ANALYSIS OF SNOW-DRIFTING VULNERABILITY. APPLICATION TO BOTOŞANI COUNTY

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Abstract. Currently, in the continental transitional climate, the snow-drifting phenomenon registers different intensities which are becoming harder and harder to oversee and classify into a certain typology. The North-Eastern region of Romania is highly susceptible to a intensive snow-drifting vulnerability, due to its position in the exterior of the Carpathian arc. In the present article, we have analyzed the climatic and geomorphologic parameters, as well as road infrastructure in Botoşani county, trying to evaluate the snow-drifting vulnerability of transport infrastructure. From the hypothesis that the snow-drifting vulnerable areas are the resultant of morphologic and morphometric factors, like relief (through exposition, slope, hypsometry etc.) and climatic factors (prevailing wind direction and topoclimatic particularities), a unitary analysis was compiled, embedding these parameters in the form of a united cartographic product, equivalent to the reality on site. Rugosity, as a consequence of land use, contributes to a differential accumulation of the snow layer, particularly larger accumulations in contact areas between arborescent vegetation and grassy vegetation, as well as the contact between localities′ peripheries and the built perimeter; and also because of small areas within other land uses, ranked with lower vulnerability (like forests and orchards). The results obtained are based on spatial interpretation, quantifying the influence of each parameter with direct implication on the snow-drifting phenomenon.

Keywords: *vulnerability, drifting snow, road infrastructure, GIS analysis , Botosani county.*

1. Introduction

In case of weather phenomenon the extreme vulnerability must be defined like representing the exposure of some territories or ecosystems, relative sensitive on possible phenomena or probable weather order, which man is not sufficiently prepared to take an action. A common feature of all risks is that they triggering natural imbalances, social-economics and ecologic that causing disorder and chaos in the evolution of geosystems (White, 1971; Davy, 1991; Béthemont, 1991 , Bălteanu, 1992, 2002, Bogdan, 1992, 1994, Ianoş 1994, Velcea, 1995, Grecu 1997, 2004, Bogdan, Niculescu, 1999, Sorocovschi, 2002).

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Botosani county is one of the most affected regions by snow drift during cold season with 4-5 days of blizzard per year (Beşleagă et al., 1962). The road infrastructure and transportation sector are higly sensitive to this risk phenomenon. In contrast with risk, vulnerability addresses only the physic-geographic spatialization, eliminating from account the anthropic factor, the only element of this kind included in the study, being the road network. Even we could talk about decreasing in the trend of blizzard phenomenon in Romania (Clima Romaniei, 2008) the actuality of the subject consists in its unforeseeable character leading to immediate blockage of the transport network, which paralyzes other complex domains. The most frequent synoptic situation of blizzard manifestation is characterized by the presence of the Voeikov ridge over northern Europe, formed by the jointure of the East-European Anticyclone and the Azores Anticyclone and by an intense Mediterranean cyclone activity, amplified by the south-west –> north-east trajectory of the Jet current – fundamental dynamic condition for the occurrence of blizzards in the analyzed area (Bogdan, O.; Niculescu E., 2007).

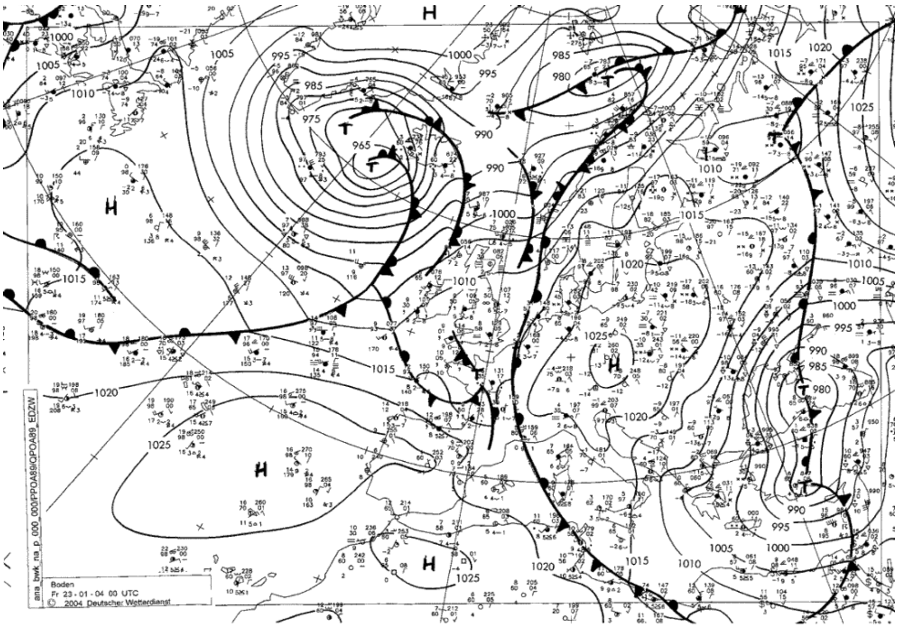


Figure 1: Distribution of baric formations over the European continent, in the context of Voeikov ridge appearing over the north of Europe (Deutsche Wetterdienst, 24.I.2004)

Because not every storm characterized by barometric and thermal gradients is considered a climate risk, because the speed of wind and the amount of fallen snow varies a lot in time and space and therefore was opted for the application in analysis of vulnerability to blizzard of Botosani county area for a typical profile of potential risk of blizzards. Not every hibernate storm characterized by barometric and big thermal gradients is considered a climate risk, because the speed and wind direction and the quantities of fallen snow greatly differ in time and space. Therefore was chosed to implement the vulnerability analysis of snowstorm in the analyzed area, a typical profile weather-phenomenon with potentially high risk (Lungu, M.; Panaitescu, L., 2010).

2. Methodology

For the elaboration of the spatial analysis, a comprehensive methodology was accepted, which would dismiss, as much as possible, eventual errors that could appear after generating the final cartographic materials.

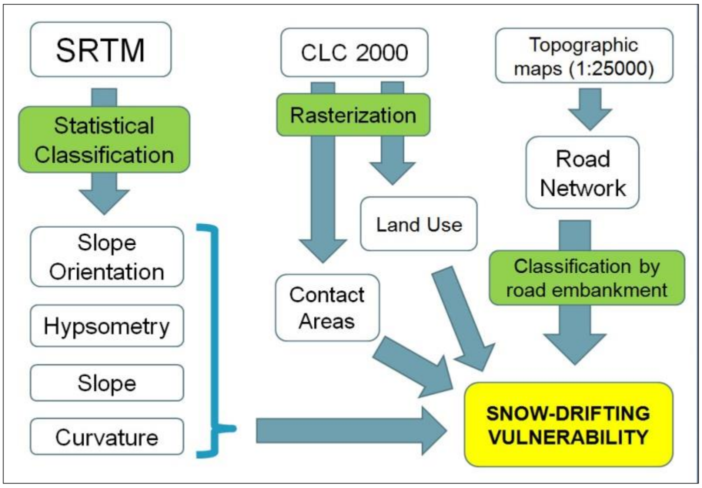


Figure 2: Methodological diagram

Being a quantitative analysis, achieved through geomatic means and techniques, the accent fell upon the accuracy of each layer included in the equation. Therefore, the most important morphologic, morphometric and climatic parameters were selected, that directly influence the manner in which snow accumulates, and the thickness of the deposited layer. Because the analysis was executed at county level, a compromise upon the scale we were working with was made, utilizing already existing layers of a very fine resolution, so that the resultants would be accurate enough to validate the conditions on site, associated with the whole county.

From the whole set of digital materials used, the basis for more than half of the raster layers involved in the final formula is an extraction from a package of data available free-of-charge online, specifically SRTM (Shuttle Radar Topography Mission) data. The spatial resolution is associated with the measures of a pixel with 80 m sides. The SRTM was utilized as reference layer for generating corresponding layers for several parameters, as follows: hypsometry, slope exposition, slope incline and surface curvature (degree of concavity/convexity).

Figure 3: SRTM Botoşani

To attain the raster layer with the vulnerability classes associated to land use, the file Corine Land Cover 2000[3] for Romania was downloaded, from which land use categories specific to Botoşani county, were then extracted.

To each parameter a raster layer classified in 3, 4 or 5 vulnerability classes was attributed, depending on their specific

[3] GEOSPATIAL (www.earth.unibuc.ro)

conditions. Afterwards, from the same layer with land use, contact areas between the categories of usage with the highest and lowest value class were traced. The surface of these areas, them being in vectorial, line type format, could not be calculated; therefore a buffer was created, according to the SRTM′s resolution.

For highlighting snow-drifting vulnerability at a superior level to the purely physic-geographical one, the road transportation infrastructure was digitized (from topographic maps with a 1:25000 scale). It was then associated with numeric attributes, according to the type of road profile and the morphometric characteristics of each section of the road, after which a buffer was created. The whole set of vector layers obtained was converted into raster format, respecting the pixels′ matrix from the basis layer (SRTM).

To have a comprehensive image of the interaction among the previously stated parameters, a new raster was generated, through applying a formula of summing the layers with the final rasterized parameters, grouped into vulnerability classes. This was the final layer, which represented the basis for the snow-drifting vulnerability map.

The summation method of layers with different degrees of vulnerability was applied on a large scale in geographical areas. The areas that the method is applied are that related sciences that they studying territories or ecosystems, relatively sensitive to possible or probable phenomenons (Hiaojiang, H.X. Lan; Zhou C.H., Wang L.J.; Zhang R.H. Li, 2004; Mowen X., Tetsuro E., Gouyun Z., 2004).

Amount of factors that contribute to overall vulnerability or introducing of some correction factors that they are applied in the account formula we considered to be irrelevant, solving the problem is choosing a typical profile of blizzards, which are characterized by a wind with speed over 10 m/s, generated by high values of baric gradients from the north-west, and solid precipitation equally distributed, generated by the thermal contrast between two masses of air characterized by high values of humidity.

Setting the number of classes of vulnerability was achieved by Huntsberger relation (k = 1 3.332 * log n (10)), to ensure a correct division of series of data obtained by summing the layers that generates the snow vulnerability. The limits of these classes were determined by applying arithmetic progression as this detailing the extreme values, these classes of maximum or minimum vulnerability characteristics the area analyzed.

3. Analysis and discussions

3.1. Hypsometry. In the analysis of snow drifting vulnerability, morphometric and morphological parameters were taken into account, parameters which directly influence the way that snow builds up and the thickness of the snow layer.

Therefore, an important parameter in this analysis is hypsometry. The basis of this layer's execution was the SRTM (Shuttle Radar Topography Mission). This layer was obtained through the classification of the SRTM using a spatial manipulation language (SML – specific to TNTMips program).

The criteria taken into account for the execution of this classification refers to two types of areas which favor the association with the major and intermediate vulnerability classes. Hence, the spatial logic applied in obtaining this layer was a mirrored classification, specifically: we assume that the altitudes with the highest and lowest values have the highest vulnerability rank (5) and the ranks 3 and 4 were given to the intermediate altitudes. This assumption is based on the idea that the higher regions, generally plateau areas are characterized by greater wind speeds due to their low rugosity and the lower regions, which correspond to flat areas such as alluvial plains, where land roughness is as well very reduced, equally lead to the intensification of wind speed (Figure 1.a).

3.2 Slope. The generation of this morphometric parameter was accomplished by applying a SML language to the layer adjacent to the SRTM (the slope of the relief), obtaining a raster with 5 vulnerability classes (Figure 4.b).

The assignment of these classes was based on the idea that the more reduced declivities favor snow-bounds. Opposite to that, larger values of the slope prevent snow accumulation due to the snow flakes' saltation phenomenon (Liston and Sturm, 1998). Snow drifting's ampleness diminishes gradually along with the increase of the slope's angle.

3.3 Surface Curvature. Another physico-geographical factor which influences snow-drifting is surface curvature. This refers to the presence and amplitude of the concave and convex types of relief.

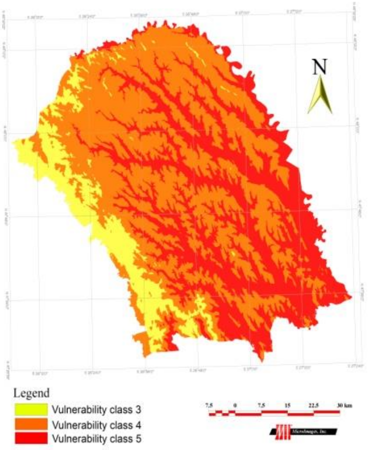
The concave relief structures (class 2) facilitate the accumulation and maintainability of the snow layer and the convex structures (class 1) provoke a spreading of the snow.

A particular situation is the contact between the steeper slopes and the areas with a reduced slope (class 4). This high value of vulnerability is given by the transition between the planiform surfaces and the incline (Figure 4.c).

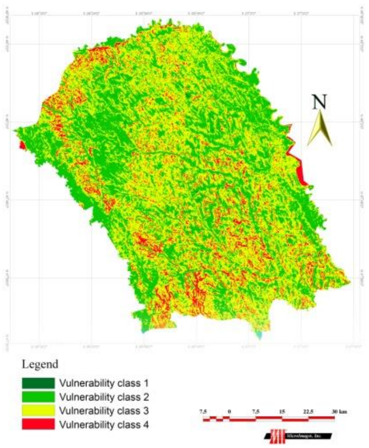
3.4. Exposition. The transportation and deposition of large quantities of snow is produced with a high degree of dependency on the relief's exposition, especially the prevailing wind direction.

The physico-geographical ampleness and the specific climatic condition of Botoşani county imply a prevailing wind direction from the NW, followed by a prevailing, northern direction. Therefore, these two classes are associated to a median vulnerability rank (direct exposure). The forth class of vulnerability is associated to retrograde cyclones. The second class, associated to western exposure, is due to the Coandă effect (alongside the channeling of air currents in NW-SW direction), and the highest vulnerability (class 5) is given by the sheltering effect (opposite wind direction).

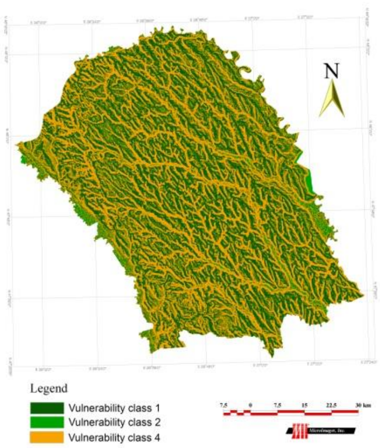
3.5 Land use. For this layer, 5 vulnerability classes were assigned, based on the degree of land surface's asperity, so that the areas characterized by high degrees of asperity were added to the class with the lowest degree of vulnerability and the areas with an almost plane surface (agricultural surfaces, grassy areas and lower areas) were given the highest degree of vulnerability, being without any vertically-developed obstacles.



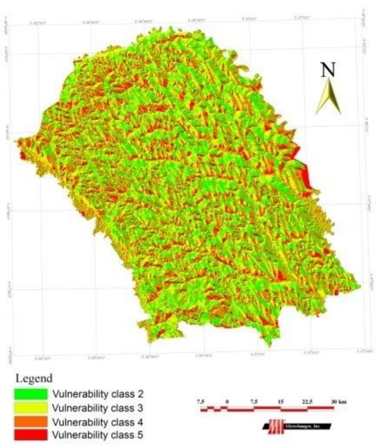
a. Hypsometry



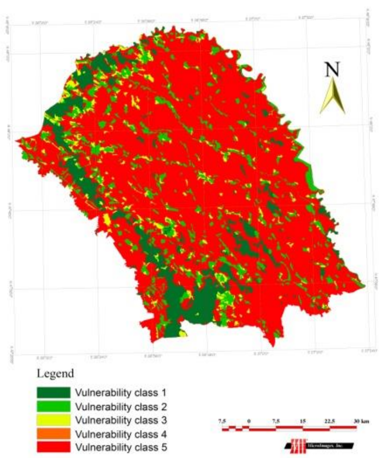
b. Slope



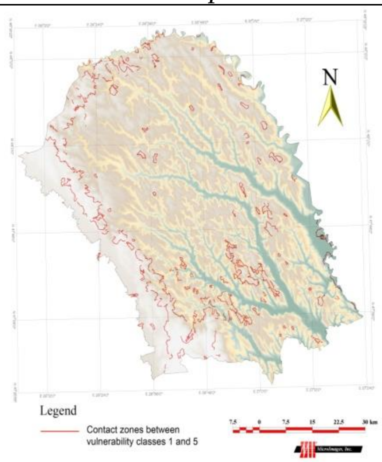
c. Plan curvature



d. Exposition



e. Land use



f. Contact areas

Figure 4: Parameters utilized in the analysis of snow-drifting vulnerability

The fundamental file for obtaining the land use layer, and so the particular vulnerability classes, is Corine Land Cover (from the year 2000). A polygon was created, in vectorial format, for every area particular to a certain vulnerability class, which was then given an attribute in the form of a numerical code, as 1, 2, 3, 4 or 5. Then the polygons obtained for the studied area were rasterized, following the standard characteristics offered by the base layer (SRTM) and corresponding to the dimensions of all the layers included in the summing process, in order to obtain the final product (Figure 4. e).

3.6 Contact areas. Land use brings up the discussion of another important factor which influences the accumulation of snow in certain key-areas, which would be the contact between the extreme vulnerability classes of land use, optimal conditions for the accumulation of snow, through reducing wind speed, being created. In this case, the areas most exposed are situated at the contact between the 1 and 5 classes, to be more precise, between forests, urban and rural spaces and swamps, grass lands, communication networks and agricultural terrain. This information was extracted in vectorial form, according to Corine Land Cover 2000 and everything was classified as being part of the number 5 class.

The contact areas were obtained through the extraction of the linear-type vectors which formed the contact between class 1 and 5 from the land use vulnerability layer, these being given attribute 4 (Figure 4. f). Because a vector line cannot have a surface, a buffer was applied and they were rasterized, in order to be included in the final summing of layers.

3.7. Road infrastructure. Regarding the integration into the analysis of the influence brought on by the antrophic alterations carried out in the design and execution of road networks, the transformation of road infrastructure into vectorial format was performed. A 75 meter buffer was applied to the road network, after which, with the help of topographic maps (at a 1:25000 scale), the areas which modify the natural conformation of the relief through the placement of the road networks, were identified and marked.

For including the anthropic alterations which directly influence the degree of vulnerability of the road network, a bonitation in 5 classes of exposure was comprised, which took into account the extent of the adjustment as well as the direction in which these sections are placed. The sections' direction was correlated with the prevailing wind direction in the normal period of manifestation of a typical blizzard in Botoșani county. Hence, the degree of snow-drifting vulnerability is higher as the section is situated perpendicular on the prevailing wind direction. After the individual analyze of the studied sections, a final vector resulted, which will later be transformed into a raster format, to be integrated into the final, synthetic, analysis of all the studied factors. This will grant the assessment of the road infrastructure areas most vulnerable to snow-drifting in Botoşani county.

3.8. Final results. After the elaboration of each individual layer for every analyzed parameter, the final product materialized as a result of their summing, into a map which highlights the spatial distribution of snow-drifting vulnerability (associated to Botoşani county) into 5 classes. Succeeding this operation, the final raster, which was unclassified, had values ranging between 8 and 27. On applying a series of statistic progressions, for identifying the best quantitative approach, it was concluded that the most appropriate method of classifying the final layer (to obtain a 5 class snow-drifting vulnerability map) is the application of geometric progression.

Table 1: Bonitation classes of the anthropic alterations to communication networks

Vulnerability class	Infrastructure element (Direction)
1	Embankment 1-2 meters (North South)
2	Embankment 2-4 meters (North South) Mixt Profile +/- 1 meter (North South)
3	Embankment 4-6 meters (North South) Cutting 1-2 meters Mixt Profile +/- 1 meter (East West) Mixt profile +/-2 meters (North South)
4	Embankment 2-4 meters (East West) Cutting 2-4 meters Mixt profile +/-2 meters (East West)
5	Embankment 4-6 meters (East West) Cutting +4 meters Mixt profile +/-3 meters (east West)

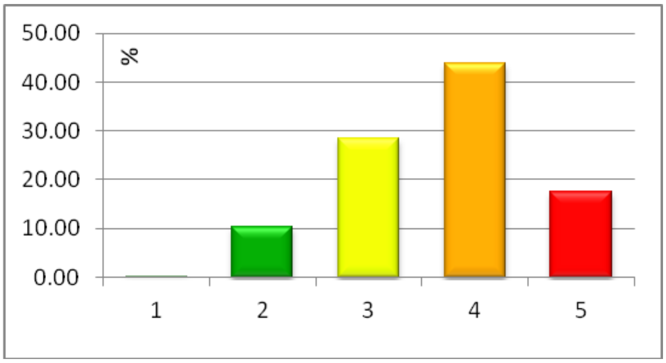


Figure 5: Classes of vulnerability frequency for all county road network

The identified road sections with a high degree of snow-drifting vulnerability are situated on Jijia valley and Sitna valley, and even downstream of their confluence, proximate to Hlipiceni locality. Analyzing the snow-drifting vulnerability map, one can observe that the sectors of affected roads - DN28C Botoşani-Dorohoi, E85 Botoșani- Flămânzi, DN28B Botoșani – Iaşi connect the most important localities. A very important aspect consist in the higher degree of vulnerability to snow drifting of county road network, more than 50% of those roads corresponding to 4 and 5 vulnerability classes.

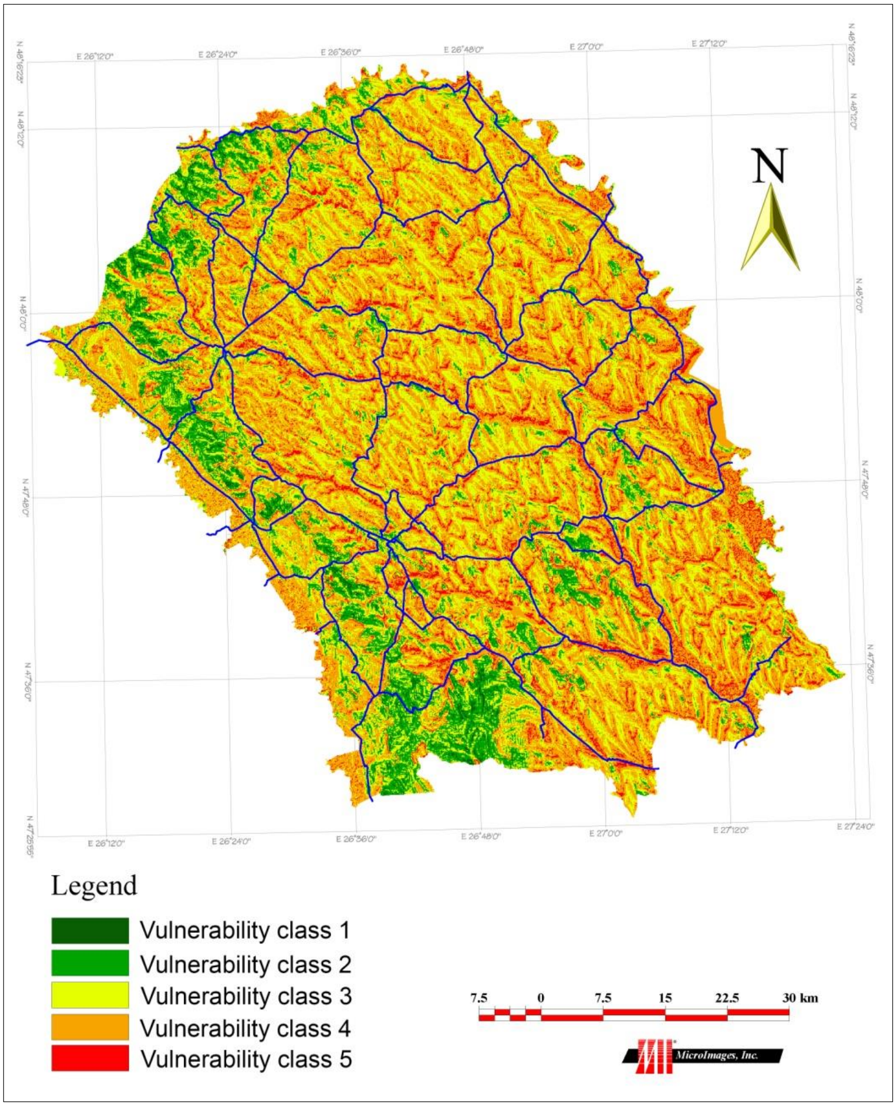


Figure 6: Map of snow-drifting vulnerability for Botoşani county

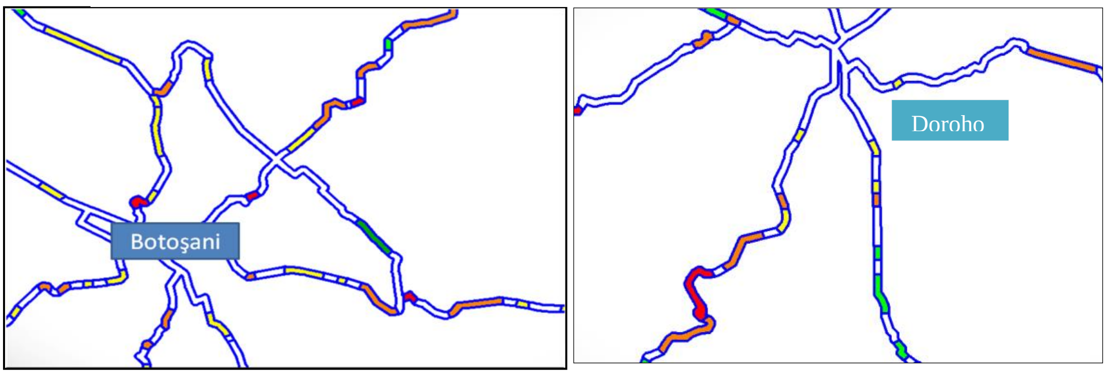


Figure 7: Road sections extracted from the snow-drifting vulnerability map for Botoşani county

Conclusions

Even if blizzard phenomenon tends to be less frequent in the last decades, the impact of that phenomenon could be even more dangerous to the transportation sector. The 3 harsh successive blizzard episodes of 2011-2012, blocking transportation, cities and villages in whole south-eastern Romania sustain this conclusion.

This study represents a first quantitative evaluation of snow-drifting phenomenon for a certain region of Romanian territory. We have tried to evaluate the most important factors that are driving snow-drifting in blizzard conditions. The GIS techniques have facilitated the integration and the summation of all those factors in a manner that was not used before.

In a further study we will try to validate these results by the mean of statistics regarding the previous intervention of Romanian Emergency Inspectorate. After that the study could represent a very useful tool for the institutions charged with intervention responsibilities in blizzard conditions.

Acknowledgements

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