Carpathian Journal of Earth and Environmental Sciences, November 2015, Vol. 10, No 4, p. 159 - 171

URBAN VULNERABILITY AND RESILIENCE IN POST-COMMUNIST ROMANIA (COMPARATIVE CASE STUDIES OF IAȘI AND BACĂU CITIES AND METROPOLITAN AREAS)

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Abstract: Resilience and vulnerability are two distinct but highly interdependent concepts useful for understanding the systems and territorial actors` response to change and unexpected shocks. There are both used in risk assessments, but also in evaluations of the adaptability and transformability of biophysical, social or economic systems. The paper makes a short, but comprehensive analysis of the concepts of vulnerability and resilience applied within the context of Romanian cities, highly complex systems that had to face multiple challenges in the last two decades either general (such as economic crises, climate change, natural and technological hazards) or urban specific (deindustrialisation, polarisation capacity loss, social segregation, emigration, urban sprawl etc.). Using and adapting a large, but rather eclectic scientific literature and methodologies, the current approach is a preliminary attempt to highlight the main indicators of urban performance in managing different disturbances. Case studies, i.e. two important cities in North - Eastern region of Romania - Iași and Bacău, are being analysed in order to evaluate individual responses of institutions and communities to specific hazards and long- term crises that have an impact on social, economic and ecological urban subsystems. The overall purpose is to propose a framework that could make possible the integration of vulnerability and resilience within the strategic plans of urban sustainable development.

Key words: exposure to hazards, vulnerability, resilience, indicators, Romanian cities, metropolitan areas

1. INTRODUCTION

Resilience and vulnerability are two different but interconnected concepts useful for understanding the response of complex systems, such as urban areas, to different challenges, i.e. to either unexpected sudden shocks or to slow insidious changes (Miller et al., 2010). Used in the analysis and characterization of risks, there are closely related to the evaluation of the adaptability and transformability of biophysical, social and economic systems. Multidimensional and polysemantic concepts, they are highly dependent on the scale of analysis, therefore being eminently dynamic (Vogel & O'Brien, 2004).

Intuitively, one could say that vulnerability is linked to a potential for harm and resilience means resisting or coming back from harm (Tromeur et al. 2012). Within the same risk assessment logic, other definitions link vulnerability to the degree of damage incurred from natural and anthropogenic hazards manifested for an individual, a community, a city, a region etc. (Hufschmidt, 2011) and resilience to the capacity to prevent, to respond or to recover in face of a real or potential damage. In some cases the two terms are used as antonyms: vulnerability of a system includes exposure to stress, to an acute or chronic disturbance and its propensity to undergo transformation, while resilience is the ability to face that perturbing event (Adger et al., 2005). Therefore it is to say that the vulnerability stems from the loss of resilience (Holling, 1995) or that a vulnerable social-ecological system is one which has lost its resilience (Folke, 2006).

However, there are also well reasoned opinions that consider resilience not just the positive counterpart of vulnerability. A system can be both vulnerable and resilient. In this sense, vulnerability is equated not only to exposure and to the potential to incur losses or to the resilience itself that refers to system's ability to temporary inability to cope with impacts, but also to recover, to recoil, to rebuild and to return to a steady state of "normality" (Miller et al., 2010). Moreover, one can say that just because a system is vulnerable it can be also resilient. The more it will suffer from a disturbance the more it can show and even enhance its resilience. The idea is highlighted by some authors up to the identification (or even confusion) between vulnerability and resilience. Thus Armaș (2007) defines social vulnerability in a study that refers to the historic centre of Bucharest as referring to the capacity of a human community exposed during the impact of a natural hazard event (in this case, an earthquake) to resist, cope with and recover.

The relation between the two concepts was well exposed by Cutter et al., (2003) who define vulnerability as a set of characteristics or qualities of systems before a disruptive event is produced, which creates the potential to incur losses or the differentiated capacity to recover after the event occurred. In this sense, vulnerability depends on exposure to a threat, sensitivity (capacity to resist it) and the ability to adapt, which indirectly implies that vulnerability includes resilience. Within the same framework, in some approaches, vulnerability includes resilience and susceptibility. Resilience is related to „existing controls" and the capacity to reduce and sustain harm, while susceptibility is related to exposure (Goudie, 2011).

By opposite, resilience is seen by some authors as an emergent property generated as a result of the relationships between highly vulnerable components and elements with a high degree of adaptability (Pike et al., 2010). In this sense, resilience includes vulnerability. Provitolo (2013) even suggests the term "resilient vulnerability" naming a meaning of the two terms focused on positive effects: when the change leads to beneficial transformation and qualitative leaps of the analysed system. From this perspective, the concept overlaps the term "functional imbalance" (Ungureanu, 2005). Resilient vulnerability implies reactions and changes of systems response to certain events that could create damage. By adaptation, innovation, self-organisation, diversity and learning capacity, vulnerabilities are able to be transformed into resilience factors. This can be analysed in terms of already existing capacities (proactive/reactive/post-active adaptability and response capacity) and potentialities (resources, resistance and sensitivity) (Provitolo, 2013).

Nevertheless, in most approaches, resilience has a stronger systemic meaning, while vulnerability is most often linked to autonomous units considered to be potentially subject to a hazard. However, both concepts provide real opportunities for the integration of various indicators that reflect the operation of complex systems such as cities and are both oriented towards response to stress or to disturbance by sudden or slow changes (Miller et al., 2010).

Cities are hubs of development and engines for regional economic growth, concentrating population, economic activities and infrastructure at risk from the impact of various perturbations. They often face various challenges such as decay, poverty, migration, pollution natural or anthropogenic disasters (Dobraniak, 2012). Their vulnerability depends on the range of hazards that could manifest in the city and the patterns of the unit one take into account (city, urban population, sector, domain). Considering cities and metropolitan areas as dynamic social and ecological systems, their levels of vulnerability will increase proportionally to the reducing levels of resilience. It is sometimes a consequence of lack of innovation and adaptation processes in a context of increasingly complex restrictions imposed by the global environment (Ianoș et al., 2009).

In Romania, metropolisation comprises an official form: metropolitan areas voluntary partnerships between big cities and the surrounding localities- that were taken into account from 2001 (Law no. 351/2001), but few of these entities are functional. By the other hand interdependent development of metropolises and their influence areas form "metropolitan realities" (Istrate & Alupului, 2012), that are harder to be framed and analysed due to their tremendous dynamics. Both official and functional metropolitan areas not only generate demographic and economic growth leading to development, but also confront major difficulties related to their inherited and enhanced inefficient metabolism (which involves growing energy and resources consumption). Urban sprawl generates risks as the towns end up being built in areas where natural risks occur while the urban technical networks are designed very quick, sometimes under-dimensioned and less efficient and the accessibility is often low (a mark of habitat dispersion), both exacerbating the effects of hazards by their interconnected dysfunctions (Serre et al., 2013). One can add the excessive consumption of resources, the functional segregation and the lack of proximity services (stores, offices, schools, medical units, and administrative buildings) and public places. The inconsistency of public transport means and routes exacerbates the high dependence on individual transport creating more vulnerability (when natural or human induced hazards occur– for e.g. heavy snows in the winter), and even more energy consumption and pollution, all these issues finally threatening the life quality within the (extended) urban environment (Ianoș et al., 2012). Unsustainable form of land use, urban sprawl induces a lack of consistency in planning and reduces the urban systems' capacity to resist and to recover in case of crisis (Hirt & Stanilov, 2009).

2. METHODOLOGICAL FRAMEWORK

2.1. Delineation of the studied area

The city is becoming an increasingly complex reality, a system comprising a high diversity of actors and assets with a tremendous dynamic that makes it difficult to describe within its narrow administrative limits. There are different criteria that could be used in order to delineate urban environment: the city as an administrative unit, morphological urban area, functional urban area or metropolitan area each presenting advantages and disadvantages in relation to the purpose i.e. to analyse the features creating vulnerability and resilience within urban environment. For this study, that tries to introduce the mentioned concept within urban planning discourse in Romania and to explore the official statistics in search for data that are consistent and reliable in order to create indicators (that could be followed by time series), the official administrative urban units and the official metropolitan areas were considered to be suitable, taking Bacau and Iasi as case studies, (Fig. 1).

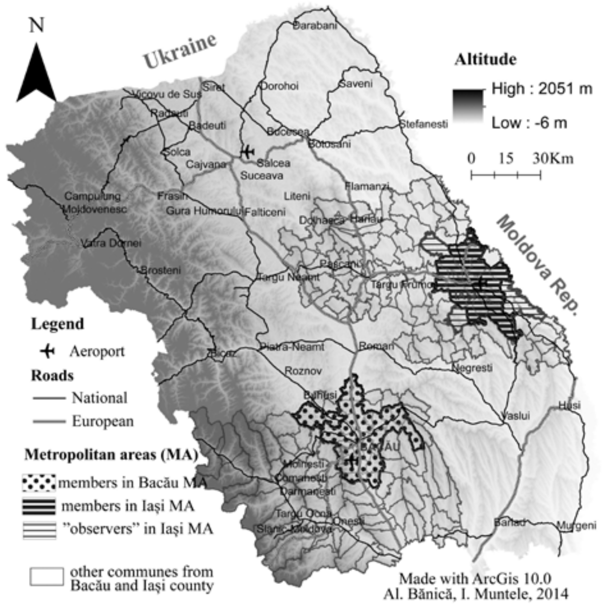

Figure 1. The position of Bacău and Iași cites and metropolitan areas within North-Est Region of Romania

If city's administrative limits are more or less clear, the delimitation of official metropolitan areas is sometimes questionable, as they do not always take into account the accessibility and the real polarizing capacity of cities. Nevertheless, the official metropolitan areas were chosen for the case study because they are existing entities and frameworks that should become functional as voluntary associations comprising a city and the territorial units influenced by it, capable to fulfil common projects in order to develop together.

2.2. Main objectives

The present paper contains a synthesis of certain preliminary results in vulnerability and resilience assessment of metropolitan area in North-Eastern Romania. First, the study had provided a theoretical background to evaluate urban structure and recent dynamics in post-communist Romania by a common approach on vulnerability and resilience. The operationalization of this general diagnosis in the analysis the two case studies of Bacău and Iași at two spatial levels (cities and official metropolitan areas) is made by testing relevant indicators of exposure, sensitivity and response/adapting capacity within a preliminary assessment of vulnerability and resilience and aggregating indicators in order to obtain a (partial) general urban resilience index (GUR). The overall purpose is to evaluate indicators capacity to reveal and be a basis for vulnerability - resilience assessment in urban environment at different scales in two urban areas from Romania.

2.3. Indicators of vulnerability and resilience applied to urban areas in Romania

It is well recognised that resilience and vulnerability are not easy to be measured (Abhas et al., 2013), but it is important to find simplified proxies based on the relevant factors that could induce them. Using a quantitative approach, could help decision makers to set targets for their actions and to monitor the results over time. However, there is an important difference, but also an undeniable complementarity between vulnerability and resilience assessment (Usamah, et al., 2014).

Vulnerability is mainly analysed in order to measure the susceptibility of people and assets to be exposed to and to suffer damage because of particular shocks while resilience uses a more systemic approach incorporating both short and long term factors (ibid.) If one takes into account the three phases of vulnerability and resilience mentioned before, an indicator-based approach is considered most suitable for the assessment of exposure, while scenario approaches or agent – based modelling are thought to be ideal for sensitivity (or susceptibility) assessment. For the assessment of response and adaptive capacity interviews are the most relevant.

The early literature presumed that frequently wealthier units are also less vulnerable and more resilient therefore the measure of wealth is sufficient for predicting vulnerability/adaptive capacity. The Social Vulnerability Index (Flanagan et al., 2011) applied to United States includes 42 demographic and social variables, but none relating to hazards although the study was focused on vulnerability to hazards. In 2011 an ESPON study on adaptation to climate change in Europe intended to imagine indicators of vulnerability to climate change and to integrate them in a single index by weighing factors delineated by an expert opinion (ESPON, 2011). The subjectivity of such an approach was eliminated by European Environmental Agency that preferred within a similar study made in 2012 simple indicators of vulnerability because an aggregated index would hide information on the factors that determines the vulnerability itself. Indicators should capture the intrinsic vulnerability of places, exposition to hazards, the capacity to control and to recover, the alternative ways of functioning, but also the preparation for moments of crisis. It is important to delineate relevant indicators that are statistically available and could be monitored for long periods of time in order to be able to analyse trends and thresholds. Although the two cities are not always comparable the major difficulty is actually generated by the lack of consistency of statistical databases and the lack of accuracy of other sources. Meanwhile one has to take into account the scalar diversity of indicators from households to neighbourhoods, from city to metropolitan area level, differentiating the significance of vulnerability/resilience factors in relation to the extent and complexity of the analysed unit. Only some (bolded in Table 1) of the proposed indicators were integrated in this study.

Table 1. Indicators of urban and metropolitan vulnerability and resilience assessed in present study

			Proposed indicator(s)	*Aggregation/Units*
Exposure	**VULNERABILITY – RESILIENCE**	**Multi-hazards indicators**	**Earthquakes/ exposed buildings**	*no. of buildings at risk/total no of buildings*
			Floods/ exposed population, social and economic assets, lands	*% built-up areas at flooding risk*
			Storms/ heavy snows	*average no. of storms/heavy snows/year*
			Heat waves/ registered events- hot days and tropical nights, urban heat island effect	*average no. of heat waves, hot days and tropical nights*
			Landslides/ population under risk	*% built-up areas at landslide risk*
			Technological hazards/Environmental pollution – SEVESO equipment, accidental pollution events, urban background pollution	*no. of SEVESO equipment/surface of the unit; no. of accidental pollution events number*
			Fires –	*no. of fires/square km/year*
			Road and railroad accidents	*no. of transport accidents/total population*
			Economic crises exposure index	*% turnover of firms decrease (2008-2013)*
Sensitivity		**Socio-demographic**	**Emigration/metropolitan stability**	*immigration rate - emigration rate*
			Poor population	*% poor population/total population*
			Aged population/Young population	*population >60/population 0-20*
			Social segregation/Income (in)equality	*Gini index value*
			Employment	*% employed / active population*
			Education	*% population with higher education*
			Health /life expectancy at birth/access to sanitation	*% people with access to sanitation*
		Economic (and infrastructural)	**Access to utilities and distribution networks (water, sewage, gas, electricity)**	*%people that have access to water, sewage, gas, electricity*
			Dynamics of housing (number, discontinuous urban fabric)	*% houses built/total no. of houses*
Response/ adaptive capacity			Urban areas functional diversity	*no. of land uses per unit*
			Road quality/public transport efficiency	*% modernised roads*
			Employees in vulnerable activities	*% employees in vulnerable activities*
		Environmental	Economic diversification	*adapted Simpson's index value*
			Access to structural funds	*value of financed projects*
			Technological modernization and renewable energy access	*Installed capacity for renewable energy/population*
			Green areas/Oxygenating areas/Protected areas	*green index value (see below)*
			Investments in environmental friendly projects	*the value of investments in environmental sector/total investments*
			Non-governmental functional association	*no. of NGO/no. inhabitants*
		Institutional and governance	Public participation to decision making	*% of inhabitants participating to public meetings*

Exposures to natural and human induced hazards that can affect urban and peri-urban areas are better assessed by a number of simple indicators that are able to show if not a comprehensive at least a reiterative and improvable image of primary vulnerability. From a rather eclectic database comprising various sources, the processed data referred to flooded areas, buildings at risk in case of earthquake, the number of fire events, potential hazardous industrial equipment (SEVESO), urban background pollution and the number of pollution accidental failures.

Socio-demographic, economic and infrastructural vulnerability indicators point out the sensitivity and adaptive capacity of population – both anticipatory and reactive (coping) when confronting disturbing events.

Some indicators of population evolving structure are indirect markers for different consequences of economic and social crisis: the dynamics of total population, the active population (share of employment and unemployment), age structure, migration (temporary departures for short or long periods, permanently leavings and arrivals). Social features that induce community resilience/vulnerability are linked to segregation processes (poor versus rich population, gated communities).

Three aggregated social indicators were calculated: *population dynamics resilience indicator* (*Ird*), *demographic structure resilience index* (by age and sex, *Irs*) and *population mobility resilience indicator* (*Irm*). ***Ird*** represents the mean value resulted from summing the ratio between the active (birth) and the passive (mortality) components and the migration balance. Positive values indicate certain amount of resilience, and the negative potential vulnerability. Expressed in parts per thousand, population components are reported, the ratio being standardized to the unit while the migratory balance is expressed as a percentage. ***Irs*** is obtained by averaging the values of the growth rate during 2002-2011 inter-census of three derived indicators: the index of demographic aging, masculinity index for age group 20 to 39 years old and aged population replacement index (ratio of population over 60 years and the 45-59 years old population). All these aggregated indicators have been standardized by reference to the unit. In this way major events that changed the structure of the population in transition economies are captured: the accelerated aging of the population, both basic and peak emigration of young people differentiated by gender (20-39 years), etc. This indicator is closely linked to the resilience of the population dynamics, reflecting the relation between structural and dynamic processes. Although calculated only for the period 2002-2011, for reasons of statistical information continuity, this indicator reflects the dynamic changes produced virtually in the entire post-communist period.

Irm was obtained by averaging three derived indicators: temporary labour force mobility abroad dynamics indicator (according to the censuses of 2002 and 2011), definitive emigration and immigration dynamics indicator for the years 1994-2009. Indicators were standardized by reporting to the unit value.

Some indicators reveal more directly the effects of economic crises on the urban and metropolitan area economy (global industrial production, income and public expenditure; dynamic structure of industrial production and services), while others are related to urban sprawl (constructed areas, the number of new buildings, new developed activities, implantation of new retailers) etc.

Two main economic resilience indicators were taking into account in current approach: *Economic resilience indicator* **(Ire)** and *urban infrastructure resilience index* **(Iri).**

Ire was calculated by weighting the evolving trends of three sets of statistics: employed population (1991-2012), unemployment (1997-2013), the share of gross domestic product (GDP) at county level from total national GDP (1991-2012). Although inconsistent, the three sets of data can capture the extent to which analysed territorial units were adapted to the rigors of the market economy. All values that indicate tendencies for specific time intervals were standardized by reporting them to the unit value.

Iri was aggregated on the basis of information on the construction of new houses and the share of population with access to utility networks (water supply, sewerage and natural gas) for the interval 1990-2012. It highlights the progress made in improving the quality of life in both cities and corresponding metropolitan areas. The index represents the average value of two derived indicators: the dynamics of housing resulting from successive mediation of evolving trends for each of the intervals, separated by the same temporal thresholds as in previous indicators, relative to the unit value (for standardization purpose) and the dynamics of the distribution networks, calculated in the same way as the average value of indicators specific to each category of utilities.

Finally, environmental indicators take into account the future possibilities to assure a lower dependence of metropolitan areas and sufficient resources to sustain growth by internal means. Although the present context of foreign investments and high cost for population make the issue controversial, renewable energy is, on the long run, an opportunity to assure a higher resilience to urban territories therefore is taken into account. Meanwhile the green areas from cities (number, extent, possibility to be connected by green corridors), but also all oxygenating areas from metropolitan areas (green areas, forests, grasslands, wetlands, water), some having the status of protected areas, are reserves of great importance that ensure the necessary redundancy (in resilience theory's terms). Not at least, the environmental governance is essential for the sustainability and resilience of urban and peri-urban territories. Therefore investments, that are essential for ecological modernization, are important to quantify. Some of these are supported by local authorities and local private companies, while others are financed by European Union or governmental funds.

Three derived indicators were considered, calculated and aggregated in order to obtain a complex indicator of environmental resilience of urban and peri-urban areas. The first indicator, *renewable energy index* **(Rei)** is based the progresses made by latest technological modernization in energy sustainability (green energy), taking into account the trend (annual growth) of the emerging domains of renewable energy – solar, wind, hydro, biomass, biogas- the installed capacity, all reported to total population for the last six years). The presence of renewable energy equipment is finally a sign of modernization, technological innovation and thus of the possibility to diminish energy vulnerability.

The second derived indicator – *green areas index* **(Gai)** takes into account the average value and trend for the years 1992-2000-2006 (Corine Land Cover), the reserves of oxygenating areas referring to land use, with a special interest in green spaces (urban green areas – here data series 1990-2011 from TEMPO database of Romanian National Institute of Statistics were used for assessing trends -forests, grasslands, wetlands and even water surfaces). All these areas play a key role in rebalancing the socio-ecological systems as they have an extremely complex territorial functionality.

The coefficients (Table 2) were established as weights by using as landmarks former results and models for annual oxygen emissions per unit area proposed in previous studies (Yin et al., 2010, Yin et al., 2015).

The land use data were obtained by intersecting geometries from Corine Land Cover and the administrative-territorial units taken into account. The share of protected areas within the units was considered an advantage and a sign of higher resilience capacity, as it involves, at least in theory, the idea that these functions will be maintained in the long term, and therefore the value was added to the final score by a corresponding coefficient according to the weight of protected area within the total area taken into consideration.

Table 2. Coefficients taken into account for calculating the green index

Type of land use	**Coefficient**
Agriculture	0.41
Forests	1
Grassland / bushes / shrubs	0.45
Wetlands(swamps)	0.65
Water bodies	0.05
Urban green areas	0.75
Protected areas	
< 10 %	0.1
10-50%	0.15
>50%	0.2

The third derived indicator, *public green investments* **(Pgi)** capture the interest of authorities in investing in environmental friendly assets (total spending for the environment, the projects that contributed to diminishing pollution and rising environmental sustainability and resilience). Imagining a relevant indicator in this area is difficult because of the heterogeneity of data sources, especially if we consider a longer time series. For this analysis we preferred the use of official statistics, consistent for all basic territorial units available for the years 2010, 2011 and 2012 which covers all environmental costs and amounts received by accessing funding programs by local authorities. These investments and expenses were recorded in the total costs for the facility.

Most of data were obtained from National Institute of Statistics in Romania (for example TEMPO database) while other were collected from various sources (Corine Land Cover, sustainable development strategies, urban planning acts, reports of Environmental Agencies etc.). The mentioned period of analysis (1990-2013) was divided into five distinct ranges, depending on the manifestation of phenomena impact on evolutionary trends: 1997, 2001, 2007 and 2010. They punctuate either the stages of Euro-Atlantic integration or the moments of recent economic crisis manifestation.

3. RESULTS

3.1. Components of urban vulnerability and resilience: indicators of exposure

The classic division between natural and human induced hazards is more and more questionable as we live in anthopocene an era marked by the dramatically increased human presence within the environment (from technological modernization to climate change) (Ogden, 2013). The fact is more visible in urban environment which is manmade by excellence. In Romania, Law no. 575/22.10.2001 takes into consideration earthquakes, floods and landslides as main natural disasters affecting most of the local territorial units. Nevertheless one can add many more other possible disasters created by accidental pollution (radioactive, chemical or biological contamination), epidemics, fires, traffic accidents or economic crises.

The two cities and metropolitan areas confront similar hazards, but the intensity of each is different, while the vulnerability of urban and peri-urban communities also differs.

The exposure to earthquakes in higher in case of Bacău metropolitan area – included in 0.24-0.28 PGA, B-C classes of seismic intensity, while Iași metropolitan area overlaps the forth zone of seismic intensity (D) with a PGA of 0,20 g. (see the seismic code P100/2004). But if one compare the number of buildings that are vulnerable to seismic shocks, the latest assessments of two County Councils (2013) show that in Bacău 84 residential are at risk, while in Iași, from a total of 350 suspected buildings, 51 are in class 1 and 56 in class II (reduced risk), while 158 were put in class 3 and 4 seismic risk (high risk).

Flooding or excess of humidity by river overflowing or draining on slopes are more differentiated spatially differentiated. In Bacău city there are only some creeks tributary to Bistrița river (Negel, Bârnat, Trebeș) that affected, in 2005 and in 2010, population and houses, while Siret river's floods affect some communities from the metropolitan area (Săucesti and Letea Veche). There are also many other rural units within the peri-urban affected by floods, as most of the localities are confronting the risk caused by overflowing rivers or draining on slopes when major rain evens occur (most of them both) (Law no. 575/22.10.2001). In Iași metropolitan area the overall risk of flooding is smaller (more than half of the communes have no significant flooding risk) as it is controlled and diminished by means of hydraulic works, but the evaluation of vulnerability shows, a much higher number of inhabitants and assets that are exposed to floods. Only in Iași city 2068 households and 1161 block stairs are under flooding risk, compared to 580 households in Bacău (ibid.).

If one takes into consideration territories affected by landslide risk, a brief assessment clearly shows the high exposure of Iași city and metropolitan area. Especially in the peripheral areas of the city and in rural areas nearby the construction of new buildings, periods of heavy rains, poor management regarding water drainage and rising hydrostatic level increased the risk of landslides occurrence and damage (Alupoae, 2013). In Bacău the phenomena is peripheral (in the Subcarpathians for e.g. in Faraoani or in Luizi Călugăra primary landslides occur). The studied urban area of Iași is affected by reactivated landslides while both primary and reactivated landslides occur in the city (Law no. 575/22.10.2001).

Fires affect mainly the private households – both in Bacău and in Iași- only a small percent (10-15%) were registered within the public domain in the last 4 years (2010-2014). They occurred mainly due to the use of damaged or improvised electric facilities (sometimes peri-urban areas confront shortages or lack of certain utilities), non-supervised open fires on agricultural land, dry vegetation, often near forest homes or granaries, failure to clean chimneys and smoke etc. The highest number of fires is produced in Iași city (168 in average), compared to (81 in Bacău), followed by Holboca (that has actually become a neighbourhood of Iași, preserving a tram connection with the city) – 19 fires. If one reports the numbers of fires to the area of the administrative units the main cities remain in the top of the hierarchy followed by peri-urban residential areas such as Hemeiuș for Bacău and Holboca, Bârnova, Tomești and Valea Lupului for Iași. This exposure indicator of vulnerability shows a facet of the process of urban sprawl – much more obvious in case of Iași, sometimes followed by increasing densities of buildings.

The presence of equipment associated with a higher risk for technological accidents is of special importance. Both studied areas still have functional facilities that either operate with hazardous substances that might explode (mainly in oil and natural gas products storage), or manipulate toxic and dangerous substances with high pollution potential (chemical industry). Most of the potentially hazardous industrial facilities are within the cities and only one in metropolitan area (oil storage at Itești, near Bacău). Therefore an indicator of the exposure to disturbing events impacting humans and ecosystems is the number of recorded pollution incidents affecting one many environmental subsystems (air, water, soil, vegetation, animals. humans). If one takes into consideration the period 2006-2011, within the North-East Region, Bacău city is first placed: 56 air pollution events caused by the malfunctioning of chemical fertilizers factory. Given the lack of appropriate modernization the still functioning capacity releases excessive ammonia emissions creating a real discomfort to residents from the city and from the neighbouring communes (Faraoani, Nicolae Bălcescu, Letea Veche). In addition there were registered a few other accidents that affected municipalities in the metropolitan area that period (soil pollution in Faraoani, water pollution in Gârleni), while in Iași only one such event was recorded: the accidental pollution from the winter functioning of the thermal power plant. A typology of analysed units taking into account the above mentioned natural and human induced hazards (Fig. 2) clearly differentiate the two cities from each other, but also from their metropolitan areas showing that high densities of people and buildings usually induce vulnerabilities that have to be tackled.

It is also obvious that due to their different geographic position, general geology and morphology, urban traditions and functional structure the units that form the two metropolitan areas are rarely exposed to the same categories of hazards.

3.2. Components of urban vulnerability and resilience: indicators of sensitivity and responding capacity

3.2.1. Socio-demographic indicators

Linking demographic attributes to social capacities is a main component of community resilience assessment (Cutter et al., 2010) and a measure of differentiated sensitivity/vulnerability within urban and metropolitan areas. Using official information available from the database of National Institute of Statistics in Romania for the period 1990-2014, concerning the components of demographic balance and the age and sex structure of the population for the two territorial structures analysed (the metropolitan areas of Bacău and Iași), some indicators were taken into account in order to delineate resilience.

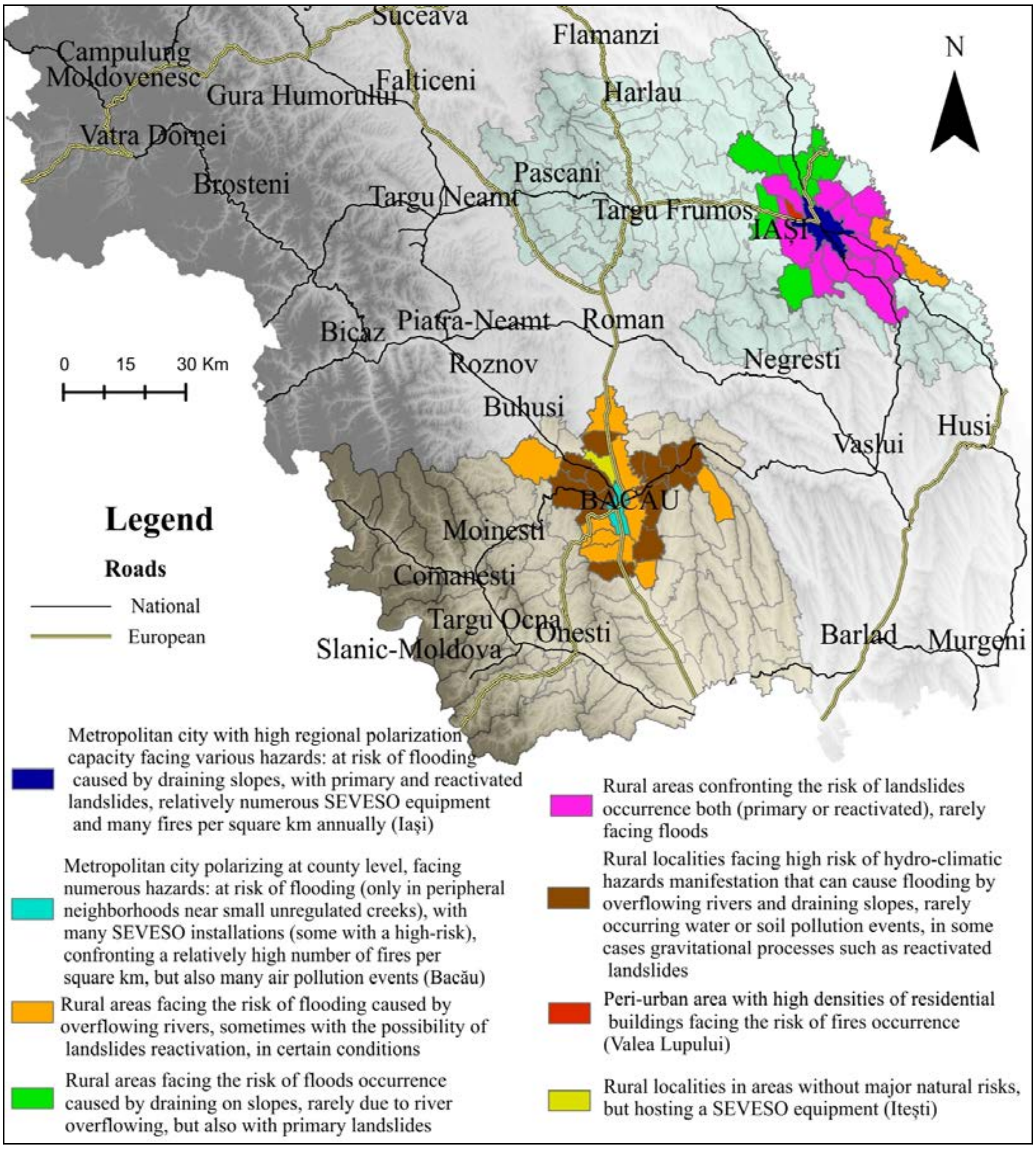

Figure 2. The typology of Bacău and Iași cites and metropolitan areas according to the exposure to hazards

Table 3. Population dynamics resilience indicator (Ird) resilience in Bacău and Iași cities and metropolitan areas (MA)

Territorial unit	Ird					
	1990-1996	*1997-2000*	*2001-2006*	*2007-2010*	*2011-2013*	*Average*
Bacău municipality	0,17	-0,07	-0,03	-0,17	-0,21	-0,07
Iași municipality	0,13	-0,05	0,04	-0,04	0,11	0,03
Bacău MA	0,10	-0,02	0,01	-0,09	-0,11	-0,03
Iași MA	0,11	0,01	0,08	0,02	0,16	0,07
Rural units from Bacău MA	0,01	-0,16	-0,02	0,16	0,02	-0,01
Rural units from Iași MA	0,12	0,12	0,17	0,37	0,39	0,21

The results are summarized the table 3. According to this analysis algorithm, there is a significant difference between the two metropolitan areas as well as between the two cities. Iași metropolitan area has not reached the critical point of vulnerability manifestation of population dynamics. One can even notice significant improvement trends in the last few years, by contrary to Bacău metropolitan area where a particular vulnerability has been felt since 1997-2000.

This divergence can be considered a mark of higher resilience increased capacity resulting from Iași Municipality, which, taken separately, also presents a much higher favourability even though, between 1997 and 2010, it has undergone an increasing vulnerability. Rural component of the two metropolitan areas manifested quite differently in close contact with high polarization ability of Iași, where the metropolisation can be considered a certainty, especially in the light of recent population dynamics.

It is the result of increasing regional polarization potential, together with the consolidation of the status of regional growth pole for Iași (Stoleriu, 2008). There should be noted that the delimitation of Bacău metropolitan area is poorly correlated with the actual capacity of polarization.

The coherency and functionality would have been higher if only the former suburban communities that are in direct contact with the municipality had been considered (Săuceşti, Iteşti and Nicolae Bălcescu). This is a sign of how arbitrary are these voluntary associations (official metropolitan areas), without actually relating to the polarizing potential of municipalities included in such structures.

Demographic structure resilience index (Irs) shows that vulnerability of demographic structures is much stronger in metropolitan areas as a result of negative dynamic accumulation, the only notable exception being the polarized rural municipalities of Iași that knew a slight improvement in demographic structure, corresponding to the dynamic resilience effect related to the displacement of significant contingent of young people from the city, that offset aging trends.

The values of population mobility resilience indicator **(Irm)** reflect certain realities that should be highlighted: Iași metropolitan area appears to be less vulnerable, because the municipality is an important attractor of immigration flows, primarily from Moldova Republic and Asian countries, a fact which is able to compensate the losses from permanent emigration directed to Western countries. It is another proof of high polarization capacity, this time at international level that provides an extra resilience to Iași metropolitan area. By contrary in Bacău, one finds an endo-dynamic character that makes the socio-demographic structures more vulnerable. In a more favourable economic context, this vulnerability can become an advantage, stimulating the return migration, but overall, Iași and its metropolitan area appears clearly favoured.

3.2.2. Social-economic indicators

Economic features are an engine of differentiated vulnerability: diversification and robustness that are able to create territorial resilience, while greater dependence and immobility are sources of vulnerability.

Economic resilience indicator (Ire) was calculated by weighting the evolving trends of three sets of statistics: employed population (1991-2012), unemployment (1997-2013), the share of gross domestic product (GDP) at county level from total national GDP (1991-2012). Although inconsistent, the three sets of data can capture the extent to which analysed territorial units were adapted to the rigors of the market economy. All values that indicate tendencies for specific time intervals were standardized by reporting them to the unit value. This indicator is strongly correlated with socio-demographic indicators, expressing rather differentiated trends: certain uniformity in the case of the metropolitan area of Iași, a sign of relative regional homogeneity between the city and metropolitan municipalities. This feature is connected to the innovative potential, but also to the competitive advantages that attract high investments and workplaces created within metropolitan area. Bacău faces a certain imbalance which disfavours the city in relation to neighbouring peri-urban localities, a sign of its socio-economic vulnerability, which correlates to a reduction in its economic importance at national level. Here also the regressive industry (deindustrialization) was also followed by incipient industrial reconversion, but the process was weaker and less diffused within metropolitan areas.

Urban infrastructure resilience index (Iri) was calculated on the basis of information on the construction of new houses (Fig. 3) and the share of population with access to utility networks (water supply, sewerage and natural gas) for the interval 1990-2012. It highlights the progress made in improving the quality of life in both cities and corresponding metropolitan areas. The index represents the average value of two derived indicators: the dynamics of housing resulting from successive mediation of evolving trends for each of the intervals, separated by the same temporal thresholds as in previous indicators, relative to the unit value (for standardization purpose) and the dynamics of the distribution networks, calculated in the same way as the average value of indicators specific to each category of utilities. For both metropolitan areas, this indicator shows positive values, reflecting a certain adaptation to changes, induced by the disappearance of the totalitarian regime, in the first place by returning to private ownership, which has stimulated investment in real estate and, secondly, after joining the European Union, by investments made using structural funds for public utilities infrastructure expansion. Higher values of rural areas are explained by the virtual absence under the communism of public distribution networks (except for a few places subject to systematization around Iași), but also because of the peri-urbanization trends, that described the evolution of indicators of population dynamics. In this way, differences between urban core and rural entities included within the metropolitan area decreased over time although there are still major gaps, closely related to the distance and accessibility. Compared to Iași, Bacău metropolitan area has lower values (particularly the city) of new housing construction which is an indication of lower resilience capacity. For example in 2008-2012, in Bacău there were built a number of just 884, compared to 3276 in Iași, four times more for a population only twice as large (Fig. 3).

The slower expansion of public utility networks can be explained by the lower surface (43.2 square kilometres, compared to 95.3 square kilometres in Iași) and higher density of housing in outlying neighbourhoods, but also by the effects of the massive industrialization and emigration of young labour force abroad.

3.2.3. Environmental indicators

The environment factors of resilience taken into account show lower functional coherence both in the metropolitan areas and cities. Lack of access to data series for most of the indicators constrained the analysis of these indicators to a more "static" one that can only be carefully used in order to control, differentiate and, partly, explain the socio-economic indicators described above.

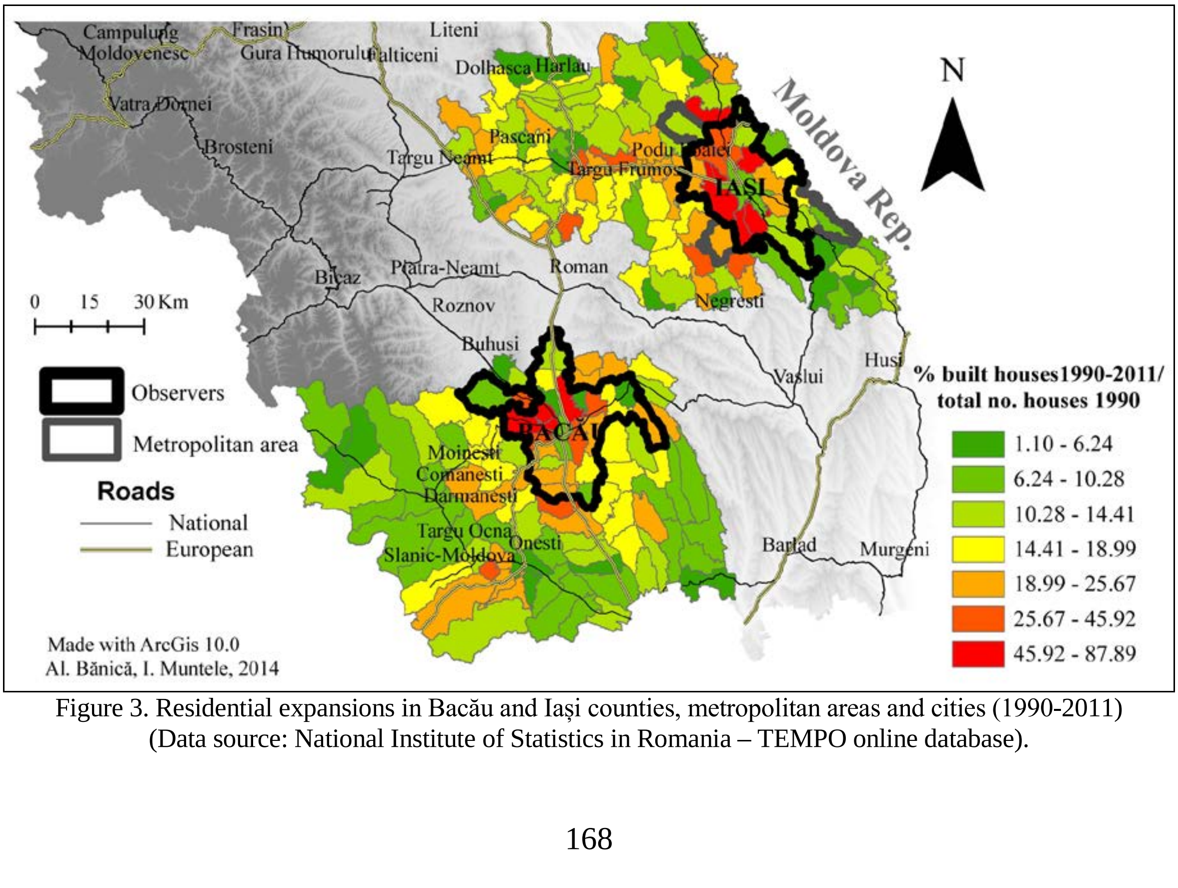

Figure 3. Residential expansions in Bacău and Iași counties, metropolitan areas and cities (1990-2011) (Data source: National Institute of Statistics in Romania – TEMPO online database).

Three derived indicators were considered, calculated and aggregated in order to obtain one complex *indicator of environmental resilience of urban* and peri-urban areas. The first indicator, *renewable energy index (Rei)* is based the progresses made by latest technological modernization in energy sustainability (green energy), taking into account the trend (annual growth) of the emerging domains of renewable energy – solar, wind, hydro, biomass, biogas- the installed capacity, all reported to total population for the last six years.

The presence of renewable energy equipment is finally a sign of modernization, technological innovation and thus of the possibility to diminish energy vulnerability. A significant difference can be noticed when comparing the two case studies. There are over 1000 MW installed in Bacău Metropolitan Area and only 6 MW in the corresponding territorial association from Iași. Nevertheless, the values for the two core cities are comparable: they both have implemented several small projects in solar energy (photovoltaic). In case of rural municipalities from metropolitan area there is a net difference in favour of Bacău's municipalities. Major projects are being implemented in Tamași, Gioseni or Saucești, while in Iași important investments in renewable energy domain are outside the metropolitan area for example in Dumești or Tibănești.

The second derived indicator – *green areas index (Gai)* show a positive trend for green areas in Bacău as new public parks were planned and built, while in Iași the expansion of built areas was sometimes made at the expense of oxygenating areas that are still better represented within the built-up area. Nevertheless both cities there is a decrease of green areas in favour of built-up areas and do not assure the minimum surface per inhabitant as established by European Union standards or by previous studies (Haq, 2011). The rural localities from both metropolitan areas represent a priceless reservoir of ecosystem services that should be preserved and capitalized by authorities: the green index has higher values in rural metropolitan areas compared to the cities.

Public green investments (Pgi) -the third derived indicator- places better Bacău city and some of its surrounding rural localities (Letea Veche, Buhoci, Traian) than Iași and its most dynamic communes in this field (Aroneanu, Lețcani). Clearly, this indicator should be used with caution, on the one hand, because it shows only a momentary situation characteristic for 2010-2012, on the other hand because the values are very much influenced by the size of the unit putting into advantage small communities that have access (sometimes small) projects that include environmental components. By standardizing to the unit, summing and averaging the three values an environmental resilience capacity index (ERCI) was obtained.

Based on the first two categories of indicators, a general index of socio-demographic and economic resilience (IRDE) was created by summing and averaging the corresponding values for the available periods. In order to obtain an annual mean, the environmental resilience indicator was weighted with a value proportional to the average number of years that comprise the environmental indicators.

By summing IRDE and ERCI, the final index illustrates the general urban resilience (GUR) (Table 4) for the two cities and metropolitan areas. It shows the downturn of Bacău city (especially after 2007) and the inconsistency of its metropolitan area in contrast to the great potential of the peri-urban by itself. Iași city and especially its surrounding area is more balanced and the latest years' data show an upward trend mostly because of the major social and economic dynamics, based on innovation and investments within the first belt of localities around the city core (Miroslava, Valea Lupului etc.).

4. CONCLUSIONS

The present work represents a preliminary evaluation for an integrated framework analysing vulnerability and resilience in Romanian urban and metropolitan areas. After formulating a common theoretical background, it proposes a sum of possible indicators for an integrated analysis taking into account exposure, sensitivity and response/adapting capacity of the studied areas.

Table 4 Socio-demographic, socio-economic indicators and environmental indicators of vulnerability and resilience in Bacău and Iași cities and metropolitan areas (MA)

Territorial unit	Ird	Irs	Irm	Ire	Iri	***IRDE***	Rei	Gai	Pgi	***ERCI***	**GUR**
Bacău city	-0.07	-0.21	-0.09	-0.17	0.09	*-0.09*	0.00	0.031	0.03	*0.061*	**-0.02**
Iași city	0,03	-0,17	0	-0,08	0,24	*0,00*	0.00	0.067	0.03	*0.097*	**0.01**
Bacău MA	-0,03	-0,14	-0,08	-0,25	0,16	*-0,07*	0.10	0.068	0.028	*0.196*	**-0.01**
Iași MA	0,07	-0,11	-0,01	-0,11	0,27	*0,02*	0.03	0.053	0.008	*0.09*	**0.15**
Bacău MA (rural)	-0,01	-0,02	-0,06	-0,23	0,29	*-0,01*	0,11	0.067	0.011	*0.188*	**0.16**
Iași MA (rural)	0,21	0,06	-0,01	-0,1	0,35	*0,10*	0.001	0.068	0.027	*0.096*	**0.40**

For reasons of access to data, only some of these indicators were actually aggregated, for the moment in order to compare urban units and components. The standardization and the successive integration of indicators highlighting the socio-demographic, economic and infrastructural vulnerability, but also the environmental and institutional resilience, finally resulted in a proposed *general urban resilience index* that could become, if revised and reiterated, an instrument for rational planning and strategic decisions.

The analysis of the three derived indicators and of the final index showed that the two cities and metropolitan areas are affected by different hazards (in terms of type, intensity, frequency) and respond differently based on their background, administrative-political decision making institutions, socio-economic structures, existing critical infrastructure, environmental resources etc. Iași metropolitan area is more functional, as it is a recognized growth pole, while Bacău metropolitan area should be reshaped in order to be better managed. Only the former suburban communes, in close proximity to the core-city, are actually connected and influenced by it and should be a part of the metropolitan areas. Iași city and metropolitan area play a regional role and has a higher demographic, social and economic resilience, while Bacău peri-urban area is more resilient in terms of environmental capacity potential.

In a broader sense, the outcome of this study relates to proposing quantitative milestones to turning crisis into opportunity for a sound, sustainable and safe urban future, if acknowledging the importance of integrating exposure to hazards, sensitivity, response and adaptive capacity factors to general development strategies and policy making. Governance and community networks should also be evaluated and measured more in depth as they have an essential role in diminishing vulnerability, providing resilience capacity.

ACKNOWLEDGMENTS

This work was supported by the strategic grant POSDRU/159/1.5/S/133652, co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007 – 2013

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Received at: 17. 10. 2014
Revised at: 31. 07. 2015
Accepted for publication at: 01. 09. 2015
Published online at: 08. 09. 2015