MULTIPLE CLIMATE HAZARDS WITH IMPACT ON TRANSPORT SYSTEMS IN DOLJ COUNTY, ROMANIA

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ABSTRACT. – Hazardous extreme weather phenomena with impact on transport systems in Dolj Country, Romania. Fog, glazed frost, hail, blizzards, snow cover and strong winds are recognized as some of the most representative climate hazards impacting transport systems. The authors computed several climate indicators based on their cumulated frequency (average annual number of days) in order to highlight the most significant hazardous phenomena using the climate database (1961-2010) of the most relevant weather stations in Dolj County and its surroundings. The indicators were computed and integrated in GIS using spatial analysis techniques resulting the regionalization of extreme weather phenomena. Also, ranking the analysed phenomena according to their importance in impacting the transport systems, a multiple climate hazard (MCH) map have resulted. The derived values were classified into three intervals corresponding to three intensity classes: high, medium and low. In order to spatially quantify the MCH, the share of each intensity class at administrative-territorial units (LAU2) was calculated.

Keywords: extreme weather phenomena, transport systems, multiple climate hazard (MCH), Dolj County, Romania.

1. INTRODUCTION

Climate change and extreme events are projected to damage vital infrastructure of which water and sanitation, energy, and transportation are particularly vulnerable (Adger et al, 2014). Thus, the negative impacts of extreme weather events (e.g. heavy rainfall/snowfall, strong winds, extreme heat/cold) on the transport sector can cause injuries and damages, as well as other economic losses (Vajda et al., 2011). These impacts are dependent on the regional climate variations and the nature of local transport infrastructure (Sims et al., 2014). Differences in performance of road, rail and waterway transport systems indicate potential impacts of climate change on transport patterns such as passenger transport (patterns in tourism) and freight transport (shifts in agricultural production), rail/road transport (infrastructure failure, accidents, traffic congestion) (Koetse and Rietveld, 2009).

The guiding principles of the EU environmental policies are targeting core areas such as air quality and climate change. In this respect, the Europe 2020 strategy aims to achieve the "20-20-20 targets" of the Climate and Energy legislative package 2020 (a 20% reduction in EU greenhouse gas emissions from 1990 levels, rising the share of EU energy consumption form renewable resources to 20% and a 20% improvement in the EU's

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energy efficiency) (European Commission, 2010; Grigorescu and Kucsicsa, 2015). Therewith, the *EU Strategy on Adaptation to Climate Change* (2013) provides increased preparedness and response to climate change impacts at local, regional, national and European level. In line with that, Romania has developed a *National Climate Change Strategy 2013-2020*, which targets, through its objectives, two distinct components: to reduce GHG emissions in order to achieve the national objectives ("Mitigation") and adaptation to climate change ("Adaptation"). Thus, it seeks measures of adaptation to climate change in vulnerable sectors such as industry, agriculture and fisheries, tourism, public health, transport, water resources, forests, energy, biodiversity, insurance, recreation and education (Sima and Popovici, 2015). Within these strategic documents, the effects of severe weather phenomena (e.g. dryness and drought, heavy rainfall, hail, blizzard, glazed frost) with impact on key sectors, i.e. transport, should be supported by mitigation and adaptation actions. In the transport systems, sometimes the adaptation efforts complement the mitigations actions. However, according to IPPC Report (2014), until now, little research has been conducted on the relationship between adaptation and mitigation strategies in this sector (Sims et al., 2014). Thus, integrated and applied studies at regional and local levels addressing the extreme weather events and their related impacts would significantly contribute to both adaptation and mitigation actions.

2. THE STUDY-AREA

Dolj County is located in the south-western part of Romania overlapping the Getic Piedmont and Romanian Plain (Oltenia Plain subunit) and Danube floodplain in the south and south-west (Fig. 1).

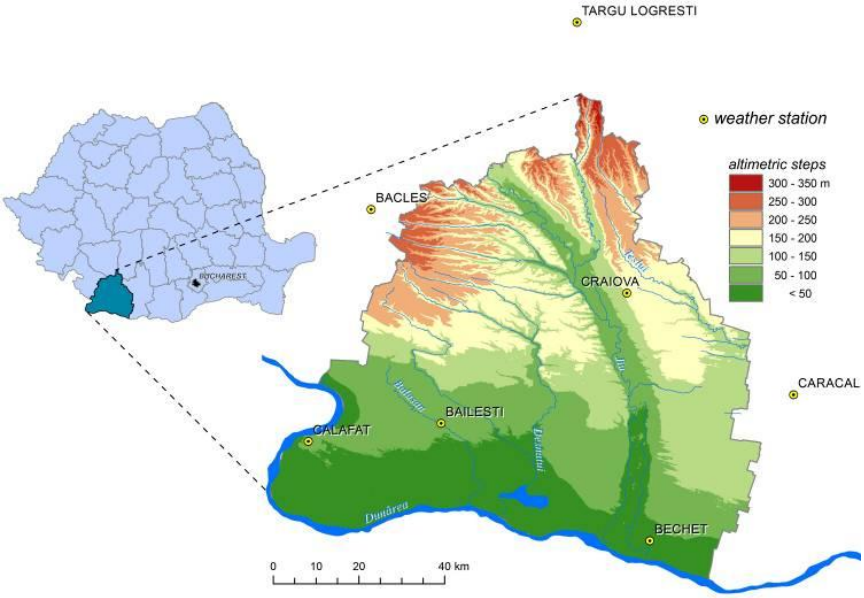

Fig. 1. ***The spatial distribution of weather stations used for the climate hazard maps/multiple climate hazard maps***

The climate hazards, which are affecting the south-western Romania, takes regional characteristics depending on the type of atmospheric circulation and the geographical position in relation to the major relief forms and the presence of the the Danube floodplain in the south and the main rivers with a general north-south orientation are added. The climatic influences driven by the extended surface of the Romanian Plain situated in the large "*cul–de-sac"* Carpathian-Balkan Depression sheltered by the bordering orographic barrier, enables the eastern advections of polar air bearing a continental influence, leading to temperature inversions on a regional scale, the persistence of winter cold waves and summer heat waves, as well as to drought and dryness phenomena (Bogdan, 2000) determining a varied exposure to climate-related extreme events with local differences.

3. METHODOLOGY AND DATA

For the current study, several indicators with relevance for the hazardous weather phenomena impacting on transport systems in Dolj County were selected. Thus, based on a complex classification of natural hazards relied on quantitative and qualitative criteria (Bryant, 1991; Croitoru and Moldovan, 2005), the authors selected an ranked the main dangerous climate phenomena in the study-area using the cumulative frequency (annual average number of days) of their occurrence. The selected indicators were calculated using the climate data recorded over the 1961 - 2010 period at seven weather stations in Dolj County and its surroundings, then integrated and computed in GIS using interpolation techniques, classification and spatial analysis (Dragotă et al, 2013; Grigorescu et al., 2013). Hence, six hazard maps, separated into three intervals depending on the minimum and maximum values of the computed indicators, have resulted. The classification was done using Natural Breaks (Jenks), a classification method commonly used in spatial data analysis. Subsequently, the ranking of each climate hazard into three classes according to their weight (importance) was carried out: 1 = small or low importance, 2 = medium importance, 3 = high importance (Tab. 1).

Table 1. ***Climate indicators with impact on transport systems and their ranking according to their weight in Dolj County***

Indicator	Classes*
average number of days with fog	3
average number of days with glazed frost	3
average number of days with blizzard	2
average number of days with strong wind	1
average number of days with hail	1
average number of days with snow cover	2

* 1 = low, 2 = medium, 3 = high

The final stage of quantification into a **multiple climate hazard (MCH)** map was based on the summation of all considered climate hazards multiplied by each one's ranking value. The mathematical relationship can be expressed as:

$$\mathbf{MCH = H_{1i} + H_{2i} + H_{3i} \ldots + \ldots H_{6i}}$$

where: **MCH** = multiple climate hazard; $\mathbf{H_1, H_2, H_3 \ldots H_6}$ = the selected climate hazards with impact on transport systems; $_i$ = the class weight (importance) after ranking.

Ultimately, the resulted outcomes were classified into three intervals according to which three multiple climatic hazard intensity classes were assigned: ***high MCH***, ***medium MCH*** and ***low MCH***.

In order to provide the spatial assessment of the multiple climate hazard with impact on the transport systems, the share of the intensity classes of the local administrative unit level (LAU2) was computed. The spatial statistical analysis was performed by intersecting the multiple climate hazard map with the LAU2 limits vector, thus resulting a table summarizing the share of the hazard intensity classes of each locality in Dolj County.

4. RESULTS AND DISCUSSIONS

The most important climate hazards impacting the road, rail and inland waterway transport systems, as well as the related infrastructure are: fog, glazed frost, blizzards, snow cover and strong winds.

Persistent ***fog*** can disturb transportation, given that the most important roads in Dolj County are developed along valleys or corridors that favor the occurrence of this dangerous climate phenomenon. Fog becomes significantly dangerous on certain sectors of the European roads where, the low-visibility along with the higher speeds and increased traffic, can result into severe accidents with casualties and property damages. By reducing visibility, fog causees problems for waterway transport on the Danube River, as well.

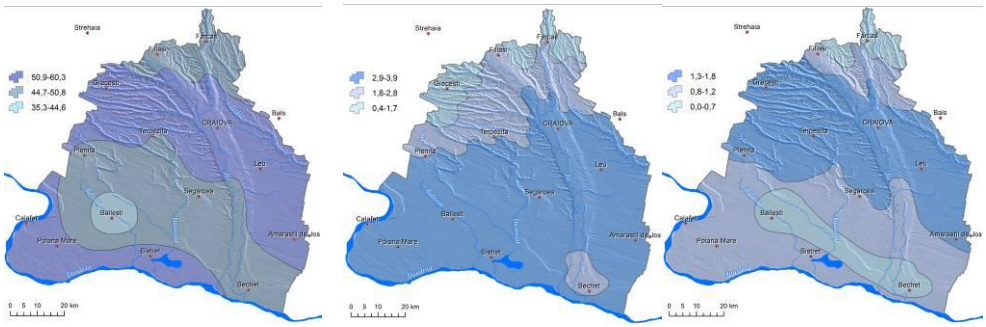

Fig. 2. ***The annual frequency of days with fog, glazed frost and blizzard***

The ***glazed frost*** is one of the most dangerous weather phenomena having a negative impact on all transport means due primarily to the significant decrease of coefficient of friction on ice layer that hinders transportation and increases the risk of accidents. In addition, ice accumulations can cause breaks in the canopy of trees, impacting on road and rail transporation, as well.

The ***blizzard*** generates severe snowstorms that result in low visibility on rutes, impeding/obstructing transporation on roads and rail, thus causing accidents. However, the blizzard may intensify the effect of ice deposits that might overload

cables and power lines. The transport routes the most affected by blizzards are generally perpendicular to its direction: Filiaşi - Craiova - Bechet; Slatina - Craiova; Craiova - Terpeziţa - Vârtop – Citadel, as well as the national roads that accompany them. However, blizzard stands as a severe and complex weather phenomenon whose effects are also dictated by the quality of infrastructure.

The ***strong wind***, through its shifts in direction and intensity and mechanical effects can severly damage road infrastructure causing restrictions to traffic flow, breaking the aerial cables, toppling the electricity transmission poles, falling over the trees along the transportations means etc.

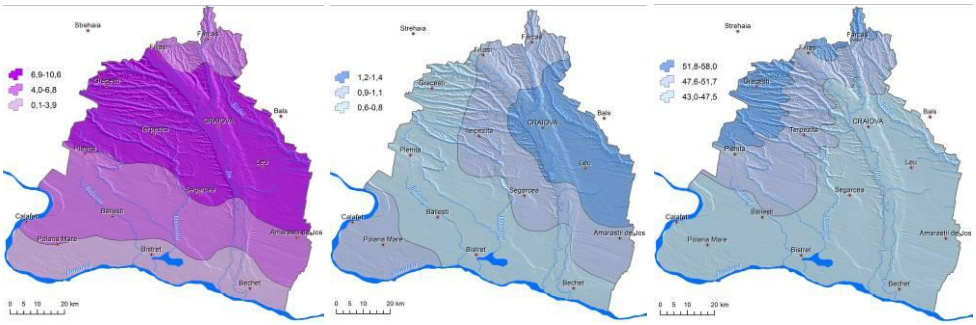

Fig. 3. ***The annual frequency of days with strong wind, hail and snow cover***

The ***hail***, through the mechanical effect of hailstones, can cause significant structural damages to roads and bridges, vehicles destruction, as well as injuries to the roadway pavement, thus leading to accidents and hindering road traffic.

The ***snow cover*** becomes climate hazard when its thickness is considerably high and, due to snow drifts, turns into snowbanks affecting the road infrastructure located perpendicular to the wind direction. Therewith, sudden snow melts can trigger floods, as well as river blocking caused by ice floes with major impact on river transportation.

The regionalization of multiple climate hazard (MCH). More than half of Dolj County (50.18%) have medium exposure to the climate hazards impacting on transport systems, thus covering the north and west of Băileşti and Segarcea Plains, south of Leu-Rotunda Field, north of Tesluiului Plateau and west of Bălăciţa Piedmont. The areas with maximum exposure to these climate hazards are located in the Leu-Rotunda Field, south of Teslui Plateau and Bălăciţa Piedmont totaling 33.04% of Dolj County. The lowest exposure (16.78%) overalp the northern extremity of the study-area (Amaradia Hills) and a continuous strip unfolding from the center of Băileşti Plain to the east, south-east in Dăbuleni Field (Fig. 4).

The local administrative units with high exposure to these extreme weather phenomena (over 90% of their surface) are Craiova municipality to which, Amărăştii de Sus, Apele Vii, Brabova, Breasta, Bucovăţ, Cârcea, Castranova, Celaru, Coşoveni, Coţofenii de Sus, Dioşti, Dragoteşti, Ghindeni, Işalniţa, Leu, Malu Mare, Pieleşti, Pleşoi, Podari, Predeşti, Robăneşti, Scăieşti, Şopot, Terpeziţa, Teslui, Tuglui and Vela localities are added.

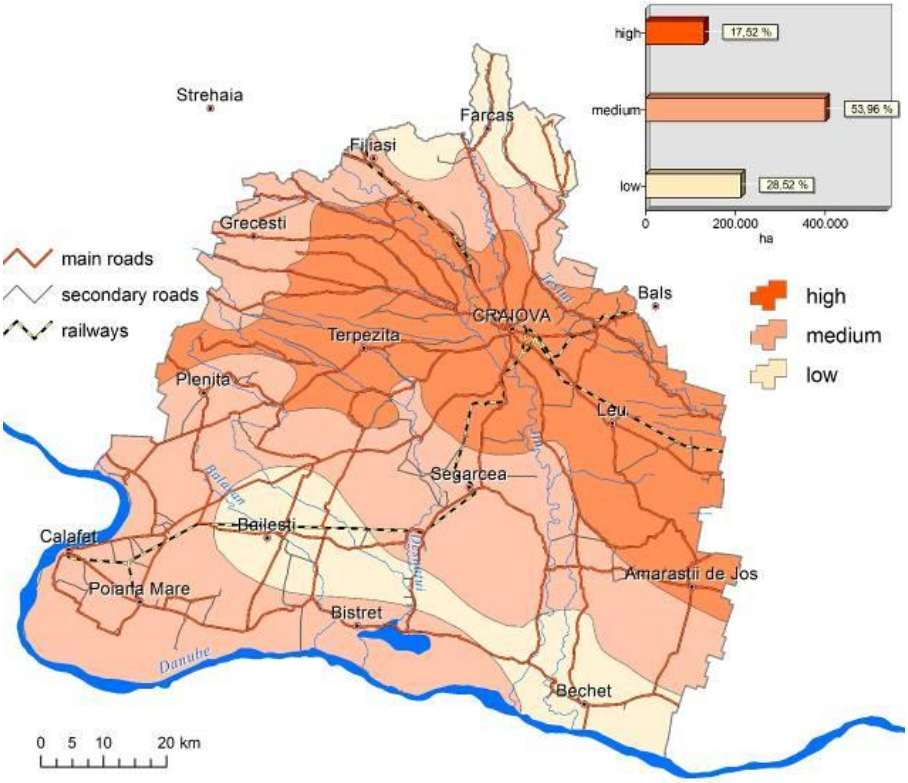

Fig. 4. ***Multiple climate hazard map with impact on transport systems in Dolj County***

A significantly reduced number of (Afumaţi, Bechet, Călăraşi, Fărcaş, Ostroveni and Talpaş) have low exposure to this group of dangerous weather phenomena (Fig. 5). The applied methodology is aimed at providing a quantitative approach on the impacts of extreme weather events on transport systems. Such approach is to be completed by risk assessment analysis and impact assessments in order to support mitigation and risk control measures at local/regional level.

5. CONCLUSIONS

The climatic conditions of Dolj Couny results in the development of a variety of extreme weather phenomena integrated by genesis, occurrence and severity with major long term effects in key priority sectors such as: agriculture, transport, technical and edilitary infrastructure and health. The frequency analysis of dangerous weather phenomena with impact on transportation have led to the delineation of areas with different intensity classes. Generally, the largest areas with high and medium intensity to these weather phenomena are located in the center of Dolj County, while in the north and south of the analysed territory the intensity values drop constantly depending on the local climate conditions.

In the future, the frequency and intensity of climate extremes are likely to continue to change, while their consequences will increasingly affect transport systems. Under these expected conditions, according to IPCC Report (2014) (Adger et al., 2014; Sims et al., 2014), climate proofing and adaptation will require substantial infrastructure investments in terms of rail/road improvements, extensive operations and service provision.

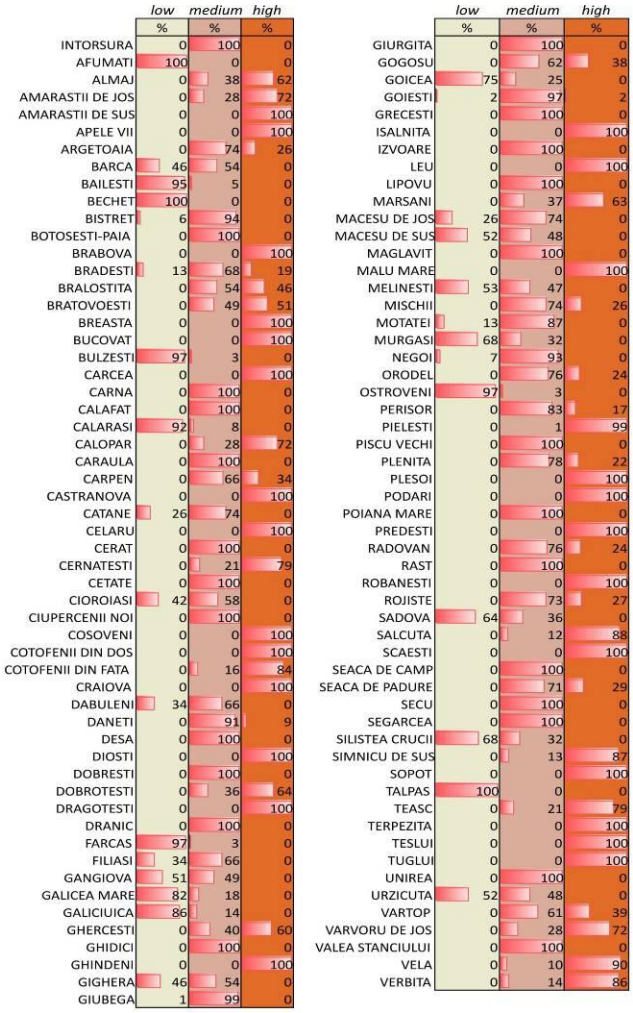

Fig. 5. ***The share of each multiple climate hazard intensity class with impact on transport systems at LAU2 level in Dolj County***

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