Centre for Research on Settlements and Urbanism

Journal of Settlements and Spatial Planning

Journal homepage: https://jssp.reviste.ubbcluj.ro

Recent Dynamics of Suburban Advancement and Building Densification in Relation to Landslide Exposure in the Main Cities of North-East Romania

Alexandru BĂNICĂ[1, 2], Marinela ISTRATE*[1], Ionel MUNTELE[1, 2], Adrian GROZAVU[1]

**Corresponding author*

[1] *"Alexandru Ioan Cuza" University, Faculty of Geography and Geology, Department of Geography, Iași, ROMANIA*

[2] *Romanian Academy - Iași Branch (ARFI), Geographic Research Center, Iași, ROMANIA*

alexandru.banica@uaic.ro 0000-0001-7781-342X

istrate.marinela@uaic.ro 0000-0002-1456-6772

ionel.muntele@uaic.ro 0000-0002-6242-850X

adriangrozavu@yahoo.com 0000-0002-4998-8625

DOI: https://doi.org/10.24193/JSSP.2024.1.02

Received: 30 January 2024

Received in revised form: 6 April 2024

Accepted for publication: 7 May 2024

Available online: 22 May 2024

K e y w o r d s: land use changes, building densification, suburban advancement, exposure, landslide probability, North-East Region of Romania

A B S T R A C T

We live in a complex and highly dynamic risk society, and given the massive environmental changes, exposure to hazards has become a critical concept that is part of all risk assessments made from a spatial perspective. In urban studies, evaluating exposure to different risk phenomena influences targeted policies and planning that can shape cities while making them safer. As in other post-socialist countries, in Romania, cities have had a highly divergent recent evolution, including processes such as urban shrinkage, the suburban advancement of cities, and urban sprawl. Focusing on seven cities from the North-East Region of Romania, the current paper is an exploratory study regarding the dynamics of exposure to landslides in relation to suburban advancement and densification of cities. Using the official statistics, available GIS databases and information based on satellite images illustrating urban land use changes in the last 20 years, the paper includes a general overview of the overall evolution of urban areas against landslide probability, followed by a more in-depth assessment of specific areas that were subject to functional change and currently include buildings that are susceptible to be affected by landslides. The results and conclusions converge towards the idea that the identified exposed areas, where actual ground movements are currently registered, need special attention from experts and authorities to identify and manage risks. The significance of our findings is underscored by their potential to inform and guide more effective territorial management and urban land use planning strategies.

1. INTRODUCTION

In a world that is increasingly diverse, complex and challenging, one of the reasons for the overall increase in the risk and impact of disasters is the expansion of human habitat and the densification of housing and infrastructure in urban, suburban and peri-urban areas (Van Den Eeckhaut et al., 2012). As cities expand towards the peripheries of the build-up area, which still have the advantage of relative proximity to the city centre, this suburban advancement involves converting former industrial and agricultural

land into residential and service areas. Moreover, sometimes this advancement is done in former areas with no specific function ("no man's lands"), sometimes in natural areas (forests, pastures, meadows) with lower favourability for building and living.

As in other post-socialist countries, in Romania, urban areas had a highly divergent recent evolution: firstly, the shrinkage of cities, the de-industrialisation followed by ex-urbanisation and de-urbanisation, when core urban areas lost population (Bănică et al., 2017; Eva et al., 2021); secondly, the suburban advancement of cities and the urban sprawl manifested by the diffusion of the urban population in the nearby rural areas, usually in a chaotic, unplanned or insufficiently planned manner. This divergence also manifested itself as an effect of lifestyle changes, primarily mobility due to more and more advanced motorisation of the population, temporary migration for work abroad with effects on individual aspirations, expansion of secondary residences, etc. (Suditu et al., 2010; Grigorescu et al., 2012; Dumitrache et al., 2016).

Although the population of cities in Romania decreased, in direct connection with de-industrialisation and ex-urbanisation of urban activities and against the background of urban sprawl, external migration and the decrease in the birth rate, the constructed areas continued to expand incrementally not only outside the built-up area but also inside it (Bănică and Picioruș, 2012; Ungureanu and Șoimoșan, 2023). New residential areas in cities capitalised on the positional advantages of some lands, benefiting from both proximity to the city and a cleaner, less disturbed environment. In the context of smart cities emergence, these peripheral areas can become the interface of diffusing "smartness" in rural areas (Ianoș et al., 2021).

Urban expansion is often attributed to the need for food, energy, space and other resources (Morar et al., 2021) under the circumstances of the increasing attractiveness of both suburban and peri-urban areas that combine the advantages of urban proximity with those of a quieter lifestyle in a quasi-rural, less polluted and less crowded areas. These areas are found in the previously unbuilt territory of the administrative-territorial unit of the city and, often, in the neighbouring communes. In the present study, we will consider only the extensions inside the urban area. The apparent deficiencies and lack of rigorousness of legislation and practices in land use and urban planning (Benedek, 2013) have favoured this uncontrolled expansion and densification of the built space of the cities and the emergence of new informal settlements. However, they do not respect the building norms in force. These new neighbourhoods are inhabited by vulnerable social groups, which adds to the fact that they are located in areas exposed to a significant probability of hazard occurrence (Oliva-González et al., 2019). All these deserve the attention of the scientific community, urban decision-makers, and responsible institutions. At the local scale, one can sometimes notice an increase in the exposure degree to certain natural or human-induced risk phenomena, e.g., the installation or reactivation of landslides (Reichenbach et al., 2014; Sujatha and Rajamanickam, 2015). Mass movements, in general, and landslides, in particular, are geomorphic hazards that can generate economic, social and environmental consequences. It is shown in the literature that among other causal factors such as geology (lithology), slope, elevation, etc., which are more stable, land use and land cover changes are dynamic drivers of landslide hazards associated with human activities (Rabby et al., 2022). Thus, changes in slope geometry, vegetation density, and land use, in general, will affect the runoff coefficient and rainwater filtration, increasing the potential for landslides (Andriani et al., 2021). Also, in the context of climate change, studies show that landslide hazards are most sensitive to precipitation variations in urbanised areas. Therefore, the cities' expansion through the densification of existing constructed areas and the development of new built-up areas by changing the land use in specific locations can increase the probability of landslide occurrence (Johnson et al., 2021).

In Romania, one of the most exposed countries to landslides in Europe, which makes it a landslide hotspot (Jaedicke et al., 2014; Micu, 2017; Jurchescu et al., 2017), these phenomena often represent the dominant process of shaping the slopes. Landslides are controlled by the geological factor, relief and land use and triggered by torrential rains, earthquakes and human activities. They can occur in all relief units but have a greater frequency in areas with greater structural and petrographic diversity, especially in hilly areas, such as the Subcarpathian area, in sedimentary mountainous areas (i.e. flish deposits in Eastern Carpathians), but also plateau areas, such as the Moldavian Plateau, the Transylvanian Depression, and the Getic Plateau (Grecu et Comănescu, 2010; Mihai et al., 2014; Micu, 2017; Bălteanu et al., 2020; Grozavu and Patriche, 2021). As mentioned, intensifying urban land occupation in susceptible areas increases landslide exposure. Some authors consider exposure as an intrinsic component of vulnerability (Cutter, 2013; Sharma and Ravindranath, 2019), while others argue that it is separate from vulnerability, i.e., a simple contact or overlap between hazard and vulnerable society (Cardona et al., 2012). However, in general, the exposure refers to the entire population and other elements at risk that are located in the area prone to the manifestation of a hazard (United Nations International Strategy on Disaster Reduction, 2015).

Through the lens of the present study, two types of evolution can increase the exposure to landslides: the densification of constructed areas in already exposed zones and the advancement of constructions by land use changes in specific areas where the susceptibility to landslide hazard is high.

Population growth and a higher construction density increase exposure (and often) vulnerability to landslide hazards (Bourenane and Bouhadad, 2021). It is also a fact that with the emergence of new construction materials and technologies, some lands, once considered unsuitable for construction, have become usable in this sense (Alupoae et al., 2014).

Our study focuses on the relationship between land use changes and exposure to landslide risk in seven important cities from the North-East Region of Romania. The central hypothesis is that densification and extension of built areas within the limits of cities/towns have increased the exposure to landslides. The specific objectives are: 1) to assess, at a general level, for all towns and cities in Romania, the relationship between the suburban advancement of the built space and the probability of the occurrence of landslides; 2) to analyse the dynamics of the built space in seven cities of the North-East region; 3) to assess the overlap of the new areas of suburban advancement or buildings densification within the administrative limits of the city/town over the areas with a high probability of landslides; 4) to discuss the appropriate policies and measures to address emerging risks resulting from the increasing exposure to landslides in the urban environment.

This approach integrates the concepts of built space dynamics, exposure, representing people, properties and activities located in hazard-prone areas (Raduszynski and Numada, 2023) and landslide spatial probability of occurrence, i.e., landslide susceptibility (Guzzetti et al., 2006; Magliulo et al., 2008; Alexoudi et al., 2011). The overall goal is to get a general picture of these processes in the last two decades and to stress the need for urban policies to counter these issues in order to improve the safety and sustainability of urban areas.

2. DATA AND METHODOLOGY

Our study is based on open-access data from various sources aggregated at the city/town level. Still, it also tries to identify problematic areas within the selected cities from the North-East Region. The article starts with a general assessment of urban development and the increase or decrease of the general level of exposure to landslides at the national level for the 319 towns and cities, including 103 municipalities. Further, the focus is moved to the scale of the North-East Region, analysing as case studies the county's capital cities (Botoşani, Suceava, Iaşi, Piatra-Neamţ, Bacău, Vaslui) as well as the Roman municipality (which is essential both in terms of population number and central geographical position within the region) (Ungureanu, 2022).

Some categories of data were used to conduct our research first at the city level and then at a micro-scale (differentiations within the city built-up area).

a). For analysing the inter-urban and intra-urban differentiations in the case of the selected cities from the North-East region, the most important indicators were extracted from an extensive database created within the project "Elaboration of Urban Policy as a Tool for Strengthening the Administrative Capacity and Strategic Planning of Urban Areas in Romania" (SMIS code 129720, SIPOCA code 711), implemented by the Ministry of Development, Public Works and Administration (MDLPA) with the support of the World Bank (2019-2021) and made publicly available on the site www.citadini.ro (Romanian Urban Policy, 2020).

In addition, some fundamental indicators were taken directly from the National Institute of Statistics in Romania database, Population and buildings statistics: Tempo online – Romanian Institute of Statistics, or from the Territorial Observatory provided by the Government of Romania through the Ministry of Regional Development and Public Administration (see Table 1). The indicators were considered cover variable periods, but we tried to identify temporal overlaps that would allow us to conduct relevant statistical analyses.

b). For differentiation at a microscale, the vector data of Corine Land Cover were used for the years 2000, 2006, 2012, and 2018 to identify land-use changes and highlight the areas intended for housing construction. We considered it essential to identify the areas that changed their previous functionality in the interval 2000-2018. Regarding the susceptibility to landslides within cities, we capitalised again on some of the results of the Romanian Urban Policy (2020). A methodology based on a statistical bivariate method – the BSA model – was used to make a detailed assessment (Roşca et al., 2016). Susceptibility categories, based on the probability of occurrence of landslide-degraded lands were designed by using the classical methodology in effect in Romania (GD 447/2003), correlating expert opinion and the information from the existing maps based on specific predictors (MLPDA and WBG, 2020; Romanian Urban Policy, 2020). These predictors include eight factors weighted to obtain specific coefficients referring to lithology, geomorphology, structure, hydrology, hydrogeology, seismic, forest and anthropogenic influences. We used the resulting GIS database based on a probabilistic model of landslide susceptibility (BSA model) based on the coefficients mentioned above, which was applied and made available by the Romanian Urban Policy documents in 2020. Of course, generating a valid landslide susceptibility map is a challenging and complex process (Kerekes et al., 2018), and there are alternatives to this model. Still, our assessment aims to derive only a general perspective on the issues that could be detailed and analysed more in-depth in further studies. We also used specific opportunities provided by satellite data to highlight the actual processes of land displacement. Thus, the European Ground Motion

Service provides consistent and reliable information regarding natural and anthropogenic ground motion with millimetre accuracy (EGMS Explorer). However, certain limitations exist in identifying some movements in the direction of satellite displacement. Still, the errors are relatively negligible at the scale and level of detail for the landslide analysis in the present study. We are interested in only a general picture of the areas that create or will create problems in the future and possible destruction or loss in the event of risk phenomena.

Table 1. The indicators used to assess exposure to landslides at town/city level.

Abbreviation	Indicator	Contents of indicators	UM	Period/Year	Source
EXT_BUILTUP	The percentage of suburban advancement compared to the year 2000	The ratio between the extended urban area in 2018 and the existing urban area in 2000	%	2000 - 2018	INS-TEMPO
BUILT_UP	Built-up area	The built-up area of municipalities and cities	sq km	2018	INS-TEMPO
EXT_CONSTR	The growth rate of constructed areas	The indicator represents the rate of change of the built surface between 2006-2018	%	2006-2018	Copernicus Land Monitoring
LAND_CONS	The ratio between land consumption rate and population growth rate	The relationship between the rate of land consumption and population growth to promote sustainable urban advancement	%	2000-2018	Copernicus Land Monitoring; INS -TEMPO
HOUSES	Number of houses	Total no. of houses existing at the end of the year in the selected cities (growth rate %, 0=year 1993)	houses	1993-2020 (2000-2018)	TEMPO Database, INS
DENS_BUILTUP	Buildings density	The ratio between the number of buildings and the built-up area	buildings/ sq km	2018	INS-TEMPO
POP% 2010-2019	Population growth rate	The percentage by which the population in 2019 increased or decreased compared to the population from the 2010 census, the latter being considered 100%	%	2010-2019	INS-TEMPO
POPULATION AT RISK	The population of the territorial administrative unit subject to the risks of landslides by risk class	The population of the territorial administrative unit is subject to the risk of landslides by risk class	%	2019	Romanian Urban Policy
PROBABILITY	Classification by classes of the likelihood of occurrence of landslides	Classification by classes of probability of occurrence of landslides. The indicator was calculated at the level of the studied cities	low, medium, medium-high, high probability	-	Romanian Urban Policy

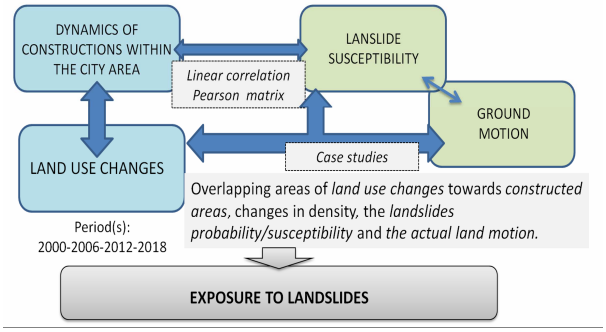

Fig. 1. Methodological scheme.

The scheme below (Fig. 1) is a synthesis of our methodological approach, which aimed to demonstrate the connections between the dynamics of the built space within the city areas, determined by the successive changes in the way of land use and landslide susceptibility, which can be highlighted even better by the current movements of the superficial layer.

The applied methods belong to classical statistics, using linear correlations, respectively, correlation matrices (Pearson), to suggest the statistical relationship between the elements taken into account. The case studies were illustrated by cartographical results made by overlaying the thematic layers in GIS to highlight newly constructed areas currently exposed to landslides.

3. RESULTS AND DISCUSSION

To establish some general coordinates for the recent evolution of building densification in areas exposed to landslides, we first conducted a statistical assessment of the situation at the national level, taking into account all towns and cities of Romania. Only then we focused and deepened the analysis on the main cities in the North-East region.

3.1. National level analysis

The advancement of constructed areas and the densification inside the city are more present in smaller,

more dynamic cities and towns. The surface occupied by construction increased, especially in the cities in the centre and North-East region, which had a more pronounced dynamics, and some newer towns in the metropolitan area of Bucharest. Still, larger cities were also subject to densification and urban restructuring (e.g. Baia Mare, Alba Iulia). In Figure 2, we highlight this indicator and the study area of the present paper.

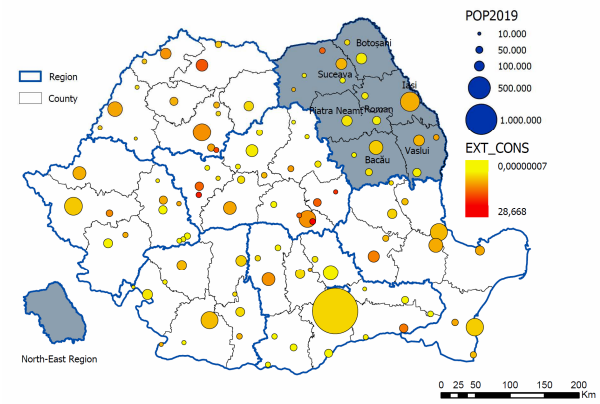

Fig. 2. Expansion of built spaces within Romanian municipalities (2000-2018). A focus on the study area (North-East Region) *(source: own elaboration; Data source: Romanian National Institute of Statistics).*

In some cases, this densification was achieved in urban areas significantly susceptible to landslides, especially in the centre of the country (Fig. 3a).

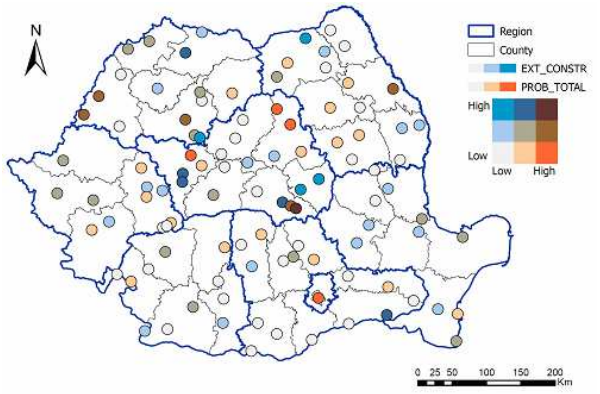

Fig. 3a. The relationship between suburban advancement and landslide susceptibility *(source: own elaboration; Data source: Romanian National Institute of Statistics, Romanian Urban Policy).*

In terms of the total population and the residential density, these have also increased primarily in the cities bordering the capital of Romania, Bucharest, but also in cities that have expanded their urban areas (for example, the case of Vaslui, which included areas previously located in the suburbs). Towns and cities with relatively high demographic growth between 2010 and 2019 and areas susceptible to landslides are generally found in the North-West and South-East Regions (Fig. 3b).

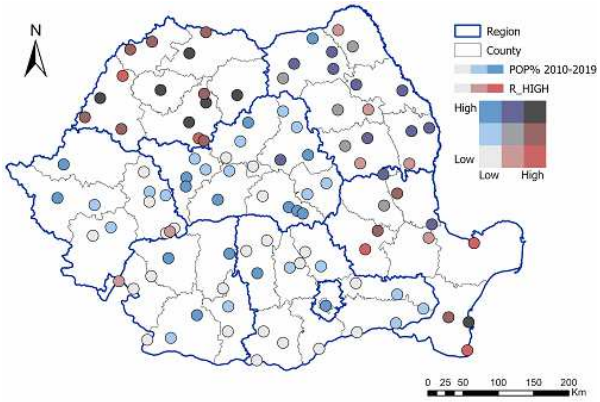

Fig. 3b. The relationship between population growth and landslide exposure growth *(source: own elaboration; Data source: Romanian National Institute of Statistics, Romanian Urban Policy).*

By contrast, in certain areas, such as the Romanian Plain and the Western Plain, the towns and cities are virtually not exposed to landslides at all. However, the direct link between the expansion of inhabited areas and susceptibility to landslides must be studied punctually, differentiated in each city, employing case studies, i.e., the seven cities in the North-East region analysed in the second section of the results.

However, the extension of the constructed area came with the downside of increased (very high and total) probability exposure to landslides (correlation coefficient of 0,159). On the contrary, the North-Eastern Region's densification occurred in medium-high and medium probability areas (medium-high - 0,221, medium - 0,130).

Table 2. Correlation matrix (Pearson).

PROBABILITY	EXT_BUILTUP	EXT_CONSTR	LAND_CONS	DENS	DENS_BUILTUP18	DENS_BUILT%11_18	POP% 10-18
LOW	-0.030	-0.067	0.045	0.001	-0.041	-0.046	-0.049
MEDIUM	-0.002	**0.130**	0.030	-0.041	-0.036	**-0.158**	0.055
MEDIUM_HIGH	-0.043	**-0.221**	0.010	0.107	**0.165**	**0.271**	0.005
HIGH	0.034	0.036	-0.067	-0.049	-0.013	-0.010	-0.048
VERY_HIGH	**0.159**	-0.023	0.014	-0.090	**-0.134**	-0.077	-0.044
TOTAL	**0.170**	0.105	0.012	**0.147**	**0.127**	-0.037	-0.044

Values in bold are different from 0 with a significance level of alpha=0.05

It highlights once again that the highest share of the population exposed to landslides is concentrated in Romania's North-Western and South-Eastern regions. The Pearson correlation matrix also shows that cities with a high density of built space in urban areas have a MEDIUM-HIGH probability of landslides

occurrence. Meanwhile, lower densities are found in areas with MEDIUM susceptibility; therefore, we can argue that there is a relative increase in landslide susceptibility (see Table 2). We should note that, in the current approach, we consider the terms of probability and susceptibility as equivalent.

3.2. Landslide susceptibility and exposure in the main cities from the North-East Region

The expansion of the built-up area within the administrative area of the main cities in the North East Region was carried out significantly differently. According to the data available from the National Institute of Statistics in Romania, in 1990-2000, the growth rate varied between 3% (Bacău) to more than 66.5% in Iași and Suceava, which had the highest growth rate. Intermediate values of this increase were recorded in Piatra Neamț 58%, Roman 38.91% or Botoșani 46.8%. After 2000, these oscillations had much lower values. Between 2001-2010 Iași increased its urban population by 17.03% and Vaslui by 19.44%, while in the other municipalities, the growth was reduced (Piatra Neamț, Roman, Botoşani) or non-existent (Bacău and Suceava). An even more minor increase occurred after 2011 when only Piatra Neamț added an area representing 11.17% to the existing urban area, and in Bacău, an additional area of 11.28% was included. Except for Iasi, where the increase of constructed areas began in the 1990s and continued at an accelerated pace until 2010, after which the urban expansion took place almost exclusively towards the neighbouring communes (Fig. 4).

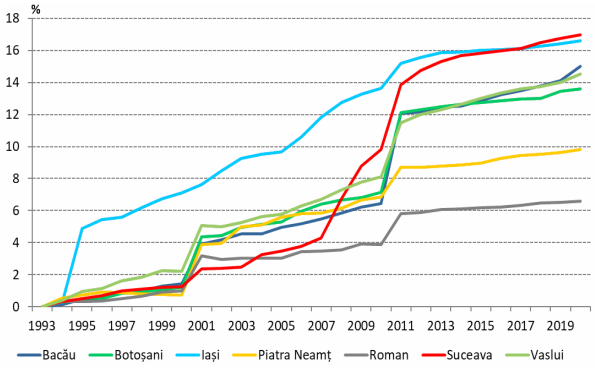

Fig. 4. Total no. of houses existing at the end of the year in the selected cities (growth rate %, 0=year 1993) *(data source: TEMPO Database, INS).*

The most spectacular such expansion was the municipality of Suceava, with a maximum increase between 2007 and 2010, and which, as a whole, reached in 2020 the same growth rate compared to the reference year 1993 (given the availability of data) as the municipality of Iasi (about 17%).

On the contrary, Roman (approximately 6%) and Piatra Neamț (10%) had the lowest growth rates. In Suceava, the rhythm has accelerated since 2007. The expansion of constructions was visible in Iași, Botoșani, Vaslui, and Suceava, but much less in Roman or Piatra Neamț in the context of massive de-industrialisation and outmigration.

Meanwhile, the surface of the territorial unit was expanded in Vaslui, Piatra Neamț and Iași by including areas more susceptible to landslides. Meanwhile, the population of most of the larger Romanian cities decreased in the 1990s and 2000s. However, in the last decade, a population growth trend in the city has been observed, for example, in Iași, Vaslui, and, to a lesser extent, in Suceava. Most of the identified transformations/developments of newly constructed areas within the city area occurred in the 2000s, while after 2006, most of the urban expansion took place outside the city area. A large number of new buildings appeared in Iași and Botoșani, while the built-up areas of Piatra Neamț, Iași and Bacău had the most significant growth. Comparatively, Suceava has maintained the exact limits of the built-up area, while, in terms of newly built buildings, the municipality of Roman experienced the most unfavourable situation. This issue, along with the specific geographical conditions (location on the terraces of Moldova and Siret rivers, near their confluence), also influences the expansion of areas susceptible to landslides, which in Roman used to be negligible.

On the other hand, Iași and Bacău have comparatively more extensive areas of land with very high susceptibility. The areas of expanded built space within the city limits emerged by land use changes from agricultural use (predominantly arable land and meadows) to densely built or more diffuse spaces or other areas with constructions. These sometimes overlap with less natural favourability, including areas with potential landslides (Fig. 5).

The residential or commercial areas resulting from reconfiguring former industrial sites have a more favourable position. Most of these land use changes occurred in Iasi (480.85 ha), followed by Bacău (174.53 ha), Suceava (141 ha) and Botoșani (129 ha). Among these extended areas marked by the change in land use, we can use, for illustration, two sample areas. The first (1) is located in Iași in the Bucium neighbourhood situated in the south of the city and where it is observable (by using the data provided by Ground Motion Service - EGMS Explorer), namely a downward movement of the land by 5 mm in the period 2015-2021 (Fig. 6).

The second sample marked in Figure 5 and Figure 6 belongs to a newly constructed area in the Marăţei neighbourhood of Piatra Neamț at the base of the Pietricica rock massif, where the land movement was around 8 mm in the five years of the assessment. In the third (3) area, located in the Western part of the municipality of Bacău (towards the peri-urban commune of Măgura), the displacement reaches only 3 mm for the same period. Even if these values are not close to the maximum values recorded in the three

municipalities for ground motion, they are still significant and indicate a considerable susceptibility in the medium and long term. Inadequate occupation of lands that are highly susceptible to landslides (re)activation can be observed, for example, in the south of Iaşi (Bucium), but also in Roman (in the northwest) and, to a lesser extent, in Botoşani and Suceava.

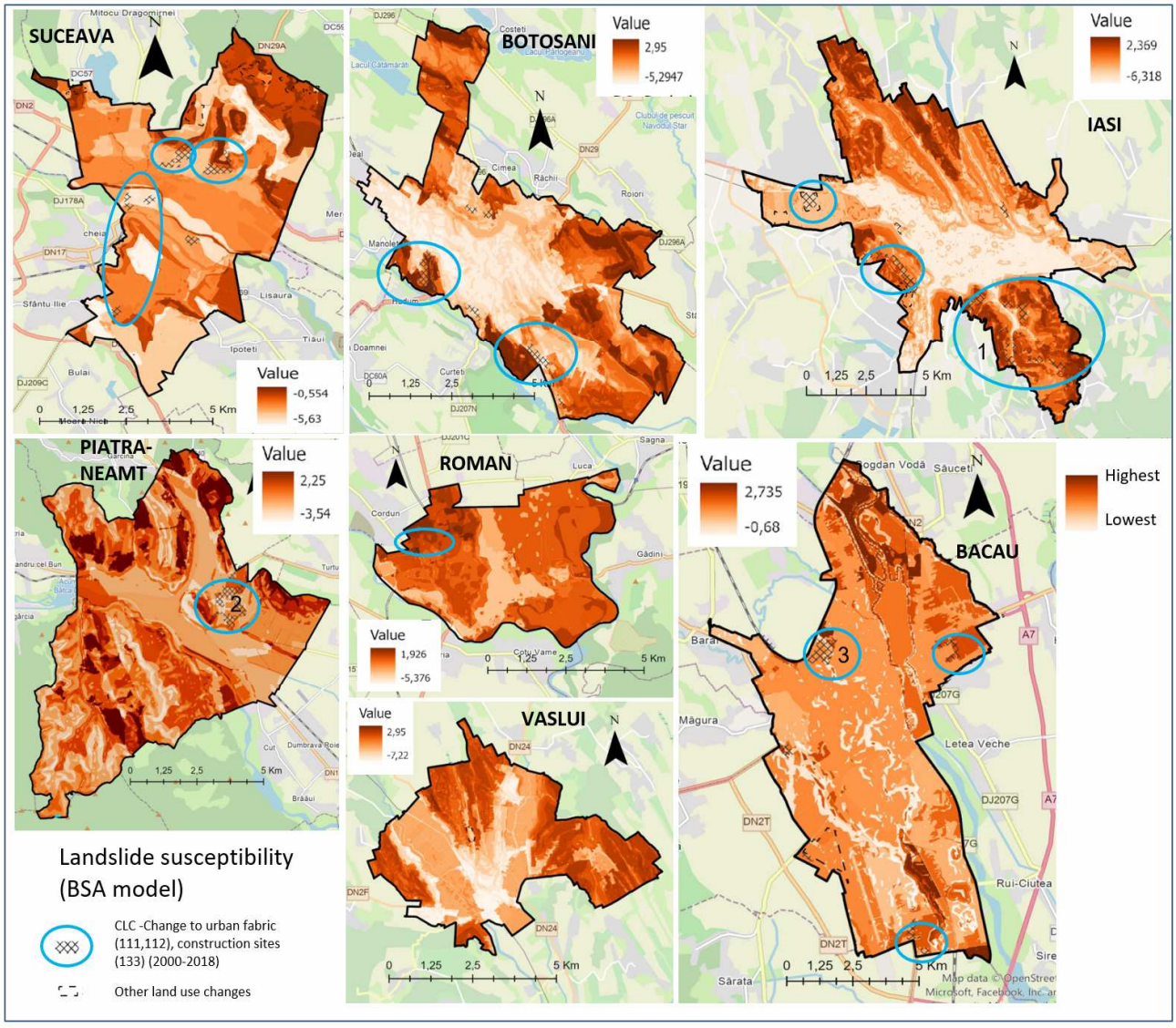

Fig. 5. Landslide susceptibility, land-use change areas (2000-2018) and the selected ground motion samples *(data source: Romanian Urban Policy, 2020)*.

The suburban advancement of Vaslui city, with newly constructed areas that present a significant population exposed to landslides, has been added. However, they are not areas known for active landslides but lands identified as having potential for mass movement occurrence. Even if, most often, the recently built areas do not entirely overlap the most restrictive areas, tendencies of expansion are noted towards areas that are prone to landslides. Moreover, we can assume that real estate pressure for more constructions in areas with high or very high landslide susceptibility will increase in the future.

Meanwhile, the exposure varies very much across categories. The situation of the analysed cities is very different: the pressure of the built space can be more significant in the cities where there is no increase in the constructed area, but only a more substantial densification within the city's limits. There are cities where building areas are advancing and are being densified to the same extent. Theoretically, the most endangered city is Vaslui (especially in the neighbourhoods included recently in the built-up city area), followed by Piatra Neamț and Iași; while looking at the actual probability of occurrence and the current events that are registered, the threat is higher in Iaşi, but also in Botoşani and Suceava. According to the Risk analysis and management plan (PAAR) in Vaslui, areas with landslides could be reactivated, especially in the eastern and western peripheral areas and the northern part of the city. However, these areas were statistically identified as areas susceptible to landslides, but not many cases of actual (active) landslides were

documented. On the contrary, in cities with (theoretically) lower susceptibility, such as Botoșani, former assessments identified the highest number of registered active landslides (33) in the NE Region (Niculiță et al., 2017).

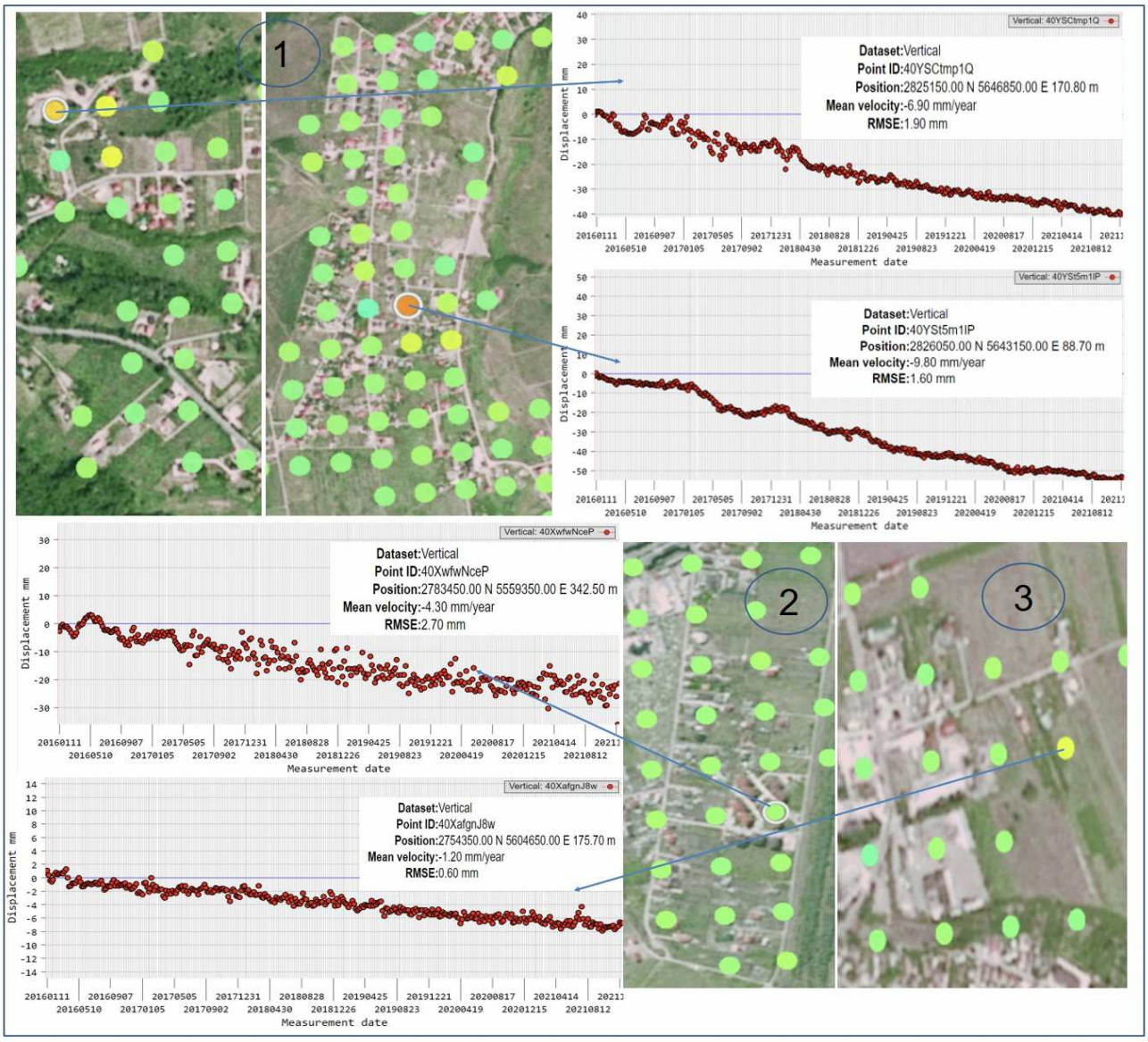

Fig. 6. Ground motion samples in selected cities (1 – Iași; 2 – Piatra Neamț; 3 – Bacău) *(source: EGMS Explorer).*

Our results, even being general and having a considerable margin of error, still give an insightful picture of a problem that should be prioritised by the decision-makers of many urban settlements where there are densification processes or suburban expansion of the habitat. The paper's outcomes can be used to ground the policies related to the national and regional system of urban settlements and urban planning at the territorial unit or neighbourhood level. Knowing the natural favourability and the restrictions related to building can be essential for adopting urban policies that consider the opportunities and obstacles set by the natural environment on the path of urban development. The policy response of the decision makers should concentrate on preventing the increase of risk through hazard mitigation and land-use planning strategies and policies. Newly developed areas with higher susceptibility to landslides and ongoing land movements require greater attention from experts and authorities to manage potential risks properly. A key element is making transparent and responsible decisions regarding the authorisation of constructions in areas that could pose shorter or longer-term issues. Also, the authorities should focus on consolidating the existing buildings to reduce the potential damages. More detailed studies must be done in all these cases using appropriate and recent data that can be useful to address the present global (and local) modification related to climate changes, i.e. the increase in temporal variability of precipitations with pronounced alternation of drought and that could be triggers of landslide especially in sensitive areas.

4. CONCLUSIONS

The present study explored the relationship between suburban construction advancement and densification patterns in the Romanian cities' administrative areas in relation to exposure to landslides. We were limited to the official administrative units. Therefore, we did not concentrate on urban sprawl but on the in-situ transformations. The current paper is a general overview that shows spatial differentiation in susceptibility and consequent exposure to landslides requiring differential territorial planning and development policies. The assessment made at the Romanian national level showed some specific patterns of increasing exposure to landslides in cities in the North-Western and Eastern regions of Romania. Moreover, the seven case studies in the North-East region illustrated various situations. However, we only focused on a few areas of interest that were subject to land use changes and are potentially more susceptible to potential landslides. We also tried to test these probabilities by confronting them with data on ground motion obtained by Copernicus Land Monitoring Service. However, more accurate methods could be applied for better results (Necula et al., 2021).

Meanwhile, some concerns emerged mainly in the case of the more Northern cities (Suceava, Botoşani, Iaşi) and, to a lesser degree, in the case of others (Bacău, Piatra Neamţ, Vaslui, Roman). The agglomeration patterns (i.e. areas that did not change their use but were densified) were not explored in depth. Assessing the favourability and the restrictions at different scales is vital for raising awareness about the existing situation and informing targeted and general national, regional and local urban policies. The MDLPA and World Bank project (used by us in the current assessment for assessing susceptibility to landslides) covered a stringent need to analyse all urban problems. Still, a comprehensive and ambitious approach can make room for errors. The use of indirect methods such as bivariate statistics (BSA) has several drawbacks: simplification of the factors that condition landslides (using only easy-to-map and available indicators such as slope, angle or lithology) and the high share of generalisation (in fact, landslides do not happen under the same conditions in all areas and the causal factors might be different for each landslide individually (Kojima et al., 2000; Van Westen et al., 2003). Therefore, more profound analyses need to be done, especially when assessing landslide probability. Also, the use of CLC is another limitation as the changes in land cover are considered in a relatively basic manner (with some errors that are challenging to detect and manage), and the analysis needs to be supplemented by a more careful look based on time-series of satellite images to identify all changes, both expansion and densification. Meanwhile, more accurate results that can be obtained in the future need to be integrated into development strategies to acknowledge the restrictions and risks and to capitalise on the opportunities offered by the territory for sustainable urban policies.

REFERENCES

Alexoudi M. N., Manolopoulou S. B., Papaliangas Th., Patronis C. (2011), Landslide Risk Assessment and Management of the Florina-Pisoderi-Kastoria Roadline (Greece). Journal of Environmental Protection and Ecology 12(1), 114-124.

Alupoae D., Asuencei V., Tuns I. (2014), Landslides, a Direct Result of Human Activities and Environmental Factors. Bulletin of the Transylvania University of Braşov. Series I: Engineering Sciences 7(56) No. 1 Special Issue, 1-6. URL: https://webbut.unitbv.ro/index.php/Series_I/article/view/4780/3678

Andriani A., Putra G. D., Ramadhani S., Putra H. G. (2021), Analysis of landslide potential due to changes of land use/land cover at the Kuranji watershed, Padang using normalised difference built-up index (NDBI). E3S Web of Conferences, 331, 03007. DOI: https://doi.org/10.1051/e3sconf/202133103007

Bălteanu D., Micu M., Jurchescu M., Malet J. P., Sima M., Kucsicsa G., Dumitrică C., Petrea D., Mărgărint M. C., Bilaşco Ş., Dobrescu C. F., Călăraşu E. A., Olinic E., Boţi I., Senzaconi F. (2020), National-scale landslide susceptibility map of Romania in a European methodological framework. Geomorphology, 371, 107432. DOI: https://doi.org/10.1016/j.geomorph.2020.107432

Bănică A., Istrate M., Muntele I. (2017), Challenges for the Resilience Capacity of Romanian Shrinking Cities. Sustainability, 9(12), 2289. DOI: https://doi.org/10.3390/su9122289

Bănică A., Picioruş D. (2012), Post-communist spatial restructuring in Bacău Municipality (Romania). Scientific Annals of "Al. I. Cuza" University of Iaşi, Geography series, 58, 61-78. URL: https://nbn-resolving.org/urn:nbn:de:0168-ssoar-319589

Benedek J. (2013), The Spatial Planning System in Romania. Romanian Journal of Regional Science, IX (2), 23-30. URL: https://www.researchgate.net/publication/306153384_The_spatial_planning_system_in_Romania

Bourenane H., Bouhadad Y. (2021), Impact of Land use Changes on Landslides Occurrence in Urban Area: The Case of the Constantine City (NE Algeria). Geotechnical and Geological Engineering, 39, 1–21. DOI: https://doi.org/10.1007/s10706-021-01768-1

Cardona O. D., Van Aalst M. K., Birkmann J., Fordham M., McGregor G., Perez R., Pulwarty R. S., Schipper E. L. F., Sinh B. T., Decamps H., Keim M., Davis I., Ebi K. L., Lavell A., Mechler

R., Pelling M., Pohl J., Oliver-Smith A., Thomalla F. (2012), Determinants of risk: Exposure and vulnerability. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In Field C. B., Barros V., Stocker T. F., Qin D., Dokken D. J., Ebi K. L., Mastrandrea M. D., Mach K. J., Plattner G.-K., Allen S. K., Tignor M., and Midgley P. M. (eds.). A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, and New York, NY, 65-108. URL: https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap2_FINAL-1.pdf

CORINE Land Cover (n.d), https://land.copernicus.eu/pan-european/corine-land-cover. Accessed on 01.09.2023.

Cutter S. L. (2013), Vulnerability. In: Bobrowsky, P.T. (eds) Encyclopedia of Natural Hazards. Encyclopedia of Earth Sciences Series. Springer. Dordrecht. ISBN: 978-90-481-8699-0. DOI: https://doi.org/10.1007/978-1-4020-4399-4_40

Dumitrache L., Zamfir D., Nae M., Simion G., Stoica I. V. (2016), The Urban Nexus: Contradictions and Dilemmas of (Post)Communist (Sub)Urbanisation in Romania. Human Geographies, 10(1), p. 39-58. DOI: http://dx.doi.org/10.5719/hgeo.2016.101.3

EGMS Explorer (n.d.), https://egms.land.copernicus.eu/. Accessed on 04.05.2023.

Eva M., Cehan A., Lazăr A. (2021), Patterns of Urban Shrinkage: A Systematic Analysis of Romanian Cities (1992–2020). Sustainability, 13(13), 7514. DOI: https://doi.org/10.3390/su13137514

Grecu F., Comănescu L. (2010), Special issues related to the landslides of Romania. Annals of the University of Bucharest, Geography Series, 59, 21–29. URL: https://www.annalsreview.geo.unibuc.ro/2010/2010_Grecu%26Comanescu.pdf

Grigorescu I., Mitrică B., Kucsicsa G., Popovici E. A., Dumitraşcu M., Cuculici R. (2012), Post-communist land use changes related to urban sprawl in the Romanian metropolitan areas. Human Geographies, 6(1), 35–46. DOI: https://doi.org/10.5719/hgeo.2012.61.35

Grozavu A., Patriche C. V. (2021), Mapping landslide susceptibility at national scale by spatial multi-criteria evaluation. Geomatics, Natural Hazards and Risk 12(1), 1127–1152. DOI: https://doi.org/10.1080/19475705.2021.1914752

Guzzetti F., Reichenbach P., Ardizzone F., Cardinali M., Galli M. (2006), Estimating the quality of landslide susceptibility models. Geomorphology, 81(1-2), 166–184. DOI: 10.1016/j.geomorph.2006.04.007

Ianoş I., Cercleux A.L., Cocheci R. M., Tălângă C., Merciu F. C., Manea C. A. (2021), Smart City Needs a Smart Urban-Rural Interface. An Overview on Romanian Urban Transformations. In J. C. Augusto (ed), Handbook of Smart Cities. Springer International Publishing, 1-21. DOI: https://doi.org/10.1007/978-3-030-15145-4_89-1

Johnson J. A., Ruta G., Baldos U., Cervigni R., Chonabayashi S., Corong E., Gavryliuk O., Gerber J., Hertel T., Nootenboom C., Polasky S., Ruta G. (2021), The Economic Case for Nature: A Global Earth-Economy Model to Assess Development Policy Pathways. World Bank, Washington, D.C. https://openknowledge.worldbank.org/handle/10986/35882

Jaedicke C., Van Den Eeckhaut M., Nadim F., Hervás J., Kalsnes B., Vidar Vangelsten B., Smith J. T., Tofani V., Ciurean R., Winter M. G., Sverdrup-Thygeson K., Syre E., Smebye H. (2014), Identification of landslide hazard and risk 'hotspots' in Europe. Bulletin of Engineering Geology and the Environment 73, 325–339. DOI: https://doi.org/10.1007/s10064-013-0541-0

Jurchescu M., Micu D., Sima M., Bălteanu D., Dragotă C., Micu M., Bojariu R., Dumitrescu A., Senzaconi F. (2017), An approach to investigate the effects of climate change on landslide hazard at national scale (Romania). In: Niculiţă M., Mărgărint M.C. (eds) Proceedings of the Romanian Geomorphology Symposium, 33rd edition, Alexandru Ioan Cuza" University Press, 121–124. URL: https://geomorfologie.ro/documente/Proceedings_SNG2017_ISSN_2559-c.pdf

Kerekes A. H., Poszet S. L., Gál A. (2018), Landslide susceptibility assessment using the maximum entropy model in a sector of the Cluj-Napoca Municipality, Romania. Revista de Geomorfologie, 20(1), 130–146. DOI: https://doi.org/10.21094/rg.2018.039

Kojima H., Chung C. J., Van Westen C. J. (2000), Strategy on the landslide type analysis based on the expert knowledge and the quantitative prediction model, ISPRS congress. International Archives of Photogrammetry and Remote Sensing, XXXIII, Part B7, 701–708. URL: https://www.isprs.org/proceedings/xxxiii/congress/part7/701_XXXIII-part7.pdf

Magliulo P., Di Lisio A., Russo F., Zelano A. (2008), Geomorphology and landslide susceptibility assessment using GIS and bivariate statistics: a case study in southern Italy. Natural Hazards 47, 411–435. DOI: https://doi.org/10.1007/s11069-008-9230-x

Mihai B., Savulescu I., Sandric I., Z. Chitu Z. (2014), Integration of landslide susceptibility assessment in urban development: a case study in Predeal town, Romanian Carpathians. Area, 46(4), 377-388. DOI: https://doi.org/10.1111/area.12123

Micu M. (2017), The systematic of landslide processes in the conditions of Romania's relief. In: Rădoane M., Vespremeanu-Stroe A. (eds) Landform Dynamics and Evolution in Romania, Springer Geography, Springer International Publishing, 249–269. DOI: https://doi.org/10.1007/978-3-319-32589-7_11

Ministry of Development, Public Works and Administration (MDLPA), World Bank Group

(WBG) (2020), Output 2. Report on the support provided to develop database, Companion paper 9 – Methodologies for calculating susceptibility to landslides, Reimbursable Advisory Services Agreement on the Romania Urban Policy (P171176)

Morar C., Lukić T., Basarin B., Valjarević A., Vujičić M., Niemets L., Telebienieva I., Boros L., Nagy G. (2021), Shaping Sustainable Urban Environments by Addressing the Hydro-Meteorological Factors in Landslide Occurrence: Ciuperca Hill (Oradea, Romania). International Journal of Environmental Research and Public Health, 18(9), 5022. DOI: https://doi.org/10.3390/ijerph18095022

National Institute of Statistics. http://statistici.insse.ro:8077/tempo-online/. Accessed on 19.09.2023.

Necula N., Niculiță M., Fiaschi S., Genevois R., Riccardi P., Floris M. (2021), Assessing Urban Landslide Dynamics through Multi-Temporal in SAR Techniques and Slope Numerical Modeling. Remote Sensing 13(19), 3862. DOI: https://doi.org/10.3390/rs13193862

Niculiță M., Adrian A., Lupu C. (2017), The landslide database of North-Eastern Romania. In: Niculiță M., Mărgărint M.C. (eds) Proceedings of Romanian Geomorphology Symposium, 33rd edition, Alexandru Ioan Cuza" University Press, 81–84. DOI 10.15551/prgs.2017.81. URL: https://geomorfologie.ro/documente/Proceedings_SNG2017_ISSN_2559-c.pdf

Oliva-González A. O., Ruiz-Pozo A. F., Gallardo-Amaya R. J., Jaramillo H. Y. (2019), Landslide risk assessment in slopes and hillsides. Methodology and application in a real case. DYNA, 86(208), 143-152. DOI: https://doi.org/10.15446/dyna.v86n208.72341

Rabby Y. W., Li Y., Abedin J., Sabiha S. (2022), Impact of Land Use/Land Cover Change on Landslide Susceptibility in Rangamati Municipality of Rangamati District, Bangladesh. ISPRS International Journal of Geo-Information, 11(2), 89. DOI: https://doi.org/10.3390/ijgi11020089

Raduszynski T., Numada M. (2023), Measure and spatial Identification of social vulnerability, exposure and risk to natural hazards in Japan using open data. Scientific Reports13, 664. DOI: https://doi.org/10.1038/s41598-023-27831-w

Reichenbach P., Busca C., Mondini A. C., Rossi M. (2014), The Influence of Land Use Change on Landslide Susceptibility Zonation: The Briga Catchment Test Site (Messina, Italy). Environmental Management, 54, 1372–1384. DOI: 10.1007/s00267-014-0357-0

Romanian Urban Policy (2020), www.citadini.ro. Accessed on 21.09.2023.

Roșca S., Bilașco S., Petrea D., Vescan I., Fodorean I. (2016), Comparative assessment of landslide susceptibility. Case study: The Niraj river basin (Transylvania depression, Romania). Geomatics, Natural Hazards and Risk, 7(3), 1043–1064. DOI: https://doi.org/10.1080/19475705.2015.1030784

Sharma J., Ravindranath N. H. (2019), Applying IPCC 2014 framework for hazard-specific vulnerability assessment under climate change. Environmental Research Communications, 1(5), 051004. DOI: https://doi.org/10.1088/2515-7620/ab24ed.

Suditu B., Ginavarb A., Muică A., Iordăchescu C., Vârdol A., Ghinea B. (2010), Urban Sprawl Characteristics and Typologies in Romania. Human Geographies, 4.2, 79-87. URL: https://humangeographies.org.ro/articles/42/4_2_10_7_Suditu.pdf

Sujatha E. R., Rajamanickam V. (2015), Landslide Hazard and Risk Mapping Using the Weighted Linear Combination Model Applied to the Tevankarai Stream Watershed, Kodaikkanal, India. Human and Ecological Risk Assessment, 21(6), 1445-1461. DOI: 10.1080/10807039.2014.920222

Territorial Observatory. https://ot.mdrap.ro/website/maps/. Accessed on 04.09.2023.

Ungureanu I. (2022), Roman. Cadrul fizico-geografic (Roman. The physical-geographic framework). In Iacob D.D. and Rădvan L. (eds.), Atlas istoric al orașelor din România. Seria A Moldova (Historical atlas of cities in Romania. Series A Moldavia), vol. 3, Roman. Editura Universităţii “Alexandru Ioan Cuza”, Iași. [Book in Romanian]. ISBN: 978-606-714-745-2.

Ungureanu T., Șoimoșan T. M. (2023), An Integrated Analysis of the Urban Form of Residential Areas in Romania. Buildings, 13 (10), 2525. DOI: https://doi.org/10.3390/buildings13102525

United Nations International Strategy on Disaster Reduction (2015), Sendai Framework for Disaster Risk Reduction 2015–2030. URL: https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030. Accessed on 10.09.2022.

Van Den Eeckhaut M., Hervás I. J., Jaedicke I. C., Malet J. P., Montanarella I. L., Nadim I. F. (2012), Statistical modelling of Europe-wide landslide susceptibility using limited landslide inventory data. Landslides, 9, 357–369. DOI: 10.1007/s10346-011-0299-z

Van Westen C. J., Rengers N., Soeters R. (2003), Use of Geomorphological Information in Indirect Landslide Susceptibility Assessment. Natural Hazards, 30, 399–419. DOI: https://doi.org/10.1023/B:NHAZ.0000007097.42735.9e