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Snow avalanche tracks mapping within Bâlea glacial valley (the Făgăraș Mountains) using semi-automated detection methods

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Abstract

Mapping of snow avalanche tracks based on topographic maps, aerophotos and field data to achieve inventories for the whole mountaineous areas in Romania is an important step in snow avalanche risk assessment and other related geomorphic processes. This requires experience and it is a time consuming process. In the absence of field data, the process of snow avalanche tracks mapping is influenced by the subjectivity of those who digitize.
Thus, we propose a semi-automated method for detection of snow avalanche tracks based mainly on geomorphometric parameters that can be extracted from the Digital Elevation Model (DEM) like slope gradient, plan and profile curvature, mean curvature, runoff.
In this study we used an object based analysis to detect snow avalanche tracks in central part of the Făgăraș Mts. This approach has two steps, segmentation and classification. First, we segmented the area based on plan curvature (which is the most important parameter that describes these snow avalanche tracks) in order to obtain objects. In the process of classification we added other conditions such as fuzzy function for slope gradient, thresholds for altitude and runoff and a shape index of objects. The results obtained were very close to the mapped tracks using digitizing techniques. The maps resulted from the classification were compared to the those resulted from digitizing in both number of objects and spatial agreement of the class of objects. There was a very good fit in case of the number of objects and total area of objects. The method could be improved if we apply on high resolution DEMs and also on more case studies with different topography and existing vector database.

Keywords: *snow avalanche tracks, geomorphometric parameters segmentation, object based classification, the Făgăraș Mountains*

Rezumat. Cartarea culoarelor de avalanșă în valea glacială Bâlea (Munții Făgăraș) folosind metode de detectare semi-automată

Cartarea culoarelor de avalanșă pe baza planurilor topografice, a aerofotogramelor și a datelor din teren pentru realizarea unei baze de date digitale în arealele montane din România este un pas important în evaluarea riscului la avalanșe și a altor procese geomorfologice conexe. Acest proces necesită experiență și foarte mult timp. În cazul absenței datelor din teren obținute cu GPS sau stație topografică, digitizarea este influențată de subiectivitatea celui care o realizează.
Studiul de față propune o metodă semi-automată de detectare a culoarelor de avalanșă pe baza integrării caracteristicilor geomorfometrice extrase din modele ale suprafeței topografice. Astfel, aceste caracteristici pot fi extrase din modelul altitudinilor, pantei, curburii. Pentru studiul de față s-a utilizat analiza orientată-obiect obiect pentur a detecta culoarele de avalanșă în partea centrală a Munților Făgăraș. Această abordare are două etape, una de segmentare pentru obținerea obiectelor și una de clasificare a acestora. Segmentarea s-a realizat pe baza modelului curburii în plan, acesta fiind cel mai important parametru în dectectarea culoarelor de avalanșă. Pentru clasificarea obiectelor rezultate s-au mai utilizat și valori caracteristice de pantă utilizând funcții fuzzy, valori prag pentru altitudine, concentrarea scurgerii apei și un indice pentru forma obiectelor. Culoarele de avalanșă obținute ca rezultat al clasificării au fost exportate vectorial și comparate cu datele existente realizate prin digitizare, obținându-se o potrivire foarte bună a obiectelor vectoriale atât în ceea ce privește numărul culoarelor cât și suprafața totală. Metoda poate fi îmbunătățită prin utilizarea unor modele digitale de înaltă rezoluție spațială și aplicarea pe mai multe areale test cu alte caracteristici topografice, și pentru care există baze de date vectoriale cu culoarele de avalanșă.

Cuvinte-cheie: *culoare de avalanșă, parametri geomorfometrici, segmentare, clasificare pe bază de obiecte, Munții Făgăraș*

Introduction

Snow avalanches are one of the most important natural hazards that act mainly in the high mountain environment. Within the Carpathians Mountains, these geomorphologic processes have an important impact on the natural environment and annually cause injuries and fatalities (Voiculescu, et.al., 2011).

Avalanche activity generates a distinctive morphologic shape on preexisting negative torrential features and also a biogeographic response that is associated to a characteristic land cover pattern (Walsh et.al. 1990), especially in forested areas, but also in alpine and subalpine domains. These areas are commonly named avalanche tracks, that develop through a recurrent avalanche activity that manifest in the same area on mountain slopes.

Bedrock characteristics, terrain morphology and climate are considered important control factors in the spatial distribution of areas that are favourable to avalanche occurrence (Butler & Walsh, 1990; Thorn, 1978).

Snow avalanche activity is commonly associated with these patterns, thus the existence of mapped avalanche tracks is important in avalanche hazard and risk assessment.

The use of Digital Elevation Models (DEMs) and other remotely sensed data in mountainous areas for landforms detection and analysis is a common approach in Earth sciences. The extraction of land-surface models from DEMs, like slope gradient, plan curvature, profile curvature, mean curvature, became an important condition for an objective analysis of landforms and geomorphic risk processes at various scales.

Semi-automated methods that use object based analysis for the detection and classification of topography increased lately with the development of the technologies that provide high resolution DEMs and imagery (i.e. Anders, Seijmonsbergen, & Bouten, 2009; Drăguţ & Blaschke, 2006; Drăguţ & Eisank, 2012; Schneevoigt et.al. 2008; Seijmonsbergen, Hengl, & Anders, 2011).

In Romania, semi-automated methods using semantic models and object-based approach have been used for the detection of glacial cirques and planation surfaces within the Southern Carpathians (i.e. Ardelean et.al, 2011; Török-Oance, Ardelean, & Onaca, 2009).

The methods that use objects are preferred to those using pixel, as they integrate GIS and remote sensing by representing the reality in a way that is closer to the human perception, meaning discrete objects and not pixels (Blaschke & Strobl, 2001).

Beyond the above mentioned approach, the advantages of this method refer to topological relations and the shape of the elements of interest, which can be integrated in the analysis (Blaschke, Lang, & Hay, 2008; Blaschke & Strobl, 2001).

Similar studies yielded maps of snow avalanche chutes in the Canadian Rockies (Barlow & Franklin, 2008) using image segmentation based on geomorphic and spectral characteristics, showing that the method has great potential to map large areas in very short time as compared to field mapping.

The aim of this study is to present a semi-automated method for the delineation of snow avalanche tracks using object based terrain analysis and semantic models implemented in a rule based classification approach in eCognition® software that can be used as a first step in mapping these features for large mountain areas that are frequently affected by snow avalanche processes.

Some mountain regions present difficult terrain regarding classical methods of mapping and require a lot of time to generate geomorphologic maps (Ardelean et.al., 2013). This method provides a solution to this shortcoming, by shortening the time for mapping and offers a more objective perspective because it includes quantifiable parameters like those derived from DEMs.

Study area

The Făgăraș Mountains are the most massive and highest in the Romanian Carpathians, with several peaks above 2500 m and landscape dominated by glacial and periglacial relief (Urdea, 2000). Our study focuses on the central part of the main ridge in the Transfăgărășan road area and its surroundings, mainly on the alpine domain of the Arpaș, Bâlea, Doamna valleys. The study area is a glaciated one with a large glacial cirque in the upper part and a glacial valley downslope.

The Transfăgărășan road is located in the central part of the study area on the northern slope of Bâlea glacial valley, this area being representative regarding the presence of snow avalanche tracks developed on steep slope on both sides of the valley (fig. 1). The elevation ranges between 1170-2507m, the highest peaks in the area being Buteanu (2507 m), Capra (2494 m) and Iezerul Caprei (2417 m). The slope gradient values on both side of the glacial valley are high (20-60 degrees), this causing important geomorphic processes like snow avalanches.

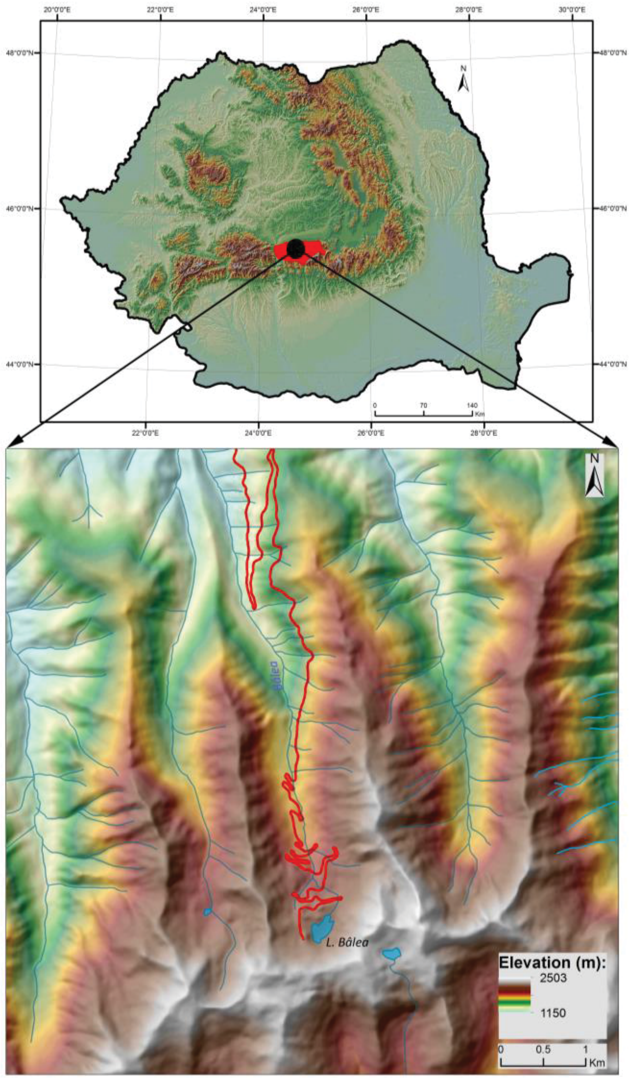

Fig. 1: Location of study area (central part of Făgăraș Mountains, maine ridge and northern valleys near Transfăgărășan highway)

Snow avalanche processes are connected with the existence of snow avalanche paths, located mainly in the glacial valley sector and less in the cirque area.

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The avalanche paths have mainly concave features, their distribution being controlled by tree cover and slope. Their starting zone is located above the tree-line and slope gradient between 25-50 degrees (Luckman, 1977).

The reason for choosing this area as a test site is related to the existence of a database with mapped snow avalanche tracks that can be used for validation: this area is also frequently affected by snow avalanche processes (Voiculescu, 2004; Voiculescu et al., 2011).

In the same time, the Transfăgărășan road and surrounding area is characterized by intense snow avalanche processes that annually affect the infrastructure and cause injuries and fatalities (Voiculescu et al., 2011).

Data and Methods

In this study we used a 12 m resolution DEM derived from topographic maps scale 1:25000.

The interpolation of altitude point values for generation of the DEM, preprocessing and filtering (5x5 moving windows) of the model were achieved in ArcGIS® and Landserf©.

The DEM model was further used to derive several land surface parameters – slope gradient, slope aspect, mean curvature, plan curvature, profile curvature and runoff, important parameters for snow avalanche tracks morphology and morphometry.

The statistic analysis of the values in slope gradient and curvature models showed long-tailed distributions, thus they were normalized using a transformation tool available for ArcGIS® that minimizes the skewness of slope gradient frequency distributions, and modifies the kurtosis of profile and plan curvature distributions towards that of the Gaussian (normal) model (Csillik, Evans, & Drăguţ, 2015).

For the area used as test site, a vector database with digitized snow avalanche tracks in polygon format (fig. 2) was used for the extraction of geomorphometric parameters and for validation purpose.

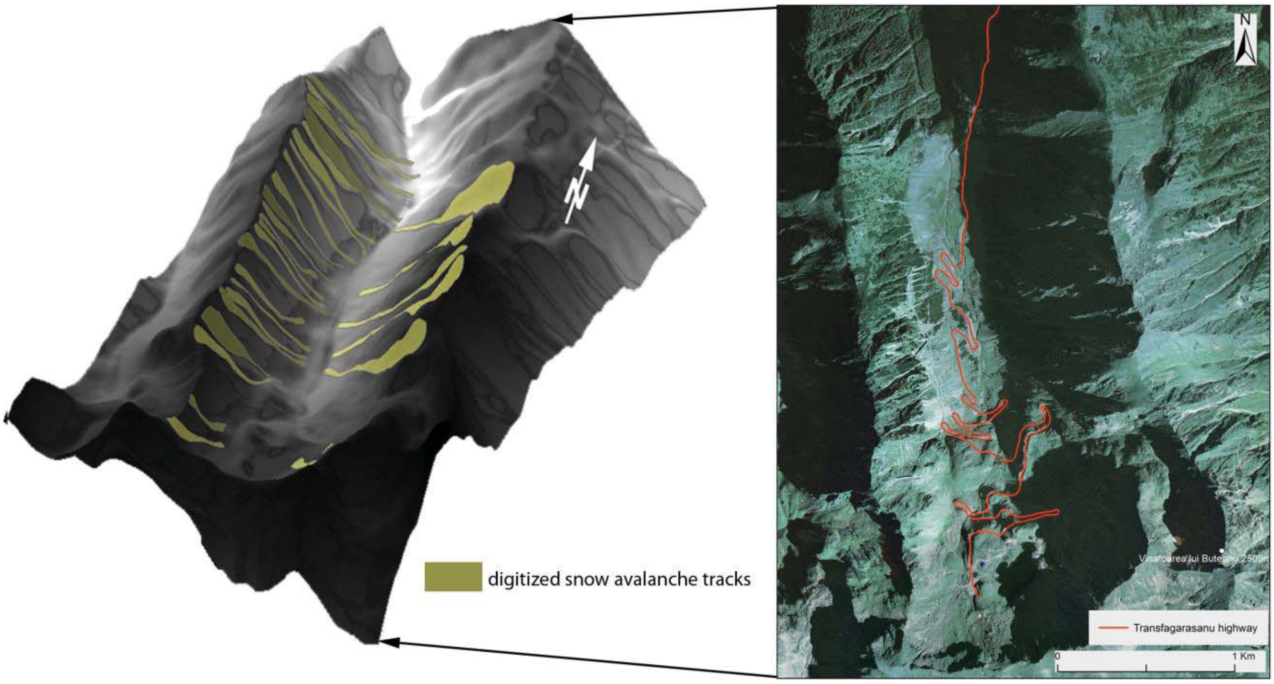

Fig. 2: Mapped snow avalanche tracks in polygon format overllaped on a hillshade model within Bâlea glacial valley

For all mapped avalanche tracks, mean, minimum and maximum value of the morphometric parameters were calculated (altitude, slope gradient, mean curvature, plan and profile curvature). For the detection of the snow avalanche tracks/paths we used a semantic model of these features based on the characteristics mentioned in literature (Luckman, 1977). This model is a link between these discrete elements in the field and their integration in computer software (Bishr, 1998; Dehn, Gärtner & Dikau, 2001) and objectively define the feature of interest.

Using these characteristics and the database with digitized polygons of the snow avalanche tracks from the Arpaș and Doamna valleys, we extracted the information derived from the DEM (altitude, slope gradient, plan curvature and the shape of the polygons). These were integrated in the classification algorithm, i.e. threshold for negative plan curvatures, high slope gradient values using fuzzy function, elongated shapes, starting zone above the timberline.

The object based analysis approach is based on two steps: a segmentation process at the beginning, followed by a classification of the objects, based on the semantic model presented above.

Segmentation is a process of dividing an image in areas or objects that are homogeneous considering the spatial and spectral characteristics (Ryherd & Woodcock, 1996). It is a regionalization method, meaning a delineation of areas as a function of homogeneity and spatial contingency (Lang & Blaschke, 2006).

In an object based approach, the whole study area is divided in different size objects using segmentation, objects that are adjacent as a spatial distribution (Blaschke, 2010) and homogeneous function of one or more properties such as spectral value or size, shape, texture, context etc. (Baatz & Schäpe, 2000). The most common method is the multiresolution segmentation, that is an optimization procedure which, for a given number of image objects, minimizes the average heterogeneity and maximizes their respective homogeneity (Baatz & Schäpe, 2000).

The upscaling from pixel level to object or spatial primitives level was realized in eCognition8.7®, a step that requires specification of the segmentation scale, that is a non-dimensional parameters, small values of this parameters return small objects with high homogeneity and large scale values give larger objects, more heterogeneous (Baatz & Schäpe, 2000).

To avoid the trial and error process of selecting appropriate scales in image segmentation, we used the ESP tool (Estimation of Scale Parameters) free available for eCognition® (Drăguţ, Tiede & Levick, 2010). This tool allows a more objective segmentation of the layers based on the local variance, a value that indicates the local variability within an image, so in a graph representation of the local variance, the breaks will indicate the optimal scale for segmentation, actually defining the objects that are very similar in the image and probably belonging to the same class in reality (Drăguţ, Tiede & Levick, 2010).

The most important layer used in image segmentation was plan curvature, this being the parameter that best describes the morphology of snow avalanche tracks and we obtained several characteristic segmentation scales based on plan curvature: 5, 16, 23, 34, 53, 62. The value of 5 was selected for the segmentation of snow paths detection and we will further focus the classification process on this particular scale.

After segmentation and generation of objects, we developed the rule set for the classification step. Because of the similar values in plan curvature for small valley catchments and snow avalanche tracks (they have similar morphology in terms of plan curvature) we identified in the beginning the class "valley" using only negative plan curvature values - in this case, a threshold of -0.2, which identifies concave entities in plan curvature. The class "snow avalanche tracks" was based on the existing "valley" class, then new conditions regarding slope gradient values were added, in this case a fuzzy membership was used with an interval of 25 - 50 degrees that best reflects the morphology of this class. Another condition, using different values for the runoff model, by trial and error process, a threshold was established to exclude those objects with high runoff values, which are considered temporary valleys.

Objects classified as potential snow avalanche tracks were merged and the resulted objects were further refined according to conditions regarding their geometry (shape and area). The snow avalanche tracks have elongated shapes and we used the shape index implemented in eCognition® with a threshold value less than 1.27 to identify only the objects with elongated shapes similar to a snow avalanche track geometry.

The resulted class of objects was exported for further comparisons with the existing snow avalanche paths database. The analysis process mentioned above can be synthesized in a schema that shows the workflow (fig. 3).

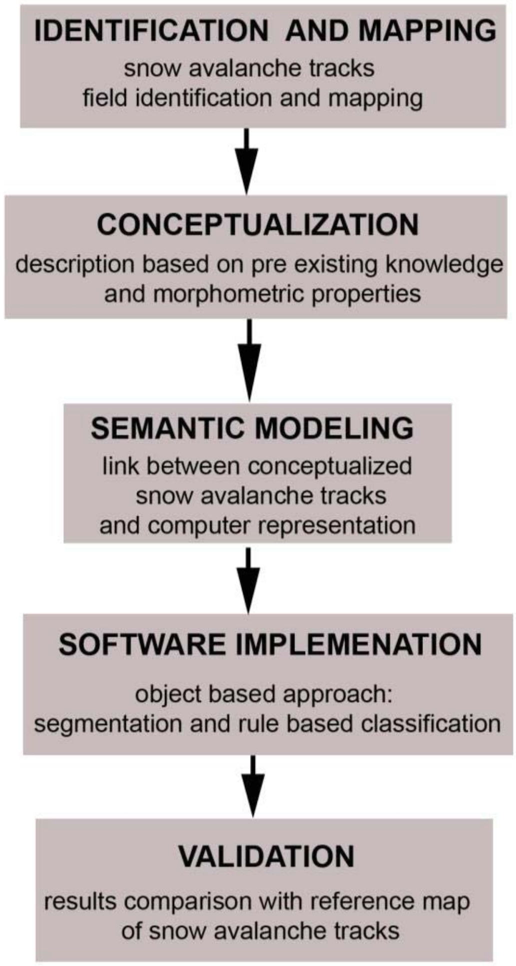

Fig. 3: Workflow scheme of the classification of snow avalanche tracks

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Results and Disscusions

The results achieved using the semantic model of avalanche tracks and classification algorithm in an object based environment were exported as vector files in the existing database in ArcGIS® for comparative analysis and visualization.

Vectorized layers with snow avalanche tracks generated from aerial photos scale 1:5000 were used as reference information for the comparison of the results and both vector layers (digitized one and exported one from eCognition®) were overlaid over the hillshade model. Further selections based on the intersection of the two mentioned layers were applied.

The method was first tested on an area that covers the Arpaș Valley and its surroundings and the results showed a similarity of 86% with the reference map of the digitized avalanche tracks.

For validation, we used the area that covers the Bâlea glacial valley and its surroundings. In this site, 30 snow avalanche tracks were digitized from various sources, located mainly in the alpine domain of the valley. Using the classification algorithm, 32 objects were obtained (fig. 4).

Only comparing the number, we can observe that the results are close to field reality (32 compared to 30), although the objects have different extent and spatial agreement. There were 4 objects identified in the forest domain, but for the forested areas a higher accuracy DEM is needed.

Regarding the spatial concordance of the generated objects with the digitized ones, we used area concordance (Borghuis, Chung, & Lee, 2007), a parameter that expresses the spatial coincidence of areas (objects) generated using different methods of mapping. This parameter generates percentages that are a measure of the agreement between the two analyzed maps. In the case of the Bâlea glacial valley, the agreement between the two methods was of 69%.

Although the results are similar in the number of features in the alpine level of the valley, there still are differences in the agreement of spatial extent of individual feature. Since the mapping scale of the two types of objects was different (i.e. the digitized polygons were realized at 1:5000 while the classified objects were generated from models at 1:25000), we can assume that this can be considered as an important factor in the resulted differences. The individual objects generated in classification are in general smaller that the objects in the reference layer and do not cover the entire runout zone of the avalanche path; they only reflect the morphology of a typical snow track with high negative values in plan curvature and a better spatial agreement in the upper part of the path, where the concavity is more evident.

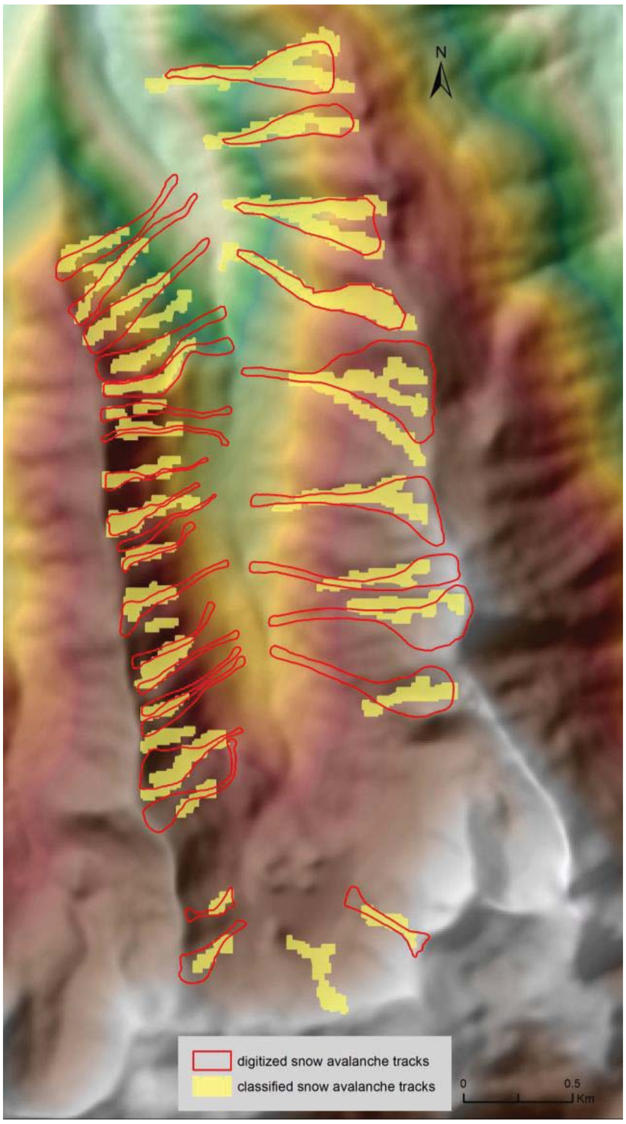

Fig. 4: Mapped comparison of the resulted objects generated by classification with the digitized snow avalanche tracks within Bâlea glacial valley

Conclusions

This study presents the preliminary results of the application of a semi-automated method for the detection of snow avalanche tracks based on DEM derived parameters within the central part of the Făgăraș Mountains. The comparison of these results with mapped avalanche tracks by digitizing techniques showed that this approach has a good potential and can be used as a first step in mapping large rough terrain areas, hardly accessible to be mapped in the field.

We still need to extend and test the algorithm and validation of the method on more detailed resolution data that have more or less the same scale with the reference data. The method can be improved if we use a high resolution DEM and also more case studies with existing vector database of snow avalanche tracks and different characteristics of topography.

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The temporal variation of suspended sediment transport according to the dominance of suspended sediment sources. Case study: the Trotuş river between 2000 and 2014

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Abstract

Based on the data series of average daily streamflow and suspended sediment load recorded between 2000 and 2014 at four gauging stations (Lunca de Sus, Goioasa, Târgu Ocna and Vrânceni), the temporal variation of the suspended sediment transport was investigated according to the prevalence of source areas. Thus, a significant temporal variability (monthly, seasonal, annual) was determined, in close relation with the amount of precipitation and the streamflow. The following equation was determined between the mean monthly suspended sediment load ($\bar{R}$) and the mean discharge ($\bar{Q}$) at Vrânceni section: R= 0,0035$Q^{2,2895}$, r=0,899. We believe this relation has a high degree of confidence for the indirect determination of solid load and it is comparable with other equations of this type. Along the entire length of the river, July was the month during which the highest suspended sediment load was recorded, with an average percentage of 37% of the total amount. At the opposite end, December is the month with the lowest documented suspended sediment load, with just 0.5% of the total amount transported annually by the Trotuş. As regards the seasonal variability of the suspended sediment load, the following values were determined along the entire length of river Trotuş: during the winter season the volume of sediment carried by the river amounts to approx. 2.1% of the total annual transported suspended sediment, the spring season accounts for 33.7% of the annual volume, the summer season accounts for ca. 55.5%, and the fall for 8.7%. In order to plot the R-Q correlation, the wettest, as well as driest years were selected for every gauging station. On the resulting plots, there were identified the thresholds based on which the two sources were separated depending on the area of origin: dominant from the catchment or dominant from the river bed. Overall, during the investigated period on the Trotuş river, the river beds contributed with about 21% of the total volume of transported suspended sediment. Depending on the type of the year (wet, dry or normal), the average input of the beds to the annual volume of suspended alluvium was as follows: 4% in wet years; 43% in dry years; 15% in normal years. The total volume of suspended sediment transported through the four sections on the Trotuş river between 2000 and 2014 amounted to approx. 39x106 t, thus the average annual volume was 2,598,000 t. A large share of this suspended sediment yield was produced during major floods. For example, at Vrânceni ca. 61% of the total sediment yield for the 15 year-period under investigation resulted from just 3 flood events (2005, 2010 and 2012).

Keywords: *Suspended sediment, temporal variation, sediment sources, suspended sediment yield*

Rezumat. Variaţia temporală a transportului de aluviuni în suspensie în funcţie de dominanţa ariilor sursă. Studiu de caz: râul Trotuş în perioada 2000-2014

Pe baza datelor referitoare la debitele lichide şi solide în suspensie medii zilnice, înregistrate în perioada 2000 - 2014 la patru staţii hidrometrice (Lunca de Sus, Goioasa, Târgu Ocna şi Vrânceni), s-a identificat variaţia temporală a transportului de aluviuni în suspensie, în funcţie de dominanţa ariilor sursă. Astfel, a fost pusă în evidenţă o însemnată variabilitate temporală (lunară, sezonieră, anuală), strâns corelată cu cantitatea de pricipitaţii şi debitele lichide. Între debitul solid în suspensie mediu lunar ($\bar{R}$) şi debitul lichid mediu ($\bar{Q}$), în secţiunea Vrînceni, s-a obţinut relaţia : R= 0,0035Q2,2895, r = 0,899. Noi o considerăm o relaţie cu grad înalt de încredere pentru determinarea indirectă a debitelor solide, fiind comparabilă cu alte relaţii de acest tip. În perioada avută în studiu, pentru întreg râul Trotuş, luna cu cel mai mare transport de aluviuni în suspensie a fost iulie, cu o pondere medie de circa 37% din total. La polul opus se află luna decembrie, care nu deţine decât 0,5% din totalul aluviunilor în suspensie transportate de către râul Trotuş. În privinţa variabilităţii sezoniere a debitului de aluviuni în suspensie, la nivelul întregului râu Trotuş, au fost obţinute următoarele valori: în timpul sezonului de iarnă au fost transportate circa 2,1% din volumul total al aluviunilor în suspensie; în sezonul de primăvară 33,7%; sezonului de vară i-au revenit circa 55,5%, iar celui de toamnă, 8,7%. Pentru construcţia graficului corelaţiei R-Q au fost selectaţi, la fiecare staţie hidrometrică în parte, anii cei mai ploioşi şi cei mai secetoşi. Pe aceste grafice au fost identificate pragurile în funcţie de care s-au separat cele două surse după aria de provenienţă: dominantă din bazinul versant şi dominantă din albie. Pe ansamblul râului Trotuş, în perioada studiată, albiile au contribuit cu circa 21% din totalul volumului de aluviuni în suspensie tranzitate. În funcţie de tipul anului (ploios, secetos, normal), situaţia este următoarea: în anii ploioşi media de contribuţie a albiilor a fost de 4%; în anii secetoşi de 43%, iar în anii normali de 15%. Volumul total de aluviuni în suspensie tranzitat prin cele patru secţiuni hidrometrice din lungul râului Trotuş, în perioada 2000-2014, a fost de aproximativ 39x106 t, de unde rezultă o medie anuală de 2 598 000 t. Mare parte din această producţie de aluviuni în suspensie a fost realizată în timpul marilor viituri. De exemplu, în secţiunea Vrânceni, circa 61% din totalul producţiei de aluviuni pentru cei 15 ani avuţi în studiu a fost realizată în timpul a doar 3 evenimente de viitură (2005, 2010 şi 2012).

Cuvinte-cheie: *aluviuni în suspensie, variaţie temporală, surse de aluviuni, producţie de aluviuni în suspensie*

Introduction

Knowing the temporal variability of suspended sediment transport and suspended sediment yield (SSY) is required for various purposes, which include: designing erosion control works (Russel et al., 2001; Walling, 2005); river morphological computations and evaluation studies of the effects of various land use management practices (Gao and Puckett 2011; Yeshaneh et al., 2014); siltation of downstream reservoirs (Rădoane and Rădoane, 2005; Guzman et al., 2013). "*Information on sediment source is of fundamental importance in understanding the suspended sediment dynamics and the sediment budget of a catchment. Information on sediment source also represents a key requirement from the management perspective, since identification of sediment sources is a key precursor to the design of effective sediment management and control strategies*" (Walling, 2005).

The volume of suspended sediment carried by a river during a wet period is significantly larger compared to the amount transported during a dry period due to the net difference in the soil structure and moisture level between the two periods. Differences also exist in terms of the number, intensity and duration of precipitation (Xia, 2010).

The aim of this study is to analyze the trend of the suspended sediment transport at various temporal scales (monthly and seasonal, annual or during flood events), depending on the prevailing source areas during that particular timeframe (either riverbed or slopes).

Study area

Trotuş drainage basin is located in the central-eastern sectors of the Eastern Carpathians and Moldavian Subcarpathians (Fig.1). The total area of the basin is 4350 km^2, whereas the length of the Trotuş river is approx. 160 km. The average long-term precipitation amounts to approx. 800 mm basin-wide, varying by ± 200 mm in the high mountain areas compared to lower areas.

The interaction between the physical geographical traits of the study area and the circulation of air masses results in deviations in the distribution of monthly and annual precipitation. Such was the case in 2005, when the precipitation recorded during the 11th-13th of July accounted for 100-150% of the multiannual average of July (Dumitriu, 2007; Romanescu and Nistor, 2011). The average multiannual discharge from the Trotuş river ranges from 0.9 m^3 s^{-1} in the upper course (Lunca de Sus gauging station) to 35 m^3 s^{-1} in the lower course (Vrânceni gauging station). Except for the gauging sites on the upper course of the Trotuş (Lunca de Sus and Ghimeş Făget), for which the highest peak discharge values were recorded between 1975 and 1985, the stations recorded the highest peak discharges in 2004-2005. Discharge values recorded in 2005 are considered exceptional historical values, with an Average Recurrence Interval (ARI) of 200 years. The highest peak discharge on the river Trotuş is considered to be the value recorded in 2005 (2845 m^3 s^{-1} at the Vrânceni gauging station), rather than the 3720 m^3 s^{-1} value recorded on the 29th of July, 1991, because the latter was not entirely generated by natural causes and was due in part to the failure of Belci dam (Podani and Zăvoianu, 1992).

The rise in the peak discharge values post-2000 can be attributed to the increasing amount of precipitation over a very short period of time.

In the Siret river basin, the percentage of precipitation related to the total sum of the maximum amounts of precipitation falling during a 24 hour period, with a value above 100 l m^{-2}, has steadily increased (8.3% between 1941-1960, 30.8% between 1961-1980, 47.5% during 1980-2000 and 67.7% after 2000) (Pleşoianu and Olariu, 2010). This could be a valid argument for the present situation, in which, of the top four peak discharge values recorded at the Vrânceni gauging station (during 64 years), two occurred during the study period (2845 m^{3}s^{-1} - 2005; 1700 m^{3}s^{-1} - 1975; 1567 m^{3}s^{-1} - 2010; and 1510 m^{3}s^{-1} - 1988).

The distribution of soil types (especially of those susceptible to erosion) is of particular importance to studies regarding the suspended sediment load. Conjunctly, Cambisols and Luvisols cover over 75% of the total area of Trotuş river basin; of these, Cambisols account for the largest area (53.35% of the basin area) divided among soil classes as follows: *eutricambosols* – 24.84% (occurring at 60 to 1000 m a.s.l. in Asău basin, along the Trotuş upstream of the junction with Asău, as well as in small catchments such as Ciobănuş, Sulţa, Şugura, Ciugheş, Tărhăuş, Valea Rece etc); and *districambosols* – 28.51% (found at 1000 to 1400 m a.s.l., predominantly in mountain areas such as the Nemira, Goşmanu, Tarcău and Ciuc Mountains). Noteworthy is the frequent occurrence of *erodosols* within the Subcarpathian area which reveals the active presence of current geomorphological processes. The typical distribution of soils according to latitudinal location and elevation is disturbed by the presence of *aluvisols* which are prevalent along river floodplains (9.46%).

The banks of the Trotuş river are typically sandy (over 70% in most instances); however, between confluences the percentage of silt and clay increases (up to 40% at Beleghet and Perchiu, 32% at Burcioaia, 30% at Comăneşti) (Dumitriu, 2007; Dumitriu et al., 2011).