Location and delimitation of the climatic changing areas: the potential of a UAVs based validation

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Key words: natural hazard maps, UAVs applications

SUMMARY

The evidence of natural disasters and catastrophes has become a concerning priority of governments and international bodies. This distress is justified by the fact that these damages raise the expenses beyond national plans of economic and social development. Indeed, the official statistics show an explosive increase in the amount of damages caused by natural disasters, especially in the last decades.

In this paper we are presenting a series of results obtained for determining the location and obtaining the delimitation of the climatic changing areas. We are presenting the maps indicating the lithographical and hydrological risk factors. The possibility of performing a UAVs based validation is discussed and a specific case is presented.

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1. INTRODUCTION

In the last decades, the climate changes are a constant factor generating natural calamities and disasters. An increasing number of events that can be considered as natural disasters took place. In the last decade, the evidence shows dramatic increases. For example, the German insurer Munich Re published an alarming report showing that the accumulation of severe natural disasters made 2011 a year of unprecedented severe damage, as there have been 335 natural disasters only the first half of 2011.

In these conditions, a system for monitoring and assessing risk becomes a necessity. For example, floods and landslides took place in 2006 in several districts of Romania - Mehedinti, Ialomita, Dolj and Harghita. According to the news agencies, more than 300 households, dozens of county roads and about 3,000 farmland hectares were affected (Fig. 1). On 3rd April 2006, the Danube River reached a level of 643 inches in the county of Braila and Galati, surpassing the flood elevations. This was the highest level recorded in over 35 years. A week later, the Danube waters broke the Isaccea dam (Tulcea County) considered one of the safest area dams in Romania. Central authorities have called for a constant surveillance of the Danube.

Fig. 1 The flood map in 2006 in the Eastern Europe

The entire series of events held in the Galati county area led us to the idea of creating an intelligent decision support, capable to perform and evaluate the environmental parameters in real-time, as a contribution to the development of the management of climatic factors. The strategic scientific objective was to build a decision-making support for the prevention and the mitigation of climate factors. The chosen geographical region for building the risk maps cover an area of about 550 square km, in the Galati County, Romania.

2. METHODOLOGY

The risk expresses the probability of occurrence of dramatic phenomena and has a random character. When disasters or calamities are caused by human activities or occur beyond, they are called natural hazards. In this study, three types of natural hazards were considered: earthquakes, slip and flooding. From these hazards, only the seismic hazard is unpredictable and almost impossible to prevent. In this paper we are presenting a study case related to the flooding hazard. The final part presents the results obtained during a reliable validation process that was performed by using a new generation of UAVs.

The aim was to draw natural hazard maps and further develop risk plots, by taking into account the sites' vulnerability. In the first stage, were evaluated only slip and floods risk areas in the Galati county, areas which in turn were differentiated and localized. From this last aspect, that natural hazard maps must have a dynamic, meaning susceptibility to any future scenarios.

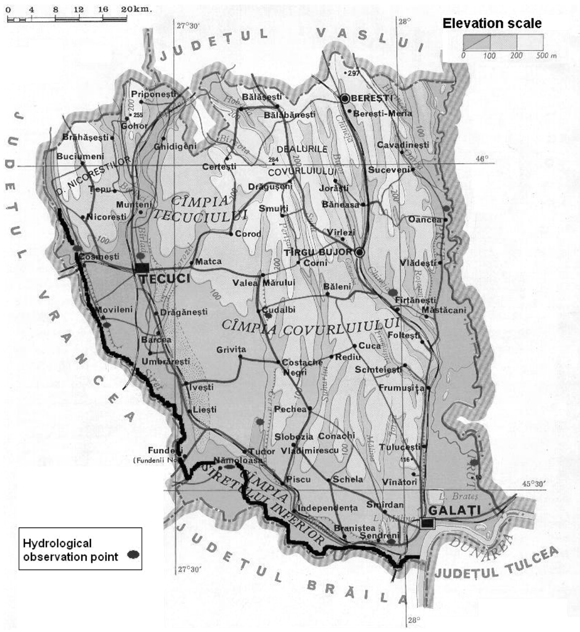

Fig. 2 Galati County with and the Danube River, Siret River and Prut River map

Natural hazard maps have an indefinite life in time and space. Expert systems developed based on these maps may be used by local authorities, for making decisions based on scientific conclusions, in an optimal and efficient way.

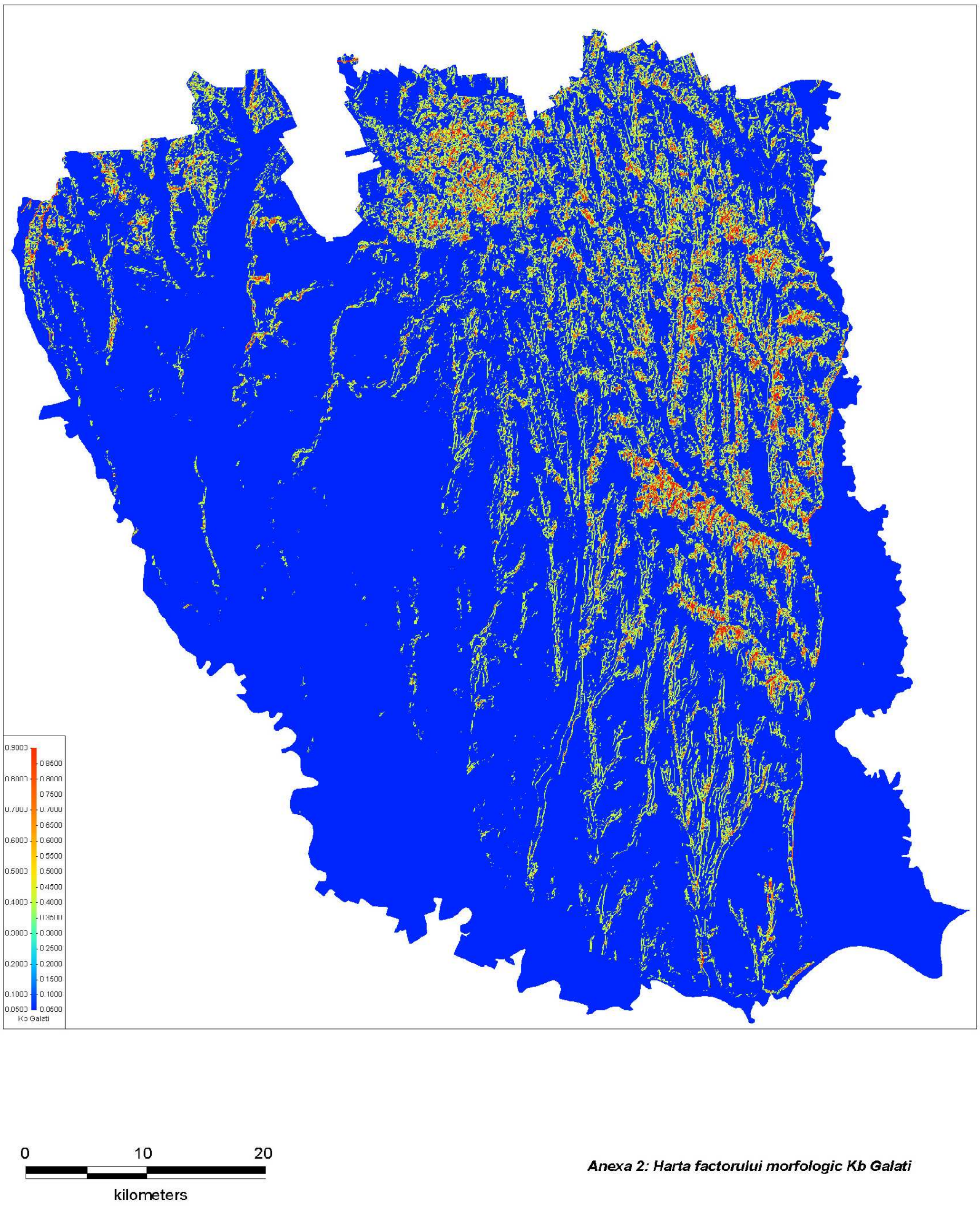

Fig. 3 The Galati County morphological factor map – Kb

The towns of Galati, Braila and Macin are located in east-south-eastern Romania, on the Lower Danube, the later receiving the Siret River and Prut River tributaries (Fig. 2). From this point of view, the Galati county is a complex contact area between very diverse physical and geographical units: the Danube valley, the mountains Pricopanului, the Baragan plain, and the lower Siret Plain Covurlui. The towns of Galati and Braila are situated at a distance of 150 km and 170 km respectively from Sulina - the terminus of the Danube and the Black Sea.

The rainfall level within this urban group is different from one city to another. The highest annual rainfall amount, of 454.9 mm, is registered in the Macin area. This value can be explained by its geographical location. In the town of Braila, the average annual precipitation level is about 437.2 mm, while the average annual precipitation of the city of Galati is 427.1 mm.

3. RESULTS

Building a decision support system designed to manage the risk of landslide in a given geographical area requires the development of an extensive software program containing monitoring procedures, and data covering a wide range of phenomena occurring in unstable natural and environmental conditions.

In this section we are presenting specific results obtained for the morphological factor map – Kb (Fig. 3). The Galati County is neither spectacular nor complicated, consisting mostly of lowlands (C. Covurlui, C. Tecuciului, C. Siret) and subordinated to a plateau (Pod. Covurlui) and a number of hills (col. Tutova). The altitudes are low (250-300 m) and grow downwards from north to south. In order to obtain the map of the geomorphologic factor Kb (Fig. 3), we have selected a territory in the southern segment of the Moldova Plateau and a segment of the Romanian Plain.

The Tutova hills (piedmont plateau of 200-300 m altitude) are found between the Siret and the Barlad rivers, being located in the northwest district. The area continues with the Tecuci Plain, in addition to plain terraces, consisting of sandy deposits, river pebbles - lake or rain.

The Covurlui Plateau is a range of hills and plateaus looking piedmont. To the east, the broken plateau of Covurlui has the form of a steep slope and affects the neighboring ravines and landslides, which dominate the lower valley of Siret. Located next to the river of Prut, the area is a combination of stairs like descending fields, to see Siret, Suhurlui, Lozova, Malina, and Covurlui. Their slopes, but also the bank of the Siret river are strongly affected by the rain.

The plain of Tecuci (100-200 m alt.) lies next to the river of Siret, and consists mainly of terraces. The Lower Siret Plain is the lowest level of relief in the county and presents itself as an alluvial plain (8-13 m alt.).

The morphological factor map was achieved by shaping Kb polygons with constant values of the slopes. For the preparation of this product, a vector map of 1: 50,000 of the county was used. The contour lines (primary and secondary) are recorded in the database, the elevation values being the main attribute. The all-vector generation of the final product was achieved by using the ArcGIS software.

4. VALIDATION AND DISCUSSIONS

In the last 3-4 years a strong tendency to use the Unmanned Aerial devices (UAV) could be observed. UAVs have been used for civilian applications just for the past few years. Initially they were developed and used for military applications. Distinct advantages of these UAVs determine the large extent of their use both in scientific and industrial related research.

In principle, a UAV system consists of an active element (the vehicle itself) and a ground-station. Control can be achieved either by manual piloting or by using the flight controls in auto-pilot mode, integrating GPS and flight routes. Due to their low-risk, low-cost, high turn-over of operation, these devices present many benefits and advantages that are unrivaled.

Unfortunately, there are a series of limitations in the use of UAV's, which could hang tough in choosing a suitable means: limitations of the payload; regulations and insurance; use of low-cost sensors (although this becomes less and less important since the technology advances).

The UAV that we have developed, built and optimized in a joint effort with Reev River Aerospace, has wingspans of 1.4m (Fig. 4) and 1.7 m respectively (Fig. 5), with a useful mass transportation (payload) - up to 1.2 kg. The 1.4 m wingspan UAV has electric propulsion, while the 1.7 m wingspan UAV has an internal combustion engine used as propulsion unit.

Fig. 4 – Mini UAV with 1.4 m wing span   Fig. 5 – Mini UAV with 1.7 m wing span

These UAVs can be operated both in manual mode and in autonomous mode. In manual mode the UAV is remotely piloted using real-time onboard video received at the ground station (Fig. 3). In autonomous mode, the UAV can take-off, fly certain flight path preprogrammed before the flight and land without human pilot intervention. All the human operator has to do is to seat back and enjoy the flight through the real time onboard video. The range of operation in both modes exceeds 30 km depending on the terrain and weather conditions. This range can be extended according to operation needs and it is not a technical limitation of the system but rather a design constraint.

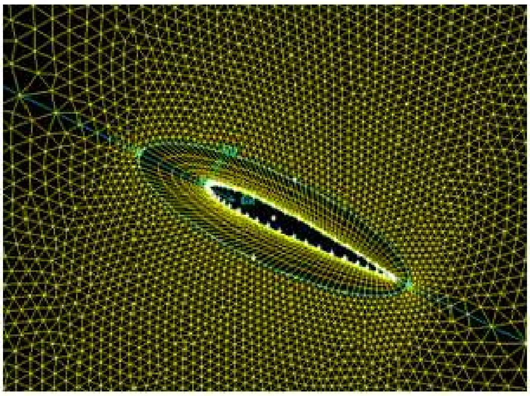

Fig. 6– The ground radio control station   Fig. 7 – The grid for numerical simulation

wing

The system was used in validating missions conducted in May 2011, in the area of Gârboavele Forest (Fig. 8, Fig. 9), and has included digital compact cameras Panasonic DZC-10, Fuji SX200, and Nikon 3100D.

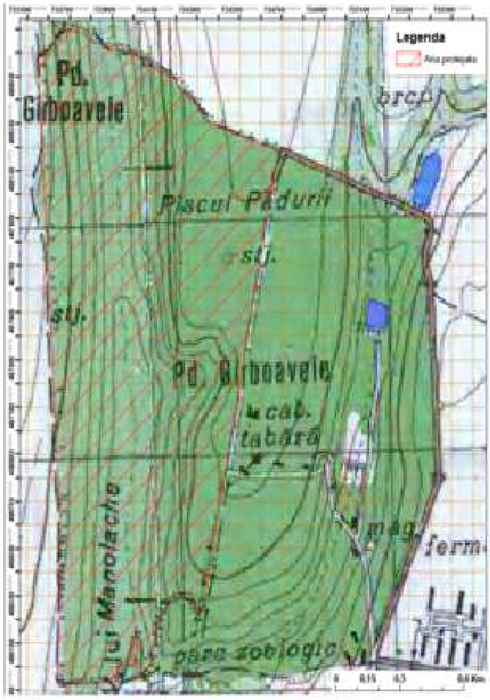

Fig. 8 – The Garboavele Wood area Fig. 9 – The Garboavele Wood orto-photo plan

Some specific conditions are imposed regarding the process of picture taking. According to requirements that are used in cadastral and monitoring applications, further processing of the images in the aero-triangulation operations is needed. The purpose of aero-triangulation processing is to provide the necessary support points for the absolute orientation of the photogrammetric models, to ensure thickening. In this way, a network of support points is obtained, in order to reduce the amount of field measurements. For this, the connection points are measured manually. These points should be the most visible points on the frames.

As a necessity, according to current technical requirements, the camera must be installed on a platform that provides vibration cushioning and gyros-stabilization of the camera body on the three axes (φ, ω, κ) ensuring acquisition nadir of photograms. According to specific norms - the inclination (φ, ω) will not normally exceed 2 degrees and 4 degrees for isolated exposures. For the verification of these specifications, in the image processing stage, a software program was developed based on the MATLAB platform. This script is built in order to assess the parameters φ, ω that are necessary for the image processing step. The main calculation algorithms are presented below.

For an elementary approach, a triangular surface element is considered. We denote by A, B, C solid peaks determined by the points on the ground, and we denote by A ', B', C ' the peaks of the same element of surface images taken by the device (Fig. 10). Given the relative positions of the points A, B 'C' (points on the photo) and of the points A, B, C (points on the ground), the relative orientation parameters of the UAV's during the flight can be determined. Noting with m - scale factor, we can write.

$$\cos\beta_1 = \frac{\ell_1}{L_1} m \qquad (1)$$

Similarly, in the triangle ACC ', we can write

$$\cos\beta_2 = \frac{\ell_2}{L_2} m \qquad (2)$$

For geometrical purposes, in the triangle ABB' we can write

$$\sin\beta_1 = \sqrt{1-(\cos\beta_1)^2} = \frac{h_1}{L_1} \qquad (3)$$

what determines the relation

$$h_1 = L_1 \sin\beta_1 = L_1\sqrt{1-(\cos\beta_1)^2} \qquad (4)$$

and similarly, we obtain the expression

$$\sin\beta_3 = \sqrt{1-(\cos\beta_3)^2} = \frac{h_3}{L_3} = \frac{h_1 - h_2}{L_3} \qquad (5)$$

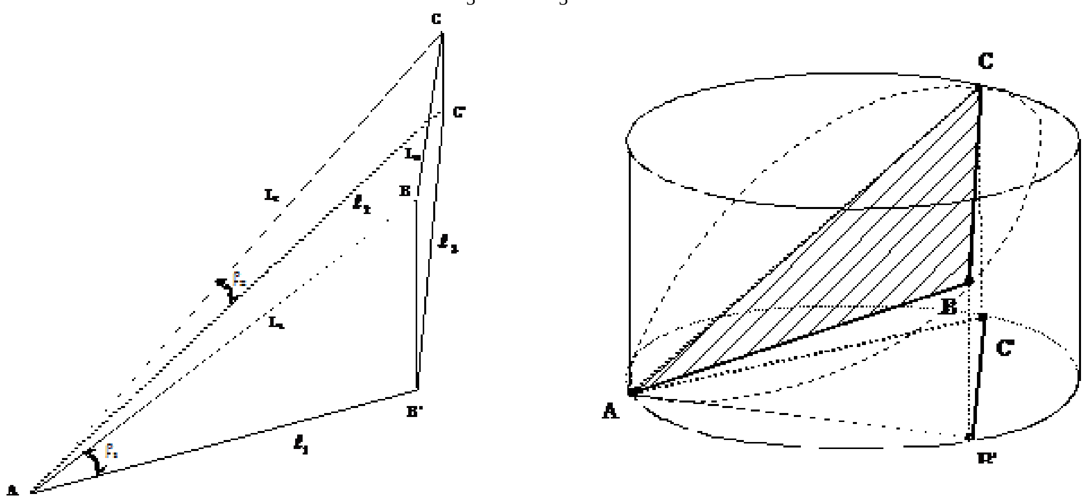

Fig. 10 – The elementary geometrical configuration

or, equivalently

$$\sin\beta_3 = \sqrt{1-(\cos\beta_3)^2} = \frac{h_3}{L_3} = \frac{L_1\sin\beta_1 - L_2\sin\beta_2}{L_3} \qquad (6)$$

or, finally

$$L_3\sqrt{1-\left(\cos\beta_1 \frac{\ell_3}{L_3}\frac{L_1}{\ell_1}\right)^2} + L_2\sqrt{1-\left(\cos\beta_1 \frac{\ell_2}{L_2}\frac{L_1}{\ell_1}\right)^2} = L_1\sqrt{1-(\cos\beta_1)^2} \qquad (7)$$

Fig. 11 – The case study area of the Garboavele Wood for the morphological factor map

Equation (7) allows us to determine the inclination angles and then the correction angles (φ, ω, κ) by considering the link between the circumscribed circle of the A ', B', C triangle and the corresponding circumscribed ellipse of the ABC triangle (Fig. 11). The (φ, ω, κ), rotation angles are necessary for a correct positioning on the ortho-photomap reference [8]. The obtained resolutions are in the average value of 10 – 8 cm/pixel.

Fig. 12 – The case study area of the Garboavele Wood for the morphological factor map validation

5. CONCLUSIONS

The use of UAVs for aerial monitoring and environment surveillance is possible and excellent results can be obtained. The additional data processing required is not very different in essence from that of data gathered with traditional human piloted airplanes. In comparison with satellite pictures, the UAV have the advantage of lower cost and higher resolution. We envision a nationwide system, with integrated ground-stations and with multi-data coverage capability continuous throughout the year.

The data fusion from such a system gives the capability to look basically at the same things through a multi-layer data approach, which can potentially produce an early warning system for weather and environment patterns. One of the most important advantage is that it has monitoring capability and allows the intervention decision point before, during and after natural disasters occur (floods, earthquakes etc.).

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