et al. 2000, Slovic 2000).

The algorithm presented as chain of elements (Fig. 1) follows the methodology logic: the hazard is characterized by place and time of occurrence. It could be different natural phenomena (in our case) or anthropogenic influence (excluded in this study). The unsafe conditions affect both (person and/or society) disturbing their zone of comfort. The risk perception is related to the conditions before and after the disaster.

Following this logic we build up a risk profile, using the theory expressed in topic Methodology.

Thereby, the risk profile for the given

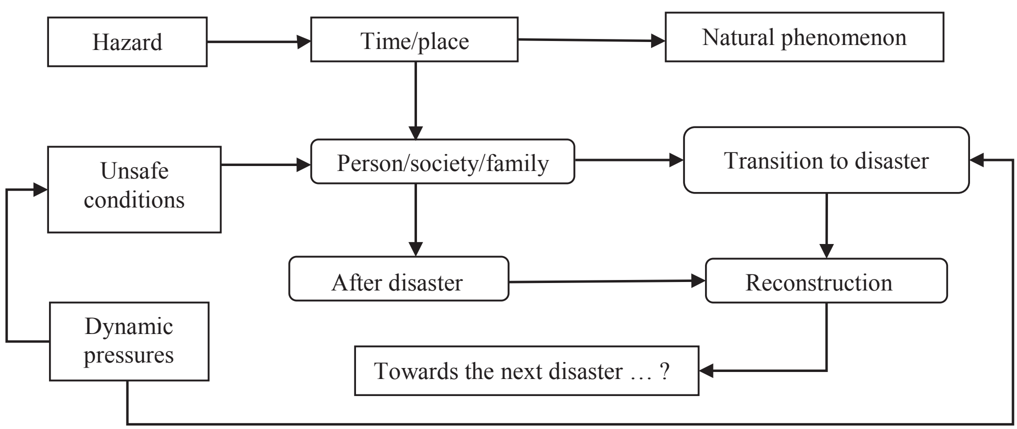

Fig. 1. From hazard to disaster (Blaikie et al. 1994).

selected area is expressed by formula (6).

$$R=w \cdot H+w \cdot E+w \cdot V+w \cdot RP-w \cdot C, \qquad (6)$$

where: H, E, V, C and PR are the values of the Hazard, Exposure, Vulnerability, Coping Capacity and Risk Perception, respectively; H_1, H_2 …, E_1, E_2 …, V_1, V_2 …, C_1, C_2 … refer to the scaled values of the indicators; and w are the weights.

As was mentioned before all four factors are well defined and used in many studies. Our goal is to include the risk perception and exposure as another main factor, not less important than others (Fig. 2). It is important to point out that the risk perception and its factors are included as novelty part of the standard methodology. It reflects the individual perception of a single person as well as the society. Both react in a different way. The person received increased physiological pressure and has to accommodate. Same is society, but the collective reaction reflects other peculiarities, which could be investigated in a future extended study.

The main feature of the methodology is the acceptance that the coefficient *w* is not equal to the five factors; it is assumed that various factors have varying weights and contribute in changing magnitude for the assessment of the risk levels. The values of weighting coefficients are defined similar as it is presumed that all risk factors contribute equally to the increasing or reducing of given risk. For the time being there are no scientific studies or technical methods which are able to defined whether the factor 'hazard' is more important than the factor 'vulnerability' or 'copping capacity'. The risk factors are closely related to environment and the areas to be considered and thus their impact can range from minimum to maximum.

• Global Change Syndromes, specific to particular natural hazards for selected areas

All syndromes must meet the following criteria, however (WGBU 1998):

- Each syndrome relates directly or

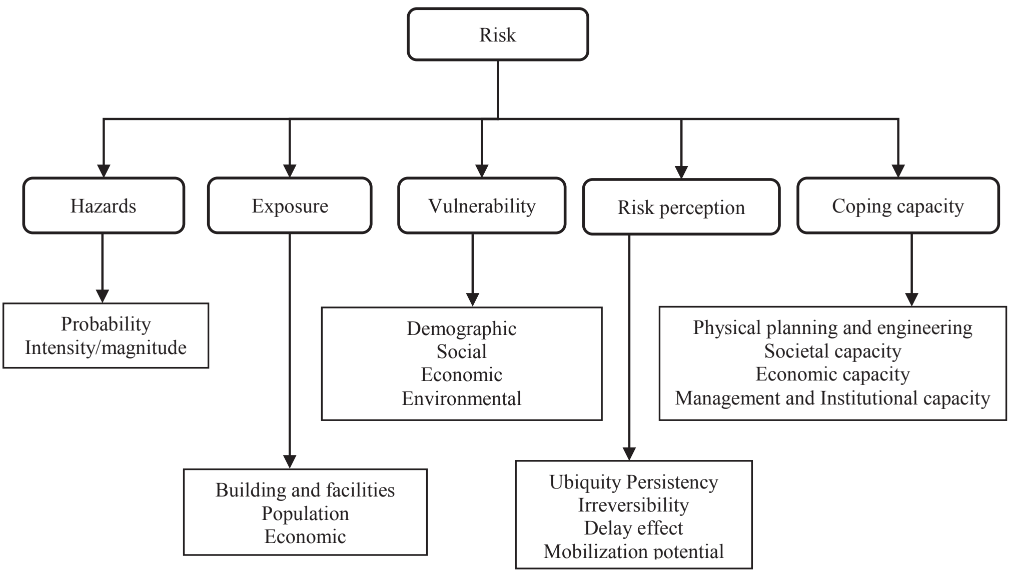

Fig. 2. The factors, included in the newly developed and adapted multifactorial methodology for risk and complex risk assessment (Frantsova 2017).

indirectly to the environment; exclusive reference to core problems within the anthroposphere is not permitted;

- The syndrome should occur as a visible or virulent cross-cutting problem in many regions of the world;

- The syndrome should describe non-sustainable development and/or significant environmental degradation.

A cardinal feature of global change is that humankind itself is now an active factor within the Earth System, playing a significant role at the planetary scale. Human interventions, as manifested in the depletion of raw materials, shifts in material and energy fluxes, changes to large-scale natural structures and critical stresses on environmental assets, are altering the very character of the Earth System to an increasing degree. The complexity of the processes involved or driven by these changes poses a major challenge for the scientific community and generates a number of new research issues.

Global change research must therefore deal with the diagnosis, prediction and assessment of global trends, the prevention of negative trends, 'repairing' existing damage (rehabilitation and reconstruction) and adaptation to the unavoidable. The hazards have clear nonlinear effects to the society and individuals (Ranguelov 2011). Therefore, the primary interactions between these trends must be identified, described and explained.

Such research should be guided by the principle of sustainable development. The crucial element of this concept, now generally acknowledged, is the interdependence of environment and development. This reflects a growing insight that human beings and their environment are closely integrated within a system of mutual interaction. Research on global change is therefore confronted with two fundamental problems. Firstly, the investigation of the Earth System requires an integrative approach because the interactions between its components operate across the boundaries of single disciplines, sectors or environmental media. The second fundamental problem is the enormous complexity of the dynamic interrelationships involved, which makes a distinct description, any overall analysis and modeling much more difficult. The only approach capable of responding adequately to these problems is one that is networked and interdisciplinary.

The syndrome concept provides a new basis for global change research, the knowledge base of which continues to be split up according to the environmental media or core problems. This sectoral or disciplinary approach is certainly justified: without searching for a deeper understanding of the individual problem areas and their functional mechanisms, it is impossible to understand the specific aspects of environmental stress.

Results and Discussion

Multifactorial methodology is validated via a former disastrous event. Forest fire in the area of Etropole, November 2010, in Stara Planina Mountain has been selected for the performance of the described methodology. According to data of the Ministry of Interior, on November 10, 37 fires were burning on the territory of the country. The most severe forest fires are located in Stara Planina, Lovech region.

One of the heaviest fires in Stara Planina Mountain, emerged on November 6, 2010 in difficult accessible, highly intersected area, near the villages of Yamna, Patno Bardo, Duckot, Zarbavica (Fig. 3). The situation is further complicated due to

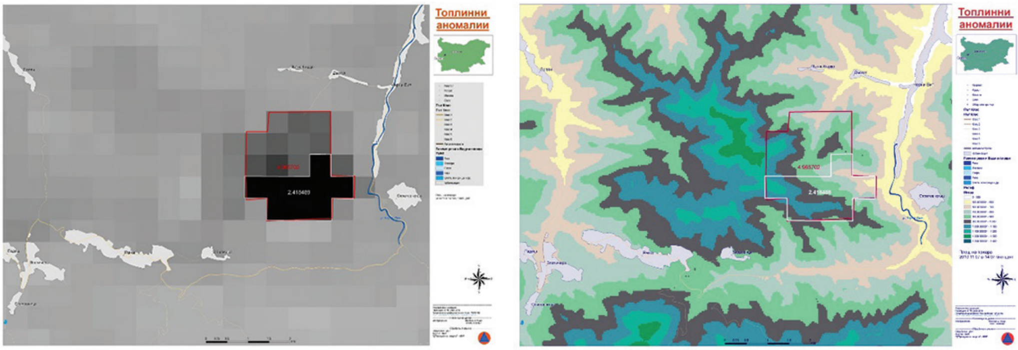

Fig. 3. Forest fire area – Etropole, November 6, 2010, Stara Planina Mountain (2418 km^2).
Note: The maps are prepared in the former DG Civil Protection, MoI.

high air temperature, strong winds in the area of fire and the very low soil humidity. The fire was suppressed on November 10 using aviation equipment.

Meteorological parameters are based on the data from United States Air Force Weather Agency (AFWA) and World Meteorological Organization (WMO), published in the official site of the United States Department of Agriculture (USDA 2019). (Some of them are presented in the figures 4, 5, 6 and 7).

WMO and AFWA data show a lack of rainfall, very low soil humidity and high level of drought. The state of the environment can be described with high volume of the fuel materials (predominantly grass, shrub and wood) with high density due to the autumn fall.

Based on the analysis of the available data (not specified here), we can conclude that under existing conditions, the fire hazard is significantly high for the given area.

Risk assessment is based on: 4 indicators for hazard; 7 indicators for exposure; 19 indicators for vulnerability; 19 indicators for coping capacity and risk perception conception. Such clarifications could be found in Ranguelov (2013). The values are divided into five risk classes and described the risk levels – the data falls in the interval between 0 and 56.25 (Table 1).

The quantification of the risk levels in five categories is a product of the numbers obtained by the application of the described methodology. They are equally digitized by a factor of 11.25. This value is due to the perception of the influence equality of the obtained risk levels.

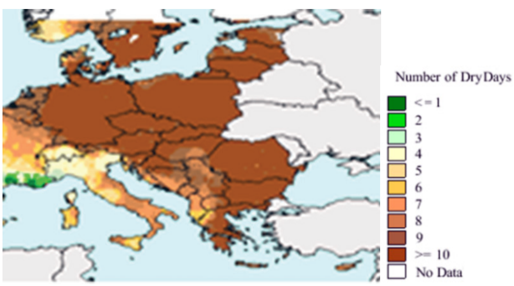

Fig. 4. Number of dry days from 01.10 to 11.10.2010. (Data from USDA 2019)

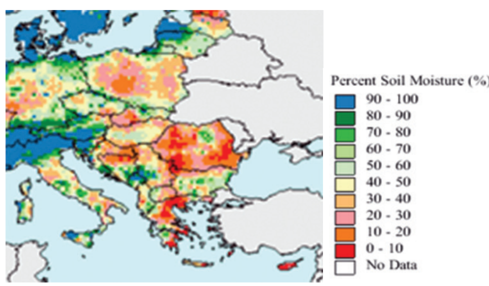

Fig. 5. Soil moisture from 01.10 to 11.10.2010 (%). (Data from USDA 2019)

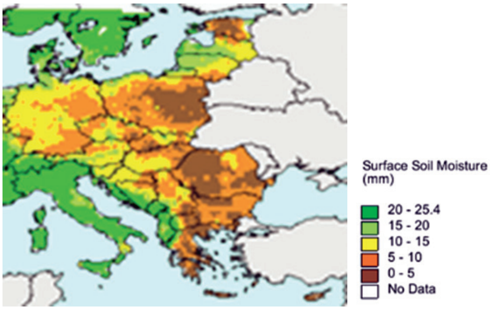

Fig. 6. Soil moisture from 01.10 to 11.10.2010 (mm). (Data from USDA 2019)

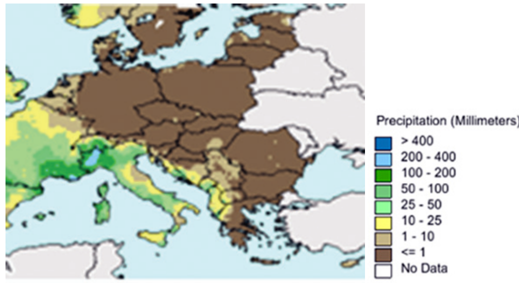

Fig. 7. Precipitation from 01.10 to 11.10.2010. (Data from USDA 2019)

Table 1. The quantification of the risk levels.

Risk levels	Very low	Low	Medium	High	Very high
Value	0–11.25	11.25–22.50	22.50–33.75	33.75–45	45–56.25

Calculated results with value 19.5 (34.67 %) show low risk profile for the given selected area which is consistent with the real situation.

Conclusions

The main conclusions are related to the adaptation and use of the developed holistic methodology about risk assessment.

The adaptation is focused to the clarification and selection of the risk factors, weighting coefficients assessment and sensitive analysis.

For the first time the risk perception is included as important factor, extending the developed methodologies, used up to now. Its quantification influence is not easy to be presented as numbers. We consider this challenge to be solved in a future study.

The application of the developed methodology to the forest fire in the area of Etropole, October 2010 in Stara Planina Mountain shows reasonable results and considerations.

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