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# Assessing environmental fragility in a mining area for specific spatial planning purposes

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**Abstract**

*Environmental fragility in a mining area is evaluated both in terms of its biophysical (natural) and socio-economic components and their anthropogenic interactions. We identified multiple criteria and indicators for this task, but then reduced these according to responses given by 60 experts in domains related to spatial planning. We used the selected criteria and indicators to develop environment fragility indices for each territorial administrative unit (LAU2) in Gorj County in south-western Romania. The resulting indices reveal quite large spatial variations in fragility and evidence that highly fragile human and physical environments are to some extent intertwined. In this respect, such environmental components as climate, soils, ecosystems, natural hazards and economic issues provide constraints on human activities, whilst humans themselves can, without sufficient care, increase fragility and adversely affect the quality of living environments for present and future generations. We also explore how such estimates of natural and anthropogenic fragility might enable better specific planning for local and regional development that aims to ameliorate both environmental and human adversity in an integrated way.*

***Keywords:*** *fragility index, mining area, specific spatial planning, Gorj County, Romania*

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## 1. Introduction

The numerous interactions between human society and its bio-physical environment tend to become more complicated over time (Harden et al., 2014). This is partially due to such factors as increasing population, an accelerating myriad of technological advances, and the shifting dynamics of various economic activities.

Mining activities in particular tend to affect adversely, both directly and indirectly, many human settlements and require careful territorial planning. Indeed, some mining activities are so harmful that the "environmental risks incline to migrate out of the area" (Vojvodíková, 2005, p. 51). In such territorial systems, it is very important to assess their environmental fragility before defining any specific features of territorial planning.

Increasingly, environmental studies demonstrate a clear focus on territorial risks, often involving trade-offs between such basic concepts as territorial vulnerability and resilience (Graziano and Rizzi, 2016). Moreover, there is an emergent preoccupation with defining environmental fragility in different territorial systems. For example, a recent study by Macedo et al. (2018) defines fragility as an "interaction between vulnerability and anthropogenic influences" (p. 1268) and develops an environmental fragility index applied specifically to the neotropical savannah biome.

In this study we attempt to define a complex fragility index which incorporates the major component fragilities of territorial systems. This index is subsequently applied to a Romanian region that is environmentally damaged by mining activities, and discusses how better planning systems can help remediate conditions.

We focus, in particular, on Romania's Gorj County, where the socialist Ceauşescu regime greatly increased energy production based on lignite to expand industrial production.

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The post-socialist dynamics of all East-European countries have witnessed strong de-industrialisation processes involving the closure of many large enterprises, including mining areas activities, the majority of which can be categorised as brownfield sites (Kunc et al., 2014). Romanian investors find such regions unattractive, especially on account of their environmental problems.

Taking into account the multiple consequences of de-industrialisation processes (Ianoş, 2016) and the lack of clear responsibilities for land rehabilitation, the affected human settlements need careful spatial planning (Cocheci, 2016) to enhance their revival prospects. Thus our approach focuses on evaluating the form and origin of local environmental fragility and how it might be managed. This task also engaged people working on spatial planning and research activities for local and regional administrations, all of whom have important environmental and planning knowledge on which we have drawn.

## 2. Theoretical background

Recent decades have witnessed many studies on both local and global environmental harms generated by such processes as climate change, rapid urbanisation, economic globalisation, and enhanced transport or communication technologies. The resulting environmental degradation decreases long-term sustainability and contributes to deepening spatial disparities in overall environmental quality (Salvati and Zitti, 2007). Consequently, land remediation strategies adopted by human communities to restore valued ecosystems (Song et al., 2018) may need to vary from place to place, a task that may become difficult where human activity has exceeded the environment's resilience capacity.

Fragility, which may be regarded as the inverse of stability, is an inherent characteristic of any ecosystem, regardless of the amount of disturbance to which it is exposed (Nilsson and Grelsson, 1995). Thus, the biophysical environment acts as a potential constraint on human activities and vice versa, introducing an element of environmental determinism into our arguments (Robinson, 2004). In ecology, for example, the concept of limitative factors (Odum et al., 1971) states that the presence and success of organisms depends on several different conditions and any condition which surpasses a tolerance limit will be considered a limitative factor. As a result, certain environmental conditions may be considered limitative factors for the development of either anthropogenic or natural ecological systems, thereby constraining human activities (Mac, 2003). Thus geologic, geomorphologic, climatic, hydrological, pedological or biological elements (Douglas, 2013), are all potential limiting factors in describing a site's suitability for different human activities (Pătroescu et al., 2012). In this context the estimation of fragility could be a key element for adopting specific procedures for planning social-ecological systems (Petrosillo et al., 2006).

Consequently, a decrease in environmental quality due to the overexploitation of mining resources, may affect the communities' capacity to survive in such conditions. It therefore becomes necessary to define a specific environmental concept, namely the fragile environment, which may suffer seriously adverse impact by small changes to key environmental or human variables. The management of this type of environment entails political, economic and social processes (Wyant et al., 1995; Oikonomou et al., 2011), which target ecological conservation and renewal while taking into account the new resources needed by existing communities. This task is often made both complex and difficult because of clashes between differing perspectives and strategies across many different spatial scales: global, national, regional and local (Drummond et al., 2015). For local and sub-regional authorities to take the best planning decisions in the case of fragile environments, including those damaged by mining activities, it is also very important to acknowledge the interactions between biotic and abiotic components, between the terrestrial and aquatic ones (Omernik and Griffith, 2014), and between the internal and external environments of territorial systems.

Political systems, which have until recently focused mainly on macro-level strategies, should also, according to Lange Salvia et al. (2019) look at the regional and local levels. And this task is likely to involve developing strategies to enable local and economically specialised communities to adapt to new conditions. The issue of likely irreversible climate change, however, is likely to complicate the management of fragile environments, requiring new strategies to allocate financial, social, economic, cultural and other resources to effectively improve both environmental quality and place prosperity in mining areas (Carvalho, 2017).

Some of the most adversely affected local communities in terms of environmental quality may well be those where national strategies for energy development require acceptance of drastic changes in land use. Communities depending on surface and underground mining or oil exploitation may have witnessed a temporary rise in economic well-being (Cocheci et al., 2015), but also often with strongly negative impacts on environmental quality (Zobrist et al., 2009; Wasylycia-Leis et al., 2014). Landscape reconstruction and ecological renewal require the transformation of degraded environments into high quality ones by improving ecological amenities, while simultaneously seeking to ensure sustainable development in local communities (Zhang et al., 2011).

The old 'man/nature' unity paradigm has been reinforced in the last fifteen years, although many years ago such analysts as Commoner (1971), and Bonnefous (1970) realised its complexity. This approach involves the morality and ethics of the space and place (Ianoş et al., 2010) and represents an important component in looking for a new paradigm concerning human-nature relations. Humans continuously seek to reduce fragility imposed by the natural environment, by moderating its various limiting factors. Such approaches however frequently impact negatively on environmental quality (Iojă, 2008). To make matters more complex, some human activities may negatively affect others. For example, areas with mining industries may impose negative externalities on landscapes and adjacent residential districts (Pătroescu et al., 2012) and adversely affect their quality of life. Health problems, for instance, are often caused by poor air quality (Gyourko et al., 1997; Douste-Blazy and Richert, 2000; Dumitrache, 2004). Hence, areas affected by anthropogenic environmental degradation may also be considered fragile environments, as they are characterised by significantly lower quality of life. Furthermore, activities such as open-pit mining or heavy industry may limit agriculture potentials or the possible development of other economic activities such as recreation and tourism locally or in adjacent areas (Spasić et al., 2007). Abandoned mining areas are particularly problematic since the realisation of new development is often associated with the high cost of site remediation (Stanilov, 2007).

Attracting investors willing to fund site decontamination and reconversion can be difficult (Constantinescu, 2012), unless remediation is sensibly required of mining companies for development consent in the first place.

Best practices in environmental management, acquired experientially over many centuries and subsequently incorporated in effective and legally enforced regulatory practices, have been the main instruments used to reduce environmental degradation. Such practices have targeted both natural environments and communities affected by the negative externality effects of various anthropogenic actions (Douglas, 2013). The latter case includes such spatial planning provisions as building restrictions to protect naturally fragile floodplains (Douglas, 2013), valued ecologies, or sanitary well-being (Ianoş et al., 2017). Thus, conservation interests can lead to the declaration of certain terrestrial or marine areas as natural protected zones characterised by specific land use development restrictions (Figueroa and Sanchez-Cordero, 2008). Such human-nature interactions often lead to spontaneous re-naturalisation or the targeted ecological renewal of degraded areas, processes that can be kick-started by defined strategies aimed at rebalancing the relationships between the two domains.

Generally, four major approaches can be identified in ecosystem restoration (Primack et al., 2008): no human actions; rehabilitation of some ecosystem structures and functions; partial spatial restoration; or complete (i.e. holistic) restoration. The last of these dimensions, which seeks the integral reconstruction of an ecosystem's structure and functions – or in other terms its natural capital – frequently neglects important social and economic dimensions (Aronson et al., 2006; Clewell and Aronson, 2013). On the other hand, re-naturalisation, which evolves spontaneously and naturally without any human intervention, may lead to the emergence and development of a different but sustainable ecosystem to the one destroyed. This aspect is essential for urban and territorial planners who, having a holistic and integrated professional background, understand both the systemic relationships between city, region, urbanity and environment (Glikson, 1971) and the processes by which ecosystems themselves evolve.

In situations where the physical environment was so drastically changed that native species cannot regenerate, as in the case of open-pit mining, ecological restoration can occur only if preceded by redistribution of the overburden removed, the addition of soil, water and nutrients, and the elimination of invasive species (Primack et al., 2008). As such, re-naturalisation, part of a cyclical phenomenon specific to territorial dynamics, included in the larger framework of territorial succession, often seems an easier and less expensive solution. Alternatively, the most effective environmental renewal strategy in some districts in terms of cost and acceptability of outcome might involve a mixed combination of ecological restoration and re-naturalisation.

Both ecological restoration and re-naturalisation can be regarded as approaches aimed at the ecological renewal of mining areas where the ecosystems have been affected by natural or anthropogenic disturbances. Hence, both renewal models can be regarded as possible measures to be included in spatial planning and environmental policy documents, to mitigate environmental degradation in such fragile areas. We considered that Romania's Gorj County, the NUTS3 county experiencing "Romania's greatest anthropic interference" (Braghină et al, 2008, p. 9), would be a suitable study area to test the possible application of the environmental fragility concept. Thus, our aim is to define the concept of a fragile environment and propose an environmental fragility index as an integrated measurement tool for the environment, to be used in designing specific planning instruments to tackle these issues, with a special focus on ecological renewal measures as the basis of targeted environmental policies.

In their scientific approaches, some scholars focus on the success factors for brownfields re-development (Frantál et al., 2015) and, indirectly, on the areas affected by de-industrialisation. In this context, we have only carried out interviews with specialists involved in spatial planning, in order to consider their vision on the most important factors that define the environmental fragility for this specific mining area.

## 3. Study area

Gorj County is located in Romania's South West region (see Fig. 1), and is the most important region for Romania's energy industry due to its high capacity hydroelectric power plants and coal-fuelled power plants (Cocheci, 2016). Coal-based electricity production decreased nationally from 40% in 2008 to 27% in 2014, however, due to the increasing proportion of renewable energy. Wind power contributed only 0.1% in 2008, but rose to 9.0% nationally by 2014, while hydro-energy rose 3% in the same period (Romania's Statistical Yearbook, 2016).

With a surface area of 5,602 square km, or 2.5% of Romania's national territory, Gorj County has a resident population of 336,995 inhabitants or 1.68% of Romania's total (National Institute for Statistics data, 2013). This county, which represents a NUTS3 (Nomenclature of Territorial Units for Statistics) unit at the European level, comprises 70 communes, although 45% of its population is located in the county's nine cities. Four of them – Motru, Rovinari, Ţicleni and Bumbeşti Jiu – are mono-industrial in the sense that a major part of their economies and employees are concentrated in a single industrial sector or even one industrial company (Dumitrescu, 2008). Their key industries are, respectively, coal production, electrical energy, oil production, and industrial machinery.

Gorj contains over 70% of Romania's stock of inferior lignite coal (Braghină et al., 2008) which feeds the high capacity power plants at Rogojelu and Turceni. Located in the Rovinari area, this lignite basin is characterised by open-pit extraction with significant environmental impact (Cuculici et al., 2011). Over 62% of Motru's morphology was transformed by coal exploitation (Titu and Balaszi, 2007). The restructuring of the mining areas, in which all underground and some surface exploitations were closed after 1996, had a great impact on villages whose economies depended heavily on open-pit mining (Braghină et al., 2011). The Romanian strategy for the mining industry for 2017–2035 (Ministerul Economiei, 2017) is an example of the attempt to overcome the economic and social disruption caused by the cessation of mining activity.

In 1999, the national government designated three 'deprived areas' in Gorj County, all related to mining activities. They were Schela (anthracite), Albeni (oil and natural gas) and Motru-Rovinari, already mentioned as Romania's main lignite coal basin. They were given special financial and fiscal support designed to stimulate investment, including 10 years without taxes for local business profits, and land for new investment. The strategy's impact was not in all cases as effective


*Fig. 1: Location of the case study area at the national level (Romania). Source: authors' elaboration*

as expected and, consequentially, the mining industry's contraction in such areas has affected the county's economy with considerable adversity (Popescu, 2000). As a result, the main dependence of the county on mining may represent a high risk from an economic and social point of view, especially over the medium to longer term (Braghină et al., 2010). Besides the negative environmental impact of mining, particularly the open-pit lignite quarries (Spasić et al., 2007), the county is also confronted with other environmental issues. Some mountain and plateau areas are vulnerable to natural flooding (Minoniu, 2011), whose effects are aggravated by such human activities as deforestation and quarrying. Frequent torrential rains are the main cause of these hazards (Marinică and Marinică, 2013). Romania's entire South-West region has experienced intense land cover changes in the last 25 years (Petrişor et al., 2010), which, combined with heavy rainfall, also increase its vulnerability to geomorphologic hazards, and especially landslides (Glade, 2003).

The County Territorial Plan developed in 2009–2011, which is the latest territorial planning document approved for Gorj County, included both a development strategy and several environmental measures: air, water and soil pollution regulations; mitigation of floods and landslides; protection of natural areas; and even the ecological reconstruction of mining areas (UAUIM, 2011). Unfortunately, there is no monitoring of these measures. Many current planning instruments in Romania lack the necessary mechanisms for implementation, especially concerning the financing of the proposed measures (Ianăşi, 2008). They are also poorly integrated with specific national environmental policies. The county environmental agencies check the implementation process, but the penalties for the offenders are too low to ensure a high level of compliance, thereby imperilling both governments and their strategies.

## 4. Methodology

### 4.1 The fragile environment concept

Throughout history, society has had to learn to adapt to evolving environmental constraints caused by either anthropogenic actions or extreme natural events (Douglas, 2013). Starting from the territorial system concept, we defined two analytical sub-systems, natural and anthropogenic, the first offering finite sets of resources to the second, which in turn has a considerable capacity to transform and capitalise on them (Ianoş, 2000b). Consequently, the territorial system conceptualisation aids us in analysing the fragility of the environment, taking into account both biophysical and socio-economic factors in particular places. The uncontrolled exploitation of natural resources and the lack of a clear land use policy may also create disequilibrium between the support capacity of the natural subsystem and the consumption of resources by local and regional communities. Such an imbalance may lead to modified ecosystems having a negative impact on human well-being, and enhanced fragility, which may at some point morph into a phase of creative destruction (Holling, 1973).

Our approach tries to develop a new dimension of environmental fragility, taking into consideration the high complexity of the internal and external environments of a territorial system, and including both natural and anthropogenic components. This is a complementary approach by comparison with other uses of the fragile/fragility concept, developed by different authors, which reflect more or less the connection with a diversity of territorial policies (Petrosillo et al., 2006; Baliamoune-Lutz and McGillivray, 2008; Ferreira, 2017; Yu et al., 2018). Each territorial system is not isolated, having structural and functional relationships with surrounding territorial systems. Both internal changes and external perturbations may disturb fundamental relationships between natural and anthropogenic sub-systems in a particular territorial system. Unbalanced changes inside a territorial system, because of overexploitation and limited eco-services, can modify the initial state and transform the internal environment in a fragile one. Because any territorial system is connected with other surrounding territorial systems, its own fragility can induce asymmetric flows of mass, energy and information between it and adjacent areas.

Consequently, complex interactions between the internal and external environments may increase environmental fragility, both natural and anthropogenic, at larger spatial scales. Such events can be very important for local and regional development (Ianoş et al., 2013), because effective management of fragile environments requires the implementation of specific territorial planning measures at different spatial scales simultaneously, as shown in Figure 2. Such a management process is alas a difficult task given issues such as regional diversity, system complexity, persistent and often unsympathetic human-environmental interactions, inevitable information deficiencies, and the presence of many lagged effects.

Given these complexities, a major question concerns the capacity of the fragile environment concept to be useful for both spatial planning and environmental policy. Effective management of complex problems can only result from improved understanding of that complexity and, as far as possible, its measurement. Insofar as it helps differentiate both the ecological and societal problems of particular areas and suggests policy avenues for their amelioration or enhancement of sustainability, we consider the concept worth investigation. We can further identify two types of fragility: current and latent. Given that many physical environments have an inherent capacity to revert resiliently to previous configurations, current and latent fragility overlap to some extent. The analysis of anthropogenic issues, however, is heavily weighted to current statistics rather than latent statistics. For example, place accessibility can be measured in terms of current modes of transport – their cost, convenience, service frequency, likelihood of hazards, and so on. In the future, the quality of internet connectivity could be far more important in adapting to a transformative high-tech world or, alternatively, new forms of physical transport might emerge. Likewise, local cultures that are risk accepting, entrepreneurial, and future-oriented might be far more important for local development prospects than more conventional measures of economic and social well-being. This theoretical approach is not the target of the current paper, however, postponing it for the future.

### 4.2 Methodological approaches

Taking into consideration (indirectly) the selected case study, we established a methodology to identify and quantify different types of fragile environments on the basis of agreed indicators and techniques for measuring the most relevant environmental components. Such analysis raises the possibility of tailor-made spatial planning measures at different scales, especially local and regional, as shown in Figure 3. Based on our definition of the fragile environment concept, we realised a set of environmental fragility types and associated criteria. In parallel, a set of criteria and indicators were proposed, with their relevance being tested

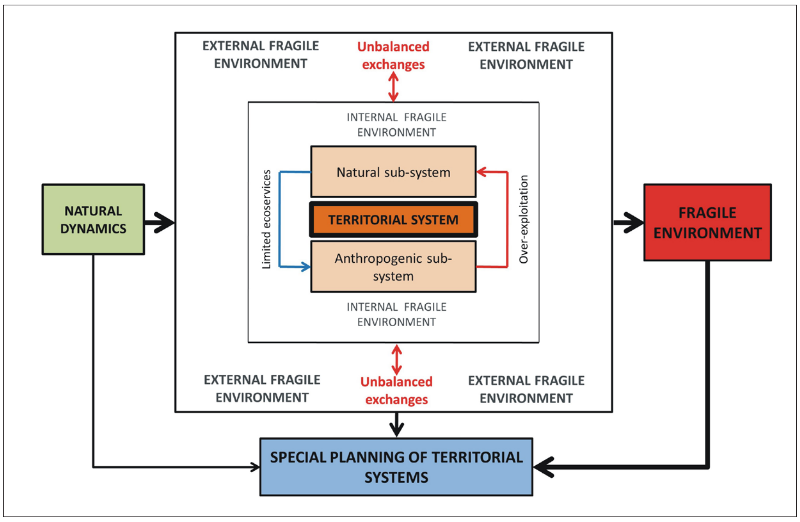


*Fig. 2: The fragile environment concept. Source: authors' conceptualisation*

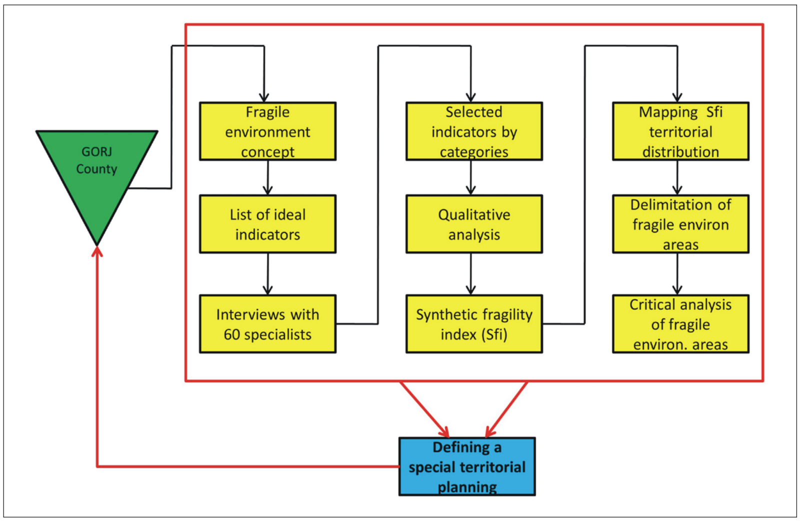


*Fig. 3: Methodological steps in defining specific territorial planning processes in a fragile environment Source: authors' conceptualisation*

in terms of the 60 responses we received from the survey of specialists in territorial planning. The specialists were selected from our network of professionals involved in spatial planning activities, regardless of their profession. The aim of the questionnaire was for the experts to grade each criterion from 1–10, without knowing the study area on which the analysis would be made. As a result of this expert assessment, we concluded that the number of indicators is less important compared with their perceived relevance to the quantification of environmental fragility. Consequently, we associated one criterion to each type of environmental fragility, with each criterion being measured through the most relevant indicator (also according to available data at local level). Consequently, we realised a list of indicators that represented the basis for our spatial analysis.

The next step was the qualitative analysis of these indicators, thus obtaining a synthetic index of environmental fragility, spatially constructed at county level. Based on the principle of territorial contiguity, the areas considered to be fragile environments were thus identified. The critical analysis of these areas revealed distinct territorial particularities. These, in turn, should be taken into account in shaping specific territorial planning measures designed to ensure improved sustainable development at the level of these newly-defined territorial aggregates.

### 4.3 Criteria and indicators

The methodology used for selecting criteria and indicators at the local level is similar to the one previously used to determine environmental restrictiveness at a regional scale (Cocheci, 2016). In order to quantify environmental fragility in areas suffering from different types of environmental issues, as described above, we first proceeded to define a typology of fragile environments, based on our literature review regarding the influence of different factors on environmental fragility (see Tab. 1). We identified nine types of fragile environments, focusing on different aspects of the environment: six describing natural fragility (from geological, geomorphological, climatic, hydrological, pedological and biological points of view); and three describing anthropogenic fragility (from land use, socio-economic and legislative points of view).

For each type of fragile environment identified, between one and five criteria describing different aspects of fragility were selected, with a total of 27 criteria being considered, as shown in Table 1. A questionnaire was designed and distributed to 75 experts in various domains related to spatial planning, with the aim to rate these criteria on a scale from 1 to 10 based on their importance. In the end, 60 specialists answered our survey. The structure of the questionnaire enabled them to comment on some items, which was useful

| No. | Fragility Type | Criteria for definition (source) |
|---|---|---|
| 1. | Geological fragility | High seismicity (Lang et al., 2012) |
| | | Sedimentary rocks which hamper foundation (Klein et al., 2013) |
| | | Small depth of groundwater (under 2 metres) (Klein et al., 2013) |
| 2. | Geomorphologic fragility | High altitudes (over 1200 m) (Bathrellos et al., 2012) |
| | | High relief fragmentation (Haddaway et al., 2013) |
| | | Presence of landslides (Papathoma-Köhle et al., 2007) |
| | | Presence of ravines |
| 3. | Hydrological fragility | High incidence of floods and flash floods (EEA, 2010) |
| | | Low quality of surface water caused by pollution (Ongley and Booty, 1999) |
| | | Low quality of groundwater caused by pollution (Stamatis et al., 2011) |
| 4. | Climatic fragility | Incidence of Drought (Tánago et al., 2016) |
| | | Negative extreme temperatures (EEA, 2010) |
| | | Positive extreme temperatures (EEA, 2010) |
| | | Low air quality caused by pollution (Douste-Blazy and Richert, 2000) |
| 5. | Soil fragility | Soil contamination caused by pollution (McClintock, 2012) |
| | | Land degradation due to soil erosion (Cerdan et al., 2010) |
| | | Low soil fertility (Sanchez, 2002) |
| 6. | Biological fragility | Presence of protected species and habitats |
| 7. | Fragility related to land use | Major land use changes (deforestation, urbanisation, etc.) (Popovici et al., 2013) |
| | | High degradation of land by human interventions (quarries, tailings dumps etc.) (Spasić et al., 2007) |
| 8. | Socio-economic fragility | Low turnover per inhabitant (Pavel and Moldovan, 2016) |
| | | Low level of education (Ramos et al., 2012) |
| | | Low accessibility (Caschili et al., 2015) |
| | | High level of land abandonment (Shengfa and Xiubin, 2017) |
| | | Declining population (Martinez-Fernandez et al., 2012) |
| 9. | Fragility of the environmental legislation | High proportion of natural protected areas (Geldmann et al., 2015) |
| | | High surface occupied by sanitary protection areas |

*Tab. 1: Types of fragility (partial fragilities) and related criteria*
*Source: authors´ compilation*

in suggesting better methodological approaches. The average ranking for each criterion was defined by dividing the sum of total answers by the number of specialists. So, the value for criterion i ($Vc_i$) was:

$$Vc_i = (\sum V_{ij}) / 60,$$

where $V_{ij}$ = the rating given by each specialist $j$ ($1 \geq j \leq 60$) to criterion $i$ ($1 \geq i \leq 26$).

In summary, for each of the nine dimensions of a fragile environment previously defined, we selected the criteria with the highest expert ratings, reducing the number of them from 27 to 8. The resulting criteria were then expressed by 8 indicators (one for each criterion) defined according to data found in official sources, research studies or the latest planning documentations, at LAU2 level (Local Administrative Unit 2 – municipalities or equivalent units, after the European Union classification of administrative units in effect until 2017). Eventually, all indicators were normalised (with 100 being the maximum value for each category), using the formula:

$$V_s = V_r / V_M \times 100,$$

where: $V_s$ = standardised value; $V_r$ is the current value; and $V_M$ is the maximum value of the values' chain.

For each LAU2 level unit, the fragility index (Fi) was defined as the sum of standardised values of all indicators. The process of summing the standardised indices makes the implicit assumption that all variables of fragility are weighted the same. At the same time, some of variables have a positive impact on fragility (as against increasing it), and others a negative one (increasing the fragility). This procedure accounts for the summation that is obtained, taking into account the issue of "+" positive variables and "−" negative variables. Computing the fragility index for each LAU2 unit, and analysing the entire value's chain, we individualised two main disruptions inside of the values' distribution. Having evaluated the fragility index for each LAU2 level (commune), we first divided the scores into three classes – high, medium and low – and then mapped their locations. In a second stage of the analysis, we designated as highly fragile any locations within Gorj County where three contiguous LAU2 units (Ianoş, 2000a; Cocheci, 2017) could be identified. Such regions were subsequently compared those parts of the County previously identified as 'deprived areas' in 1999.

Based on the analysis at the county level, we depicted the possibilities for implementing ecological renewal as a planning approach in fragile environments, taking into consideration several of the current legislative frameworks in Romania. By using such a synthetic index, territorial planning might become a real support for disadvantaged rural areas, for their better adaptation to environmental challenges, such as land degradation, climate change, population ageing and economic changes (Mocanu et al., 2018).

## 5. Results

Using a questionnaire survey, we received responses from different experts related to spatial planning: human geography (18), urban planning (16), environmental sciences (16), sociology (6), architecture (2) and engineering (2). Most of the experts (48) worked at a university and/or its research centres, while the other 12 worked in private companies. Furthermore, about half of the experts questioned (34) had at least 10 years experience in the field. Table 2 illustrates the selected criteria that received the highest average score (taking into account all expert ratings), along with the indicators that we used for quantifying each criterion at LAU2 level and the data sources that we consulted. We used data from the latest existing studies at county level (regarding environmental quality assessment and spatial planning documents: see Tab. 2). The analysis for each fragility

| Fragility type | Criterion | Score | Indicator | Source |
|---|---|---|---|---|
| Geological | High seismicity | 7.86 | Highest value of terrain acceleration for earthquakes with average return period of 100 years: acceleration index decreased from south-eastern (0.16) to north western (0.08) communes. | Master Plan of Gorj County (2011) |
| Geomorphological | Presence of landslides | 8.76 | Number of landslide areas (over 200 square metres) in LAU2 unit. The highest values are registered in Bustuchin and Rosia de Amaradia (seven landslides). | County Plan of Risk Analysis and Coverage (2009), amended by field investigation |
| Hydrological | High incidence of floods and flash floods | 8.79 | Presence/absence (on rivers, flash-floods or both). | Master Plan of Gorj County (2011) |
| Climatic | Low air quality caused by pollution* | 7.52 | Presence/absence of sources of air quality degradation. | County report regarding environmental quality (2013) |
| Pedological | Soil contamination caused by pollution | 7.24 | Number of contaminated sites in LAU2 unit: 155 contaminated sites are located in Gorj County, concentrated in just 24 LAU2 units. | Regional Action Plan for the Environment 2014-2020 |
| Land use | High degradation of land by human interventions – coal quarries, tailings dumps etc. | 7.69 | Surface of degraded land (ha). Only Godineşti commune has no degraded land, in comparison with Câlnic and Mătăsari with over 1900 ha of degraded land each. | National Institute of Statistics data (2013) |
| Socio-economic | Low accessibility | 7.86 | Accessibility index (one point for each identified transport infrastructure problem). | Master Plan of Gorj County (2011) |
| Environmental legislation | Natural protected areas | 7.79 | Percent of Natura 2000 SCI site area from total LAU2 units' areas. | Ministry of Environment dataset, GIS analysis |

*Tab. 2: Selected criteria and indicators used for quantification*
*Source: authors' compilation*

type (partial fragility) showed an overlapping between the most-quoted biological fragility criterion (presence of protected species and habitats) and the legislative fragility one (natural protected areas). In this case, we decided to take only one of them into account when calculating the fragility index, and we have selected 'the natural protected areas' as characterising the Legislative fragility type. The main argument was that natural protected areas enclose the majority of protected species and habitats, conforming to several Romanian laws and norms. This means that we kept only eight criteria (eliminating the biological fragility) and eight of the most relevant fragility indicators.

A Fragility Index was computed for each LAU2 unit by summing the standardised values, recognising (and assuming) that each of the 8 variables was weighted by the respondents at roughly the same level. Theoretically, the fragility index value is contained in the general interval from 0 (no fragile features) and 800 (summed maximum value registered for each of the eight selected criteria).

The fragility index, calculated using the normalised values of the above-mentioned indicators, registered values between 116.60 (commune of Săuleşti) and 507.02 (town of Tismana). The upper tertile of the data series (i.e. 33% of the population is less than or equal to the 33rd percentile value) included 23 LAU2 units (fragility index value of at least 340), based on which we defined four different fragile areas, each containing at least three contiguous LAU2 units (see Fig. 4 and Tab. 3). Taking into account the average size of each LAU2 unit (commune), we consider that for this county an area is significant enough if it has a total surface of more than 150 square kilometres.

An analysis of the spatial distribution of the fragility index within Gorj County shows high values in the northern part (due to natural features – mountainous area with low accessibility and a high density of protected species), as well as the high values within 7 of the 9 cities in the county – especially industrial or mining cities such as Rovinari, Bumbeşti-Jiu, Ţicleni or Târgu Cărbuneşti. The fragile areas that we identified are closely related to important mining areas in the county, as further discussed in the next section.

The four fragile areas contain 18 LAU2 units (approximately 25% of the county's administrative territorial units), four urban and 14 rural. In three of these fragile areas, the fragility source is an anthropogenic one and is related to mining: open-pit coal-mining (Rovinari

| Fragile area | LAU 2 units | Main fragile elements | Source of fragility |
|---|---|---|---|
| Rovinari | Urban: Rovinari<br>Rural: Bâlteni, Câlnic, Fărcăşeşti, Mătăsari, Negomir, Urdari | Air pollution (all), soil contamination (Bâlteni), land degradation (Mătăsari, Câlnic) | Coal mining |
| Ţicleni | Urban: Ţicleni, Târgu Cărbuneşti.<br>Rural: Licurici | Air pollution (all), soil contamination (Ţicleni, Târgu Cărbuneşti), Low accessibility (Ţicleni) | Oil and natural gas extraction |
| Amaradia Valley | Rural: Căpreni, Cruşet, Hurezani, Stejari, Turburea. | Air pollution and seismicity (all), low accessibility (Stejari), soil contamination (Turbure) | Oil and natural gas extraction |
| Parâng | Urban: Novaci<br>Rural: Crasna, Baia de Fier | Air pollution (Novaci, Crasna – wood industry), Protected areas (all), low accessibility (Baia de Fier) | Natural features (mountainous area) |

*Tab. 3: Fragile areas in Gorj County. Source: authors' categorization*

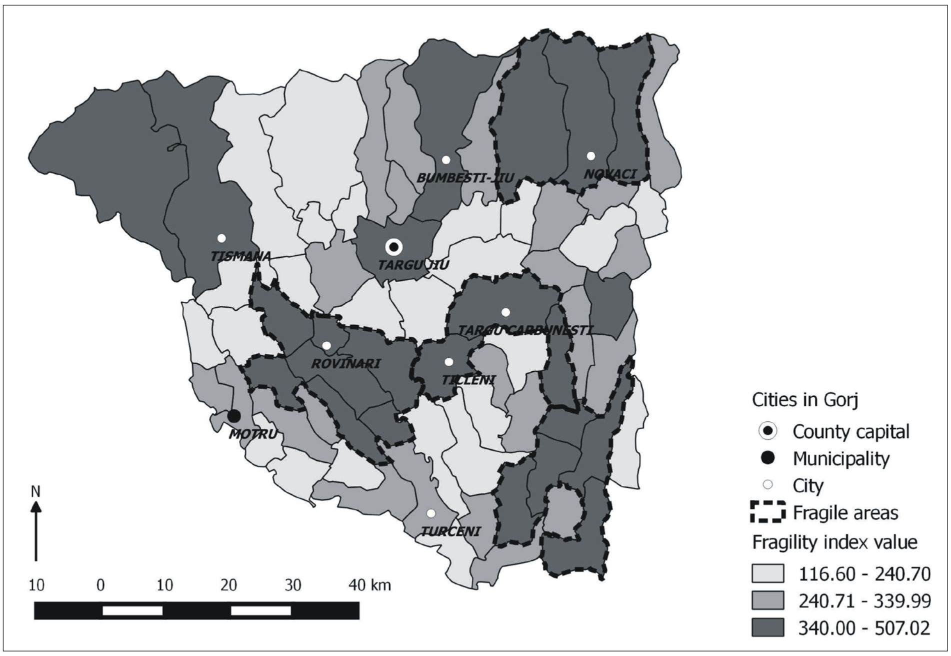


*Fig. 4: Fragility index at LAU2 level and delimitation of fragile environmental areas*
*Source: authors' categorisation*

fragile area) and oil and natural gas extraction (Târgu Cărbuneşti and Amaradia Valley areas). This confirms the significant environmental impact of the county's energy industry, as stated in the description of the study area. This is mostly caused by the high capacity power plants' main source of energy, which is the lignite coal in the Motru-Rovinari basin.

A more detailed analysis of the existing fragile elements in the four fragile areas that we identified highlights the problem posed by the mining industry to air quality and soil contamination (Rovinari, Ţicleni and Amaradia Valley fragile areas), with the coal industry (Rovinari area) also responsible for significant land degradation due to open-pit mining. The situation is different in the Parâng fragile area, where fragility is mostly related to the presence of natural protected areas (with many protected species), and the low accessibility caused by the natural features of the territory (mountainous area).

## 6. Discussion

Starting from the fact that Gorj County has a special territorial structure, with a diversity of fragility types, and with a strong restructured mining activity which has asked for government decisions favourable for further development, we have considered that this is a good sample location in which to apply our methodology.

### *6.1 Comparative analysis between fragile areas and deprived areas*

A Romanian law enacted by the National Parliament in 1999, defined deprived areas as being characterised by at least one of the following conditions: (1) the existence of mono-industrial productive structures accounting for 50% or more of the region's total employees; (2) over 25% of the employees in the area affected by collective layoffs due to the restructuring of economic units; (3) an unemployment rate 30% or more higher than the national average; or (4) isolated areas with poorly developed infrastructure (Cocheci, 2015). The financial incentives offered to firms established in these areas did not have the expected impact, however, and did not lead to the economic development of the deprived areas (Săgeată, 2012).

The comparison between the fragile areas identified and the deprived areas in Gorj County shown in Figure 5 thus illustrates the connections between environmental fragility and social and economic issues.

Hence, seven out of the 13 LAU2 units in the Rovinari deprived area have also been included in the Rovinari fragile area, while the city of Târgu Cărbuneşti was included in both the Albeni deprived area and in the Ţicleni fragile area. This highlights the need for a better integration of sectoral policies at regional, county and local level, in order to tackle both environmental and social vulnerabilities. Taking into account that the territorial fragility is more connected with the anthropogenic influences generated by mining activities, for Gorj County, these areas constitute a priority in spatial planning.

Mine site abandonment is one of the situations in which the lack of control and minimal mitigation actions for environmental degradation result in great economic, social and environmental impacts. The fragility index confirmed our initial hypothesis regarding environmental issues in the mining areas of Gorj County, while the comparison with the deprived areas declared by law highlighted the link between environmental fragility and limited development possibilities. Considering the environmental degradation in such areas, we need to consider what spatial planning instruments, linked with environmental policy measures, and could be used to ensure a sustainable development of these areas in the future.

### *6.2 Implications for specific territorial planning*

Apart from any recuperation alternatives, some development strategies may also have to focus on ensuring a high-rate exploitation of the natural resources. We should also admit that effective management of these themes is a 'whole-of-society' issue involving all tiers of government, private business, media, various kinds of

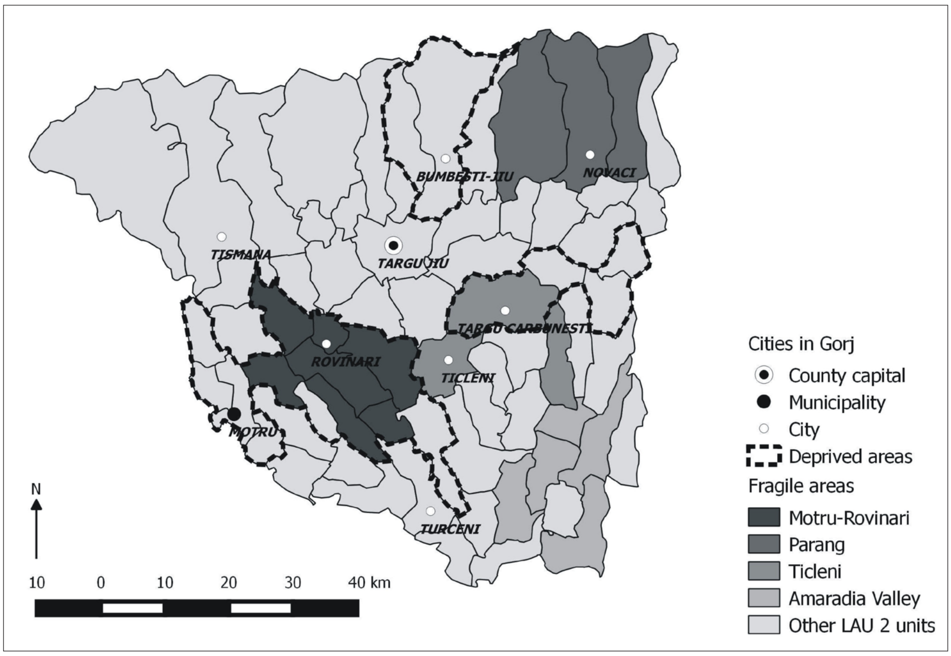


*Fig. 5: Comparison between fragile areas and deprived areas in Gorj County*
*Source: authors' elaboration*

social institutions, individual activists, and so on (Yaskal et al., 2018). It requires strong leadership across all of these dimensions and strong networking to, in effect, mould people's culture in the direction of caring passionately for environmental quality and also seeking high quality local development. All this has to be underpinned by clear and strongly enforced regulation and education about the skills necessary to deliver preferred outcomes. So, effective planning and management are a multi-faceted and complex task (Sorensen, 2017).

In the case of Gorj County, the implementation of effective management frameworks requires coordinated actions among all relevant actors. These comprise local populations and associated community groups, business corporations, government authorities mainly at local and county level, and various national agencies dealing with such key arenas as environment, economic development, education and transport.

In practice, the main focus is likely to be on the cleaning of affected sites and on planning their re-use. In mining areas, the rehabilitation process should prioritise the reduction of environmental degradation by reducing landslide risks and by re-integrating the degraded land into the ecological circuit. This would be a significant contribution towards the improvement of local and regional environmental quality. A key element, however, is the long time – often decades – required for stabilising tailing dumps, as well as the very high costs associated with these actions (Spasić et al., 2007).

In a recent study, Bański et al. (2018) define for Poland, areas of strategic intervention, respectively growth areas and problem areas. For delineation of problem areas, at a regional level, they used 21 indicators equally covering natural, social and economic issues. The main finding regarding problem areas is that their identification is consistently useful for a better application of strategic planning. Our study, using another methodology, shows the importance for the fragile areas of defining special planning procedures to prioritise a sequence of actions to enable balanced territorial development.

Moreover, the legislative framework in Romania has covered these problems only partially, and not in an integrated manner. Most of the existing legislation regarding degraded environments does not have associated financial mechanisms, and thus relies only on state funding. Ideological factors also make such actions difficult to implement, since the closure of economic activities contributing significantly to environmental degradation often conflicts with the local population's need for jobs.

The mining activities located in Gorj County are operated only by a State Company: Oltenia Lignite Company, which has the responsibility to make rehabilitation of the areas degraded by coal exploitation. As only the costs for the affected areas are covered, all additional phenomena generated directly and indirectly by coal exploitation are left to be solved by local and regional authorities. In our view, the region's extractive industries work to the benefit of Romania as a whole and, therefore, the nation as a whole has a financial responsibility for environmental restitution, whether re-establishment of original ecologies or re-naturalisation, or some mixture of the two. National responsibility may go further and embrace anthropogenic renewal, including re-educating workers with new skills, as well as infrastructure improvements (e.g. health, transport, and so on).

In this context, the use of an environmental fragility index can aid in the identification of LAU2 units with significant environmental issues, thus underlining their common problems. Given the lack of clear and specific public policy in this arena, the creation of voluntary Intercommunity Development Associations (or Local Action Groups) could be a good opportunity for communes and small cities to act together in finding solutions and external financing opportunities for these common problems. The national government could help trigger such local actions financially, but national or regional private organisations could play a role. Modern regional anti-fragility requires a myriad of innovative approaches (Taleb, 2012). If some scientists have demonstrated, about one hundred years ago, a similarity of interactions between the four planetary surfaces and regional/local places (Ianoş et al., 2018), then why cannot we try to identify and to extrapolate the mechanisms of regional or local environmental fragility, in further approaches, to the global level?

Taking into account the problems generated by the permanent and huge interventions of the coal industry on natural and socio-economic components, the definition of specific planning processes for this area is fully justified. Such planning could facilitate the understanding and raise the awareness of the population and the territorial actors to simulate the effects of any important changes before they are made, and to establish short- and medium-term priorities.

## 7. Conclusions

A vision of development based on an eco-systemic approach (Vădineanu, 1998) considers territories transformed by people as a specific organisation level of the life on Earth, related to a vision exclusively focused on natural ecological system. Similar to individual living entities, human society is also limited in its development due to the constraints of fragile factors, which can often put the integrity of socio-ecological systems under doubt (as the pressure of inappropriate economic activities dramatically decreases the quality of environmental services). The complexity of operations required in the ecological renewal approach to a human-changed territory requires a careful analysis of the social and economic subsystems in that area, in order to find a new desirable equilibrium between the natural and socio-economic systems. In this approach, a simple dereliction of the resource extraction sites generates strong restrictions on the development of the human communities.

Consequently, the forced industrialised areas in the 1970s and 1980s in Romania require a controlled re-naturalisation of the derelict lands, followed their de-industrialisation by adequate central government financial, administrative and scientific resources. Hence, the decisions regarding ecological renewal approaches need to become an important part of territorial development and environmental policies. While the case study area involved a Romanian county, the environmental issues related to mining areas in a post-industrial and a post-socialist context can be extended to other examples in Eastern Europe as well (Stanilov, 2007). In the cases of closed mining exploitation, especially the case of open-pit mining, the alterations of the physical environment long with the re-distribution of land use in such areas affected by re-naturalisation processes, can have important impacts on the settlement network, as well as on the quality of life and life-styles of the local population.

The proposed index of environmental fragility, referring to different environmental fragility aspects of the environment (geology, geomorphology, hydrology, climate, soil, society and its impact), can be used as a tool designed to integrate the analysis of the structural and functional elements of both the natural and the anthropogenic sub-systems. These elements are included within the proposed aggregated index, which could offer a real tool for local and regional authorities and, especially, for those facing the mitigation of closure effects of the mining activities. The strong point of this index is the fact that it offers a comparative view on the affected territory and aids in the differentiation of the local communities in their efforts to have a new environmental quality.

The measurement of the environmental fragility index at local and regional level shows that some areas in the county, especially rural areas, face significant environmental and socio-economic problems, with most of them also being part of the deprived areas declared by law in 1999. In this regard, a first step would be for communes facing similar issues to become partners through the creation of Intercommunity Associations, which would aid them in financing larger projects together.

At the LAU2 scale of analysis, this index can be used in the elaboration of local and intercommunity strategies and policies. Nevertheless, the currently-used indicators to quantify the different fragility criteria could be improved, depending on the re-organisation of the collection data system at local level, as most of the studies realised at county level have started to be outdated. Adding new data series, especially those characterising natural phenomena such as imminent landslides, potential flood areas or even quality of air indices at LAU2 level, as well as enlarging the access of researchers and local administrators, could greatly aid in making environmental reconstruction more rigorous, appropriate and efficient.

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