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Forum Geografic - Studii și cercetări de geografie și protecția mediului
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CONTENTS

Volume XIV, Issue 2 / December 2015

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Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 95-100
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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.

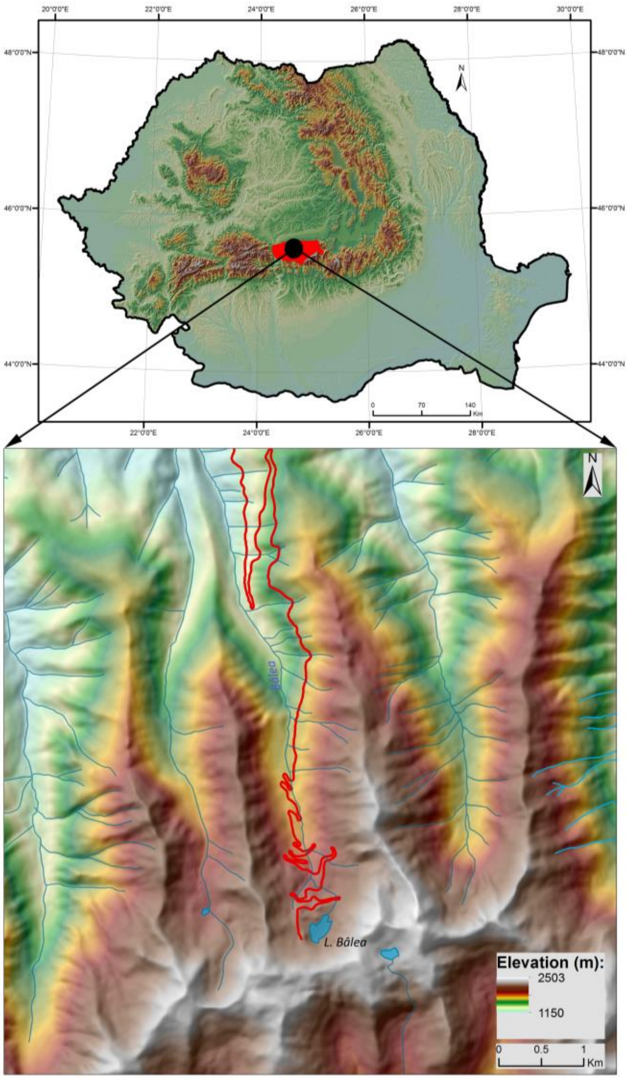

Fig. 1: Location of study area (central part of Făgăraș Mountains, maine ridge and northern valleys near Transfăgărășan highway)

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.

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.

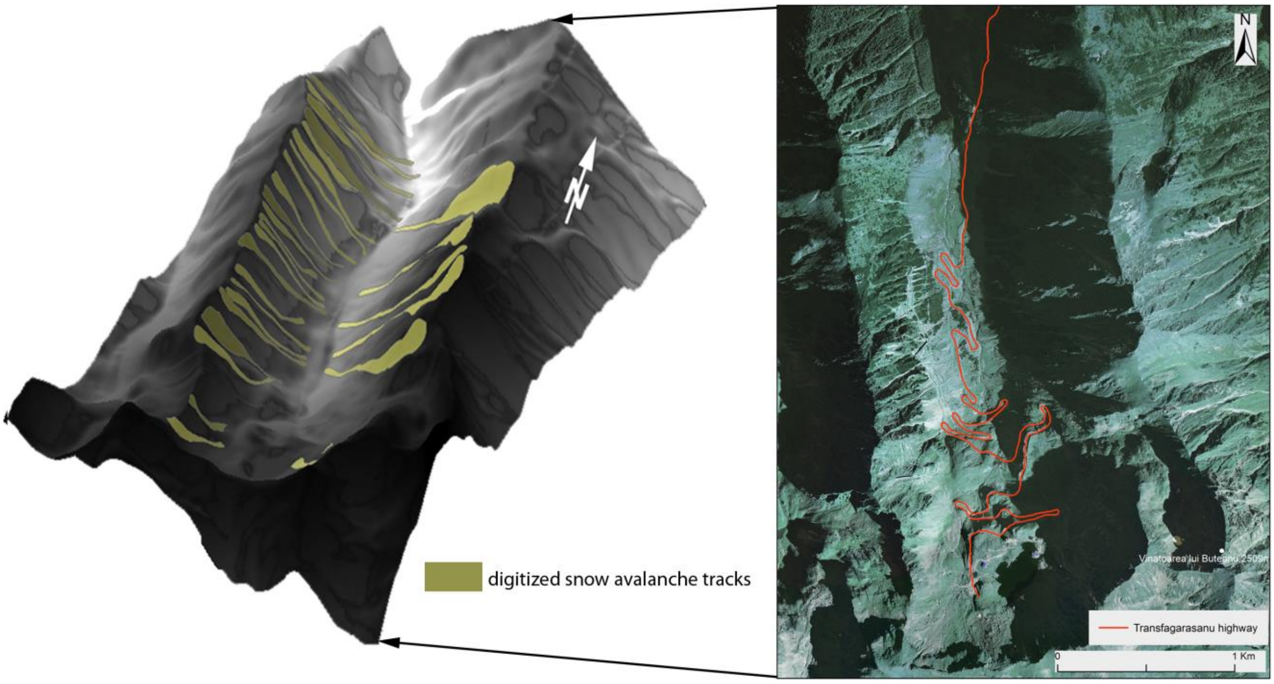

Fig. 2: Mapped snow avalanche tracks in polygon format overllaped on a hillshade model within Bâlea glacial valley

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).

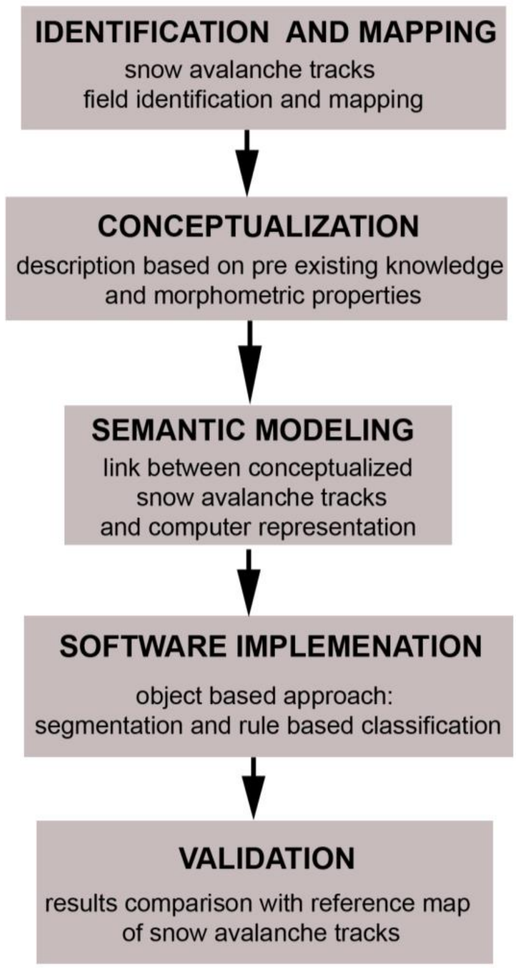

Fig. 3: Workflow scheme of the classification of snow avalanche tracks

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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.

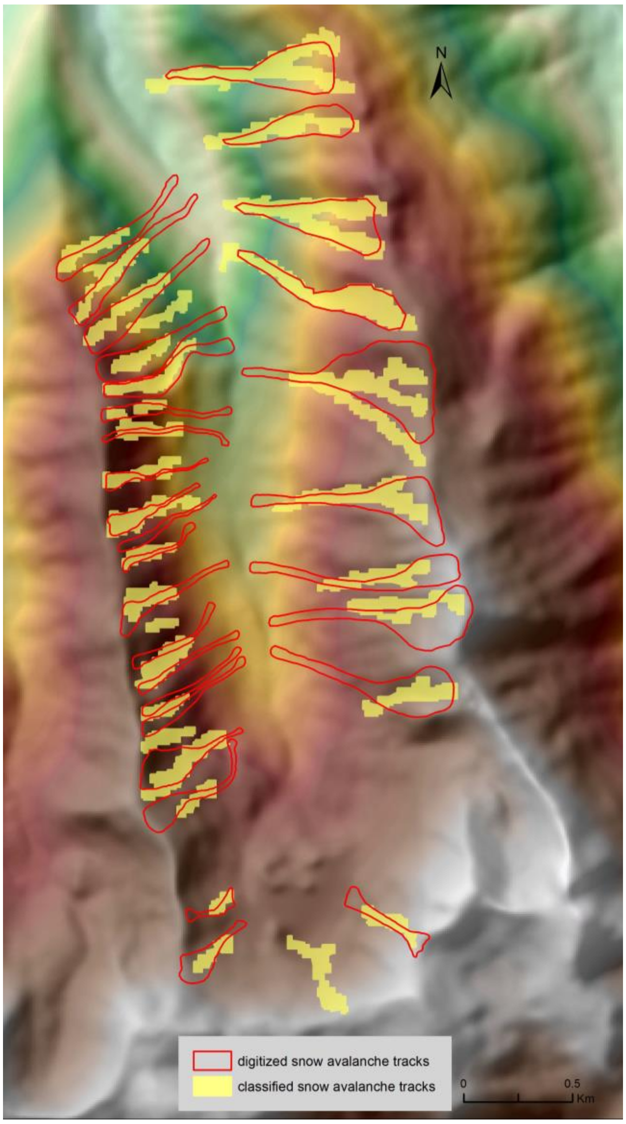

Fig. 4: Mapped comparison of the resulted objects generated by classification with the digitized snow avalanche tracks within Bâlea glacial valley

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 (R̄) and the mean discharge (Q̄) at Vrânceni section: $R= 0{,}0035Q^{2{,}2895}$, 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 (R̄) şi debitul lichid mediu (Q̄), 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).

Forum geografic. Studii și cercetări de geografie și protecția mediului
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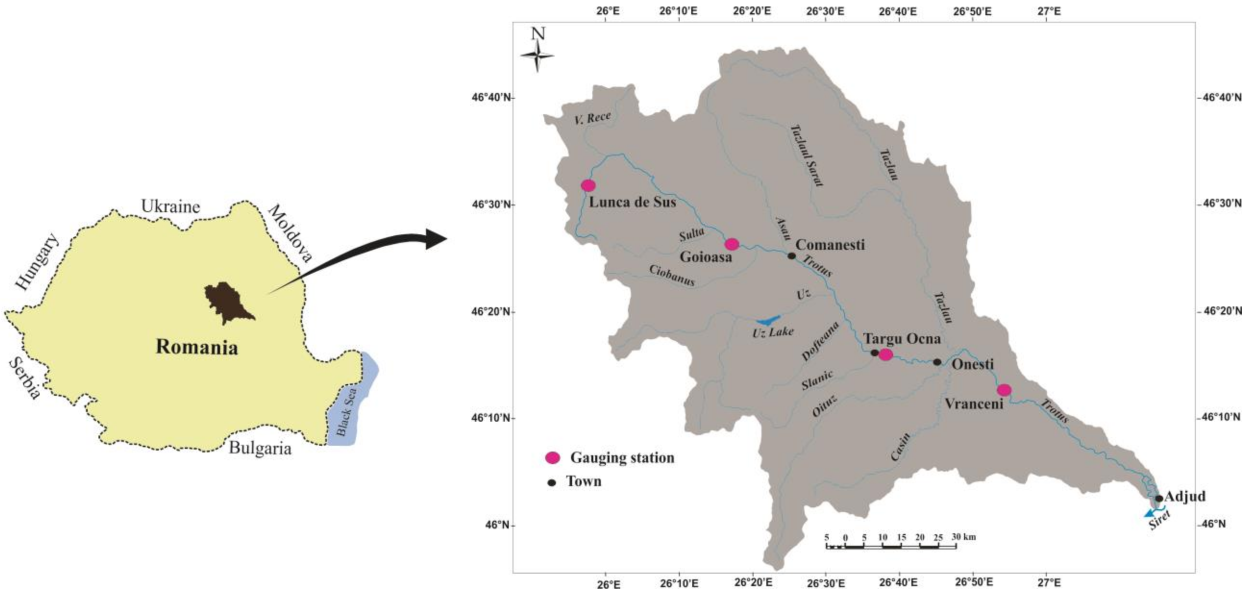

Fig. 1: Study area

Data and methods

The temporal variation of the suspended sediment load and the prevalence of source areas were investigated based on data series of daily, monthly and annual average values of the streamflow and suspended recorded load between 2000 and 2014 at four gauging stations: Lunca de Sus (146 km from the confluence, area of the drainage basin – 88 sqkm), Goioasa (106 km – 781 sqkm), Târgu Ocna (69 km – 2091 sqkm) and Vrânceni (37 km – 4092 sqkm) (Fig.1). These data were processed using statistical indicators of data distribution (average, median, modulus, standard deviation, coefficient of variation etc.).

The problem of sediment sources according to the area of origin was addressed using the methodology introduced by Grimshaw and Lewin (1980) based on the R = f (Q) equation, which takes on different forms depending on the season and the size of transported material, resulting in high scattering which can suggest the following (Rădoane and Rădoane, 2003, 2007):

a) the upper limit of the graph indicates summer discharge when the sediment load and streamflow are high and the alluvium originates mainly in the catchment;

b) the lower limit of the graph typically indicates fall-winter discharge when the sediment load comes mainly from the river bed.

The investigated period (2000-2014) was chosen due to the observed trend of significant increase in the suspended sediment load, particularly along the mid- and upper course (Fig.2). Thus, at Târgu Ocna gauging station, the multiannual mean value of the suspended sediment load was 14.6 kg/s from 1950 to 2000, whereas between 2000 and 2014 the average was 34.8 kg/s. The same tendency was documented at Goioasa and Lunca de Sus stream gages, whereby the mean multiannual suspended sediment load was 2 to 3 times higher between 2000 and 2014 compared to the previous interval, 1950 to 2000.

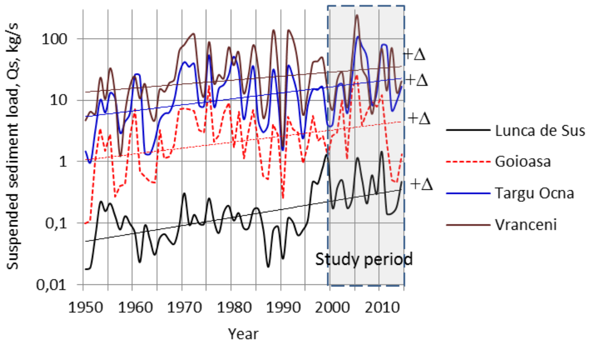

Fig. 2: Trends of annual mean suspended sediment load

Wet or dry years were determined based on the following equation:

$$(Q_{myr}-Q_{mmyr})/Q_{mmyr} \quad (1)$$

where Q_{myr} is the average discharge for one year, and Q_{mmyr} is the mean multiannual discharge. If the value is positive, the respective year is considered wet; conversely, when it is negative the year is classified as dry. Throughout the study period just three years rank as wet (i.e. 2005, 2006 and 2010), whereas 2000, 2001, 2003, 2007, 2012, 2013 are dry, and the remaining ones are considered normal.

Results and discussions

Temporal variability (monthly, seasonal, annual) of suspended sediment load

Both the streamflow and the suspended sediment load are highly variable over time. Between 2000 and 2014 the mean values of the suspended sediment load on the Trotuş river ranged from to 2274 kg/s at an average monthly discharge of 234 m^3/s in July 2005 at Vrânceni streamgage to just 0.001 kg/s at an average monthly discharge of 0,285 m^3/s in January 2000 at Lunca de Sus. The years whereby the highest sediment load was recorded were 2005, 2012 and 2010; during the same years the annual volume of suspended sediment (Qs) at Vrânceni gauging station was 7,769,760 t in 2005, 2,274,330 t in 2012 and 2,191,511 t in 2010. The peak value which coincides with the historical value) of 52,500 kg/s (at a discharge of 2845 m^3/s) was recorded at Vrânceni gauging station on the 13th of July 2005.

The suspended sediment load values mostly fall into the general trend documented on rivers from the temperate zone. Along the entire length of the river, between 2000 and 2014, July was the month during which the highest suspended sediment load was recorded, with an average share of 37% of the total amount (Fig.3.A). This is a consequence of the number and magnitude of flood events occurring in July (in 2004, 2005, 2010) which boosted the transport of alluvia. Conversely, December is the month during which the lowest suspended sediment load was documented, with just 0.5% of the total amount transported annually by the Trotuş river.

The mean monthly suspended sediment load at the four gauging stations show the same trend observed along the entire river length (Fig.3.B). For example, at Vrânceni streamgage ca. 47% of the total amount of suspended sediment was transported in July, whereas the share of suspended sediment carried in January, February, November and December is, with little exception, below 1%. This only applies for the investigated period; throughout time, the month with the largest amount of transported suspended sediment varied depending on major flood events. Thus, floods occurring in certain months have decisive influence on the multiannual monthly variation of the suspended sediment load.

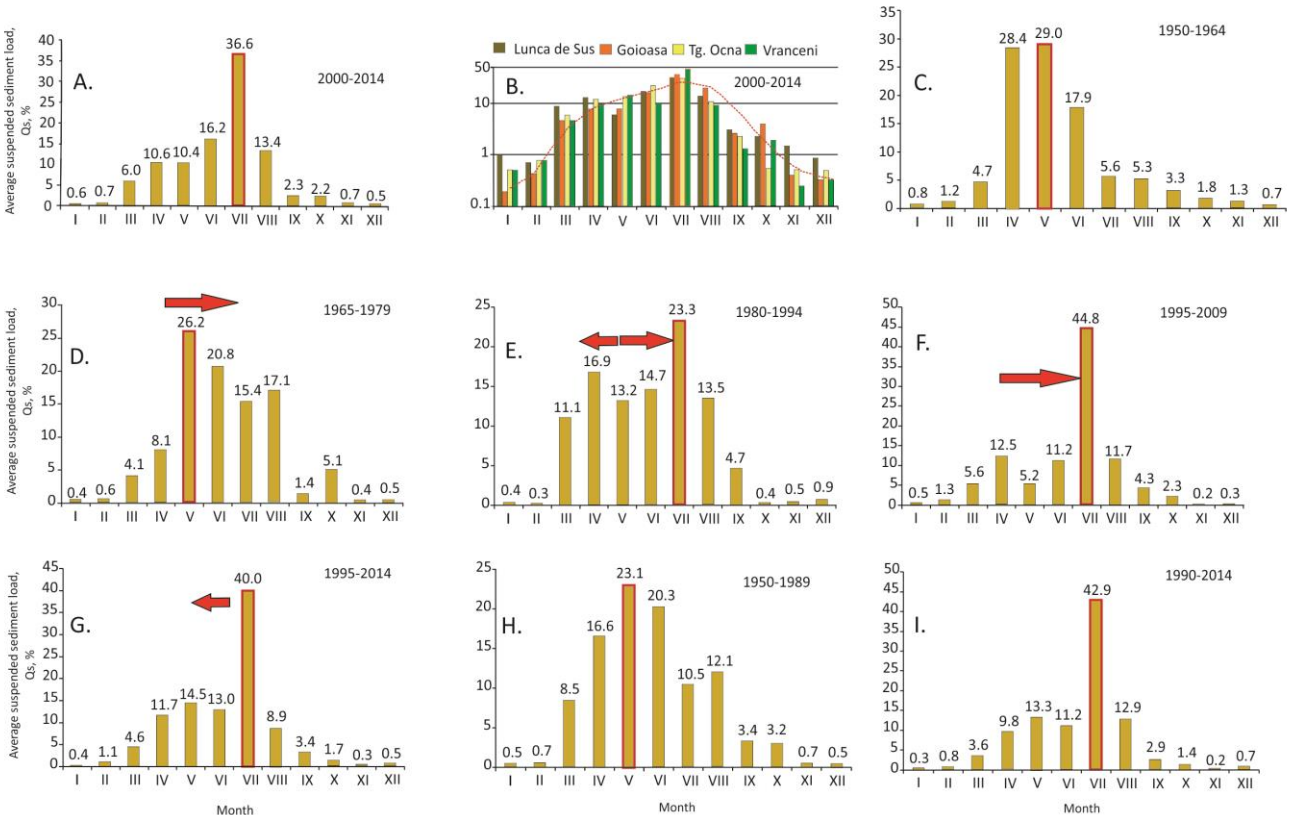

Fig. 3: Variability of monthly percentage of suspended sediment load: (A) average for the Trotuş river; (B) average at every gauging station; (C) average from 1950 to 1964 at Vrânceni gauging station; (D) average from 1965 to 1979 at Vrânceni gauging station ; (E) average from 1980 to 1994 at Vrânceni gauging station; (F) average from 1995 to 2009 at Vrânceni gauging station; (G) average from 1995 to 2014 at Vrânceni gauging station; (H) average from 1950 to 1989 at Vrânceni gauging station; (I) average from 1990 to 2014 at Vrânceni gauging station

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A major flood event during which large amounts of alluvia were transported will remain imprinted in the monthly trend of the suspended sediment load until a new event of similar magnitude will succeed in changing the old monthly distribution. Between 1950 and 1979, the month of May held the largest share of the amount of transported suspended sediment due to the fact that for ca. 30 years the largest floods (1953, 1960, 1961, 1965, 1970, 1971, 1975) occurred during this month (Fig.3.C and D).

From 1980 to 1994 a double shift was documented: at the beginning of the interval, flood events tended to concentrate in March-April, thus resulting in the increasing share of April and March (continued through the floods in 1984, 1988 and 1993), while the share of May was still high (due to the floods in 1981 and 1993); towards the end of the interval the largest share of suspended sediment transport shifted to July and August as an effect of the flood events in 1991 and 1992 (Fig.3.E). After 1995, the flood events from 1997, 2004 and particularly 2005 were instrumental in establishing July as the month during which the largest amount of suspended sediment is carried through the river channel (45%) (Fig.3.F) for over 20 years. After 2009, a slight decrease of the share of July was documented, conjunct with increasing shares of April, May and June, as a result of the flood events of 2010 and 2012 (Fig.3.G). In terms of the month with the largest share of transported suspended sediment, at Vrânceni two separate phases can be distinguished: between 1950 and 1989, the month with the highest percentage was May, albeit the values were nearly uniformly distributed from March until August; however, after 1991 the transport of suspended sediment has become overly concentrated in July (Fig.3.H and I).

As regards the seasonal variability of the suspended sediment load, between 2000 and 2014 the following values were determined along the entire length of the Trotuş river: during the winter season (months I, II and XII) the volume of sediment carried by the river amounts to approx. 2.1% of the total annual transported suspended sediment, the spring season (months III-V) accounts for 33.7% of the annual volume, the summer season (months VI-VIII) accounts for ca. 55.5%, and the fall (IX-XI) for 8.7%. During the winter season, when the substrate is typically frozen, the suspended sediment load ranged between 14.3% at Târgu Ocna gauging station (in the winter of 2009) and 0.028% at Goioasa streamgage (2005) (Fig.4.A). In some years, spring thaw is accompanied by abundant rainfall, which results in the significant increase of the volume of transported suspended sediment. This phenomenon is clearly visible in dry years, when the alluvium transported during the spring season can amount to as high as 90% of the total annual volume; e.g., in 2012 the suspended sediment load recorded during the spring months at Târgu Ocna and Vrânceni gauging stations accounted for 91%, and 98%, respectively, of the annual volume. Values exceeding 80% were reported in 2000 and 2004 at Lunca de Sus (Fig.4.B).

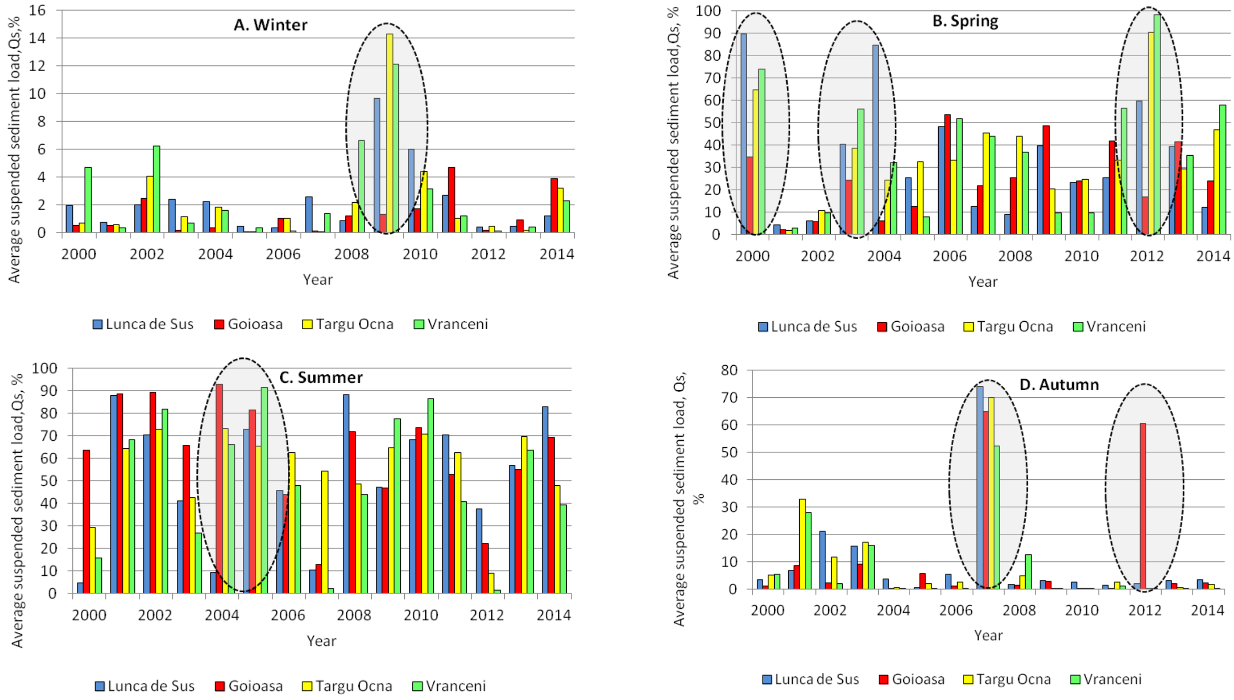

Fig. 4: Distributions of suspended sediment discharges during four climatic seasons at four sediment stations along the Trotuş River, 2000-2014 water years

The summer season accounts for the largest share of the total annual amount of suspended alluvium, particularly as an effect of major floods; in-between floods, however, the values of the solid load are rather low (Obreja, 2009). Within the investigated period, 2000 and 2005 stand out as the years when the percentage of the suspended sediment transported during the summer season accounted for over 90% of the total annual volume (Fig.4.C). In the fall season, the lack of major flood events resulted in low sediment loads, with the notable exception of 2007 and 2015, when the share of the sediment transported during the fall reached over 60% of the annual volume, particularly in the upper and mid-course (Fig.4.D).

From 2000 to 2014 the peak stream discharge recorded at Vrânceni gauging station was 2845 m^3/s (July 13, 2005, 200 years RI). By setting class amplitude at 25 m^3/s, up to 600 m^3/s, 24 classes were obtained, each comprising at least one value. An additional 3 discharge values exceeding 600 m^3/s (i.e. 769 m^3/s; 1468 m^3/s şi 2845 m^3/s) were ranked in a single 25th class "*above 600 m^3/s*".

During the three flood events whereby the peak discharge exceeded 600 m^3/s, 26% of the entire suspended sediment load measured in the 15-years period was transported (approx. $25x10^6$ t).

On July 13, 2005, only, no less than 4.5 $x10^6$ t of suspended sediment were transported, accounting for 18% of the entire amount. Based on these data, the 1122 m^3/s discharge value (10 years RI) would represent the effective discharge of the Trotuş river at Vrânceni gauging station, which is rather inaccurate, as the state of the river was highly distorted by this extreme event. By excluding stream discharge values recorded on the 12th and 13th of July 2005, we determined that the effective discharge at Vrânceni streamgage from 2000 to 2014 is 237.5 m^3/s (1.2 years RI), which carries approx. 13% of the total suspended sediment load transported by the Trotuş river. The occurrence duration of this discharge value is 0.2 of the time. The average daily streamflow with the highest frequency (66%) at Vrânceni gauging station ranges between 2 m^3/s and 25 m^3/s; however, the amount of suspended sediment transported at these discharges is relatively low (approx. 2.1%).

The following equation was determined between the mean monthly suspended sediment load ($\bar{R}$) and the mean discharge ($\bar{Q}$) at Vrânceni section: $\bar{R} = 0.0035\ \bar{Q}^{2,2895}$, 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.

Temporal variability of suspended sediment sources

In order to plot the R-Q correlation throughout the 2000-2014 period the wettest, as well as the driest years were selected for every gauging station. On the resulting plots, the thresholds were identified according to which the two sources were separated depending on the area of origin: *dominant from the catchment* or *dominant from the river bed*.

At Lunca de Sus streamgage, the threshold distinguishing between the two source areas was determined between 0.8 and 1.5 m^3/s (Fig.5). The bed provides on average approx. 33% of the suspended alluvia, whereas the catchment supplies the remaining 67%.

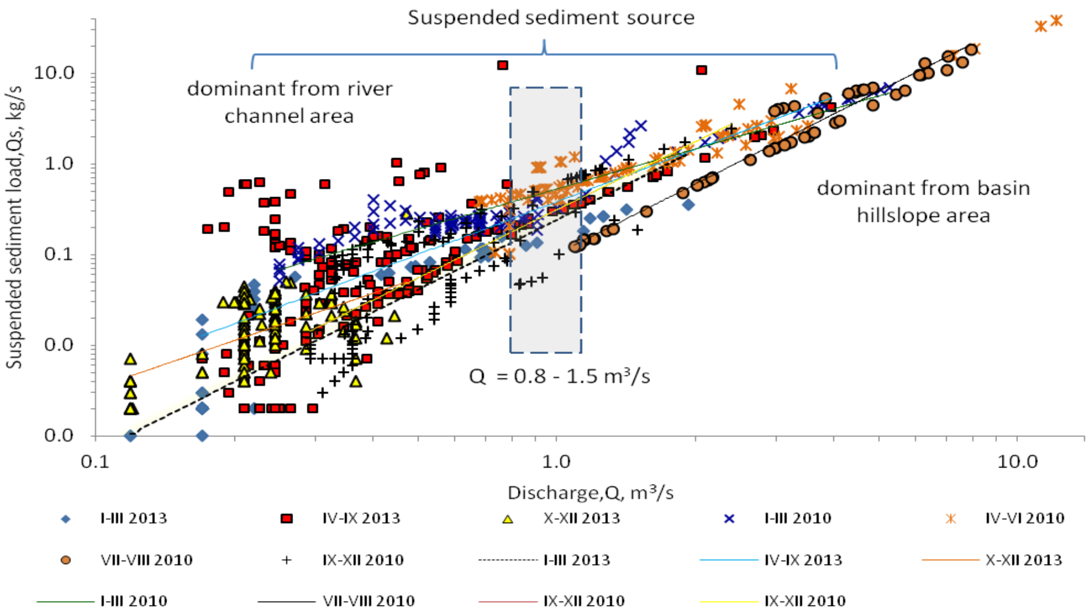

Fig. 5: Identifying sediment sources based on the mean daily suspended sediment load at Lunca de Sus gauging station

Seasonally, the parameters vary as follows: during summer, the catchment can provide on average ca. 50% of the sediment transported annually, whereas the input of the bed, albeit large in terms of sheer amount, is comparatively smaller (ca. 22%); in fall and winter the input of the slopes decreases compared to the input of the bed, which on occasion can supply as much as 100% of the alluvia transported during these seasons (although relative to the entire year, they only account for 1-3%).

Extreme events, and floods, in particular, heavily influence the size of the catchment – bed ratio: in 2013 (low precipitation and stream flow discharge), of the total 5,830 t of suspended sediment measured, 74% originated in the river bed; in 2010 (abundant rainfall and a peak discharge of 17.6 m^3/s), of the total measured 46,466 t of suspended sediment, just 10% was provided by the bed.

As regards the monthly distribution, it has been noted that during winter and fall lomnths, as well as in dry years (Fig.6), the bed provides the largest amount of alluvia, albeit this is considerably smaller in terms of volume compared to the one supplied by the catchment slopes.

At Goioasa gauging station, the threshold between the two source areas was established between 7 and 10 m^3/s (Fig.7). From 2000 to 2014 the beds provided, on average, ca. 25% of the total transported suspended sediment, distributed seasonally as follows: 5.6% during the winter season; 2.93% in spring; 15.06% in summer and 1.16% during the fall. During the spring and summer seasons the catchment slopes supply approx. 77% of the total volume of suspended sediment.

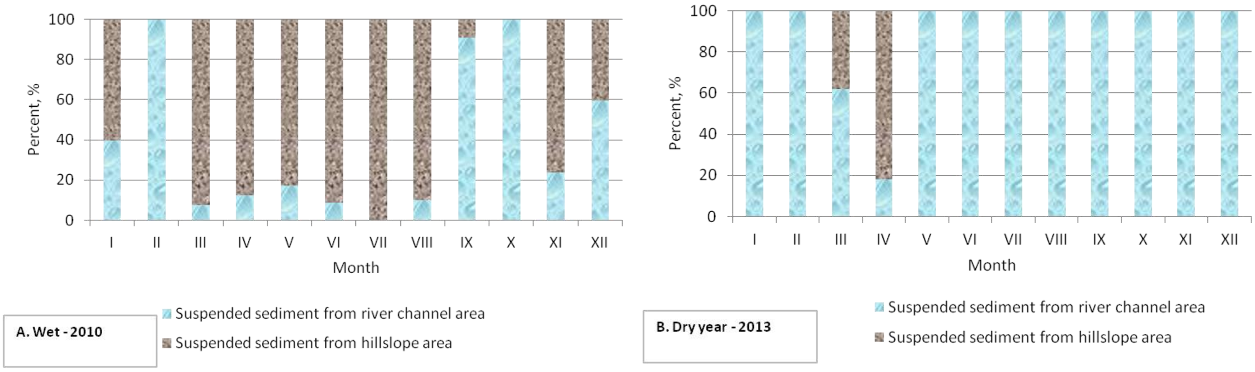

Fig. 6: Monthly percentage of sediment provided by river beds and catchment slopes at Lunca de Sus gauging station

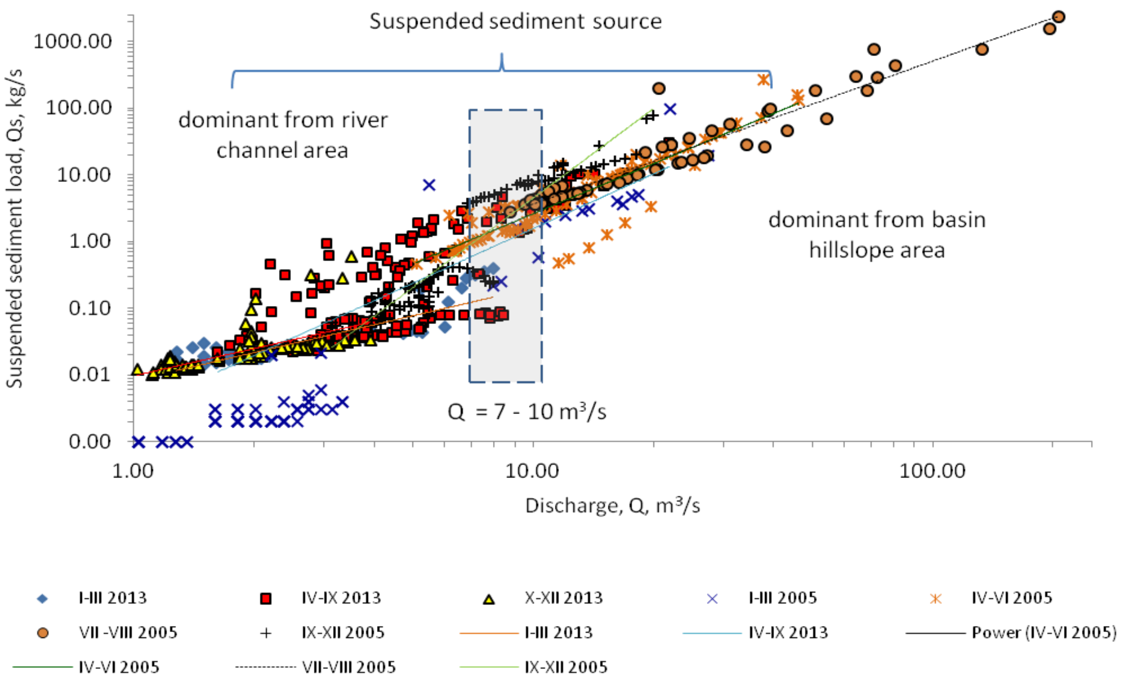

Fig. 7: Identifying sediment sources based on the mean daily suspended sediment load at Goioasa gauging station

In 2005 (wet year), the slopes provided ca. 99% of the total 852,612 t of suspended alluvia transported through Goioasa section, whereas in 2013 (dry year) the beds accounted for ca. 37% of the total amount. Two floods (2nd -5th of April and June) were able to transport 63% of the total volume of suspended sediment (14,371 t), while during the remainder of the year the contribution of the slopes was nearly null (Fig.8).

The data recorded at Târgu Ocna section indicate that river beds provide a significantly lower amount of suspended sediment, i.e. just 18% of the total volume. At this streamgage, the threshold between the two source areas was determined between 17 and 25 m^3/s (Fig.9).

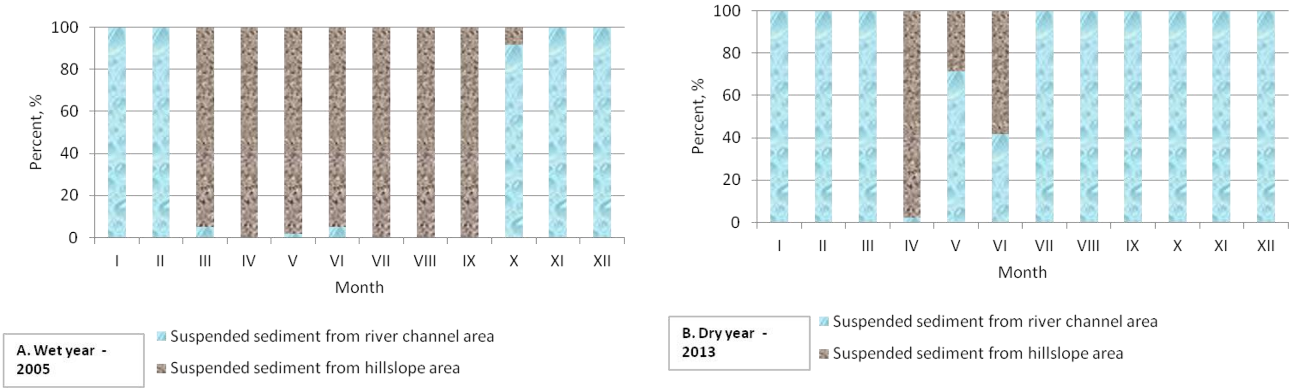

Fig. 8: Monthly percentage of sediment provided by river beds and catchment slopes at Goioasa gauging station

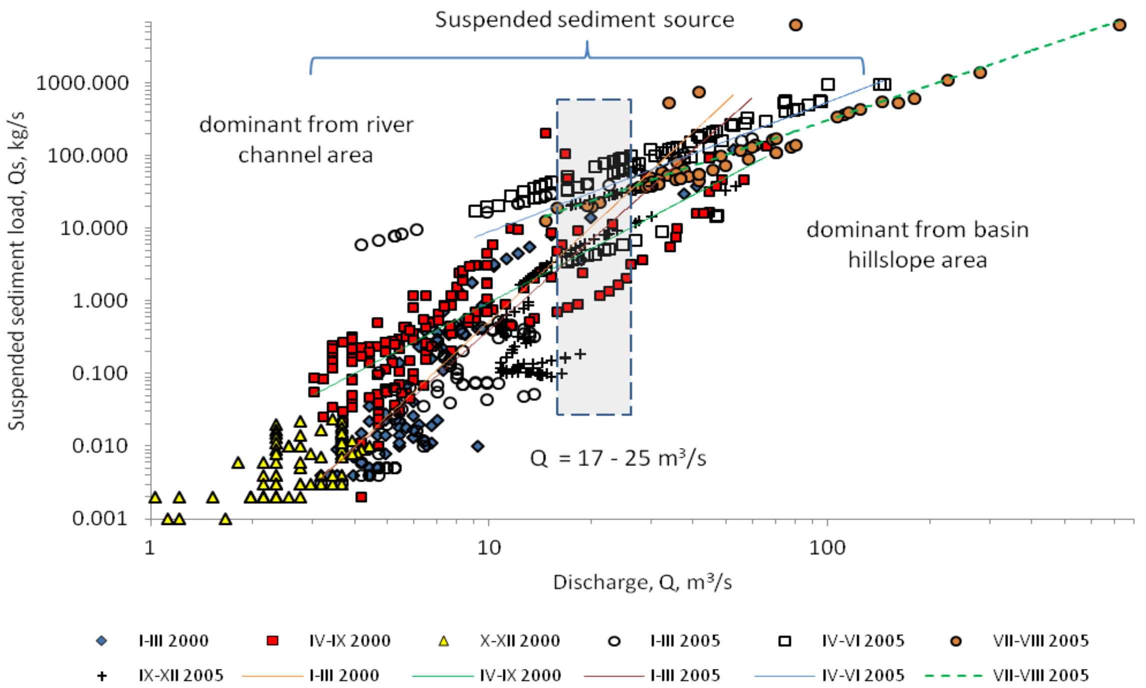

Fig. 9: Identifying sediment sources based on the mean daily suspended sediment load at Târgu Ocna gauging station

In 2005 the catchment slopes supplied 96% of the total suspended alluvia, which was estimated at 3,308,048 t; no less than 50% of this amount was transported in July. In 2000 (dry year) the river beds provided approx. 40% of the total volume of suspended sediment carried by the Trotuş river through Târgu Ocna section; moreover, for 8 months of 2000 the beds provided the majority of the suspended alluvia. In a normal year (e.g., 2002), the beds account for approx. 15% of the sediment load.

At Vrânceni gauging station, where the separation threshold was established between 30 and 50 m^3/s (Fig.10), the contribution of the river beds to the suspended sediment load is ca. 11%. However, it has been observed that the amount of sediment supplied by the beds remains constant, in general, regardless of the water year (wet, dry or normal), ranging from 80,000 to 100,000 t. In a wet

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 101-112
http://dx.doi.org/10.5775/fg.2067-4635.2015.055.d

year, such as 2005, during summer the catchment slopes deliver approx. 91% of the total volume of suspended alluvium transported throughout the year, whereas in a dry year (e.g. 2013), their percentage decreases to 40-50%. In 2013 ca. 60% of the total amount of sediment was transported in just a few days in July. Overall, during the investigated period on the Trotuş river, the river beds contributed to about 21% of the total volume of transported suspended sediment. Depending on the water year (wet, dry or normal), the average input of the beds to the annual volume of suspended alluvia was as follows: 4% in wet years; 43% in dry years; 15% in normal years.

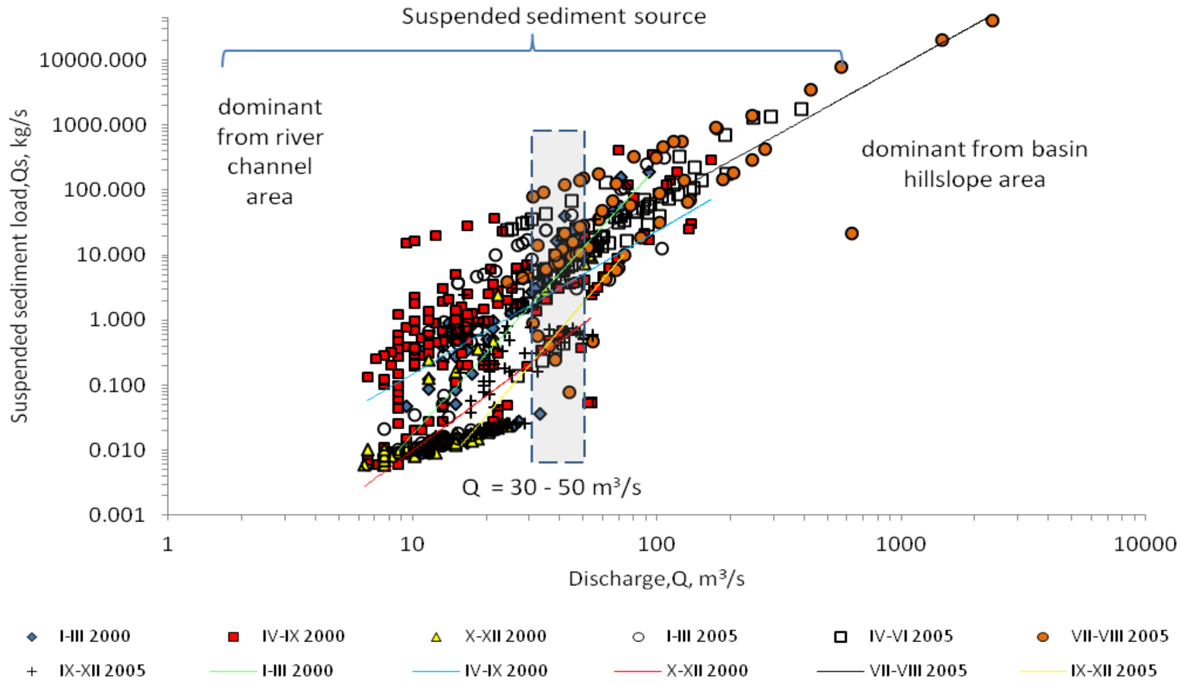

Fig. 10: Identifying sediment sources based on the mean daily suspended sediment load at Vrânceni gauging station

Sediment yield

Hicks et al. (1996) has indicated that the main factors affecting regional variation in sediment yield are basin mean annual rainfall and, to a lesser and more contentious extent, basin geology. Griffiths (1982) considered that secondary climatic effects, such as differences in the intensity, frequency, and duration of storms, are also important.

The total volume of suspended sediment transported through the four sections on the Trotuş river between 2000 and 2014 amounted to approx. $39x10^6$ t, thus the average annual volume was 2,598,000 t (Table 1). 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) (Fig.11).

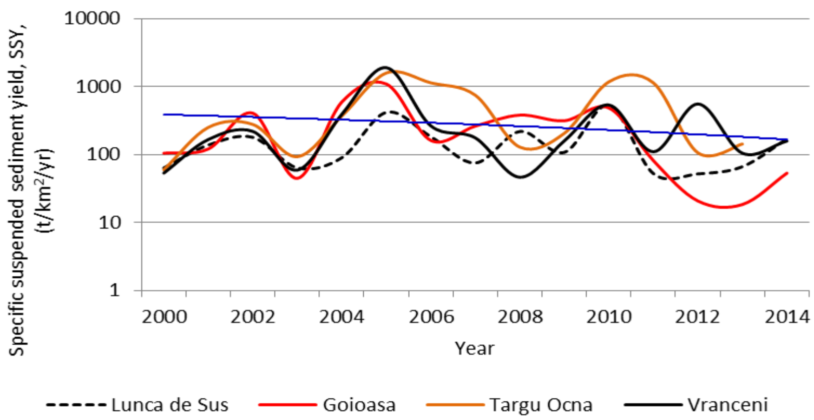

Fig. 11: Specific suspended sediment yield between 2000 and 2014 at the four gauging stations

It was found that at Târgu Ocna, the gauging station measuring the input of a drainage basin with an area of 2091 sqkm, the specific suspended sediment yield is 528.9 t/sqkm/yr, whereas at Vrânceni (which determines the input of a basin of 4092 sqkm) the specific suspended sediment yield is lower, i.e. 326.5 t/sqkm/yr, albeit the suspended sediment load is nearly double (37 kg/s compared to 19 kg/s) (Table 1; Fig.11). This can explain, to some extent, the tendency of aggradation of the Trotuş river bed/channel in the mid-course, and degradation in the lower course, but mostly the increase in colluvial or alluvial sediment storage (Vanmaercke et al., 2015). In fact, the inverse relationship between the specific suspended sediment yield and the area of the drainage basin was often reported in the literature (Schumm, 1977; Dedkov, 2004; Dumitriu, 2014). This trend indicates that the total suspended sediment yield increases downstream, but to a lower extent compared to the increase of the drainage area. Thus, the specific suspended sediment yield diminishes as the drainage area augments. The highest suspended sediment yields were typically documented in wet years. This means that the climate might play an important role in the sediment transport process. There are, however, situations where, in certain dry years, spring floods contribute significantly to the increase of suspended sediment yield; this is the case of 2012 (with mean annual discharge far below the multiannual average - 22 m^3/s compared to 34 m^3/s), when 71% of the total sediment yield was produced in the course of one day (the 25th of May) (Fig.12).

Table 1 Data concerning the suspended sediment yield between 2000 and 2014 at the four gauging stations

Year	Lunca			Goioasa			Tg. Ocna			Vranceni		
	SY	%	SSY	SY	%	SSY	SY	%	SSY	SY	%	SSY
2000	5597.0	2.6	63.6	81770.1	2.5	104.7	125109.2	0.8	59.8	218608.6	1.1	53.4
2001	12150.6	5.7	138.1	94455.2	2.9	120.9	524536.5	3.4	250.9	682379.0	3.4	166.8
2002	15737.9	7.4	178.8	317297.4	9.8	406.3	579367.2	3.7	277.1	895901.2	4.5	218.9
2003	5609.4	2.7	63.7	34884.1	1.1	44.7	194682.1	1.3	93.1	241448.3	1.2	59.0
2004	7906.6	3.7	89.8	463357.2	14.3	593.3	771868.3	5.0	369.1	1598895.2	8.0	390.7
2005	36739.0	17.4	417.5	852612.2	26.4	1091.7	3308048.3	21.4	1582.0	7769760.4	38.8	1898.8
2006	16131.7	7.6	183.3	125946.7	3.9	161.3	2372511.2	15.3	1134.6	1081169.5	5.4	264.2
2007	6620.6	3.1	75.2	205044.9	6.3	262.5	1559094.5	10.1	745.6	718561.9	3.6	175.6
2008	19204.0	9.1	218.2	296894.3	9.2	380.1	268380.0	1.7	128.4	189975.2	0.9	46.4
2009	9477.2	4.5	107.7	245545.8	7.6	314.4	429580.4	2.8	205.4	651620.1	3.3	159.2
2010	46466.3	22.0	528.0	378665.2	11.7	484.8	2457606.9	15.9	1175.3	2191510.7	10.9	535.6
2011	4616.3	2.2	52.5	63587.5	2.0	81.4	2372511.2	15.3	1134.6	450112.4	2.2	110.0
2012	4576.2	2.2	52.0	16196.7	0.5	20.7	221875.6	1.4	106.1	2274329.9	11.3	555.8
2013	5830.4	2.8	66.3	14371.2	0.4	18.4	299227.1	1.9	143.1	428297.8	2.1	104.7
2014	14976.7	7.1	170.2	41609.9	1.3	53.3				647567.5	3.2	158.3
Total	211639.9	100.0		3232238.5	100.0		15484398.4	100.0		20040137.5	100.0	
Av.	14109.3		160.3	215482.6		275.9	1106028.5		528,9	1336009.2		326.5

SY – suspended sediment yield (t); SSY – specific suspended sediment yield (t/km^2/yr); % - period 2000 – 2014; Av. - average

Fig. 12: Mean suspended sediment yield a normal year, a wet year and a dry year

Conclusion

Concerning the monthly variability of suspended sediment load, after 1991 an over-concentration of sediment transport during the month of July was documented. At the four gauging stations, July accounts for the following percentages of the total amount of suspended sediment transported during the period under investigation: Lunca de Sus 33%; Goioasa, 37%; Târgu Ocna, 31% and Vrânceni 47%. During the summer season approx. 56% of the total suspended alluvia were transported. Regardless of the water year (wet, dry or normal average year) the catchment slopes are the primary source of suspended sediment. Even during dry years, river beds are unable to exceed 40-45% of the total volume of suspended sediment transported by the Trotuş river. The sediment yield ranged from 4,576 t (Lunca de Sus – 2012) to 7,769,760 t (Vrânceni – 2005). The specific sediment yield is directly related to the area of the drainage basin in the mountain area (160 t/sqkm/yr at Lunca de Sus; 276 t/sqkm/yr at Goioasa and 529 t/sqkm/yr at Târgu Ocna), whereas in the Subcarpathians and plateau sectors the relation between the two parameters is inverse (326 t/sqkm/yr at Vrânceni).

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Forum geografic. Studii și cercetări de geografie și protecția mediului
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Geotechnical Properties of Some Soils in a Tar Sand Area of Southwestern Nigeria

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Abstract

Engineering properties of some soil samples in Idiobilayo and Idiopopo areas of Southwestern Nigeria were studied with the aim of determining their geotechnical properties which can aid in the exploitation plan of the tar sands deposits in the area.
A total of six sampling locations with three samples each were established in the study area. Samples of soil both disturbed and undisturbed were obtained from the trial pits to a depth of about 1.5m at 0.5m vertical interval. The disturbed samples were subsequently subjected to classification tests such as grain size distribution and consistency limits using British standards 1377 procedure. However, the undisturbed samples were subjected to permeability test.
Results obtained in this study showed that the area of study is underlain essentially by sandy soils, with substantial silty content. Clay and gravel content are quite minimal. The particle size distribution curves confirmed a general dominance of silt to coarse-grained sand size particles in the soil matrix with minor but complimentary clayey and gravelly materials. Amounts of fines in the soils are less than 50% except in trial pts 4 and 5 where they are slightly above 50%.
The soils consist of sand (60.0 %) and silt (35.0 %). The percentage of fines (silt and clay sized fraction) in the soils was about 38.0 %, and makes the soils good base for landfill, since recommended percentage of fines, should not be less than 20.0 %. However the obtained values of permeability coefficient of 5.5 X 10^{-6} mm/s to 1.2 X 10^{-4} mm/s call for the lining of the base to avoid groundwater pollution by leachates.

Keywords: *Tar sands, landfill, geotechnical, plasticity index, leachate*

Rezumat. Proprietăţile geotehnice ale unor soluri din zona nisipurilor bituminoase din sud-vestul Nigeriei

Proprietăţile unor mostre de sol din regiunile Idiobilayo şi Idiopopo din SV Nigeriei au fost studiate pentru a determina proprietăţile lor geotehnice care pot fi folosite în planurile de exploatare a depozitelor de nisipuri bituminoase din zonă.
În zonă au fost stabilite şase locaţii, fiind prelevate câte trei probe din fiecare locaţie. Mostre de soluri perturbate şi neperturbate au fost prelevate din gropile până la o adâncime de aproximativ 1,5 m la un interval de 0,5 m pe verticală. Mostrele perturbate au fost supuse ulterior testelor de clasificare privind distribuţia granulometrică şi limitele de consistenţă folosind procedura 1377 din standardele englezeşti. Mostrele neperturbate au fost supuse unui test de permeabilitate.
Rezultatele obţinute în acest studiu au arătat că zona luată în considerare are la bază în principiu soluri nisipoase cu un conţinut nămolos consistent. Distribuţia curbelor granulometrice a confirmat în matricea solului dominanţa generală a particulelor fine de nămol până la cele nisipoase grosiere, cu materiale complementare argiloase şi de pietrişuri. Cantităţile fine din soluri sunt mai mici de 50%, cu excepţia gropilor 4 şi 5, unde acestea sunt uşor peste 50%.
Solurile sunt alcătuite din nisipuri (60,0%) şi aluviuni (35,0%). Procentul de particule fine din soluri (fracţiunea granulometrică prafuri şi argile) a fost în jur de 38,0%, ceea ce face solul să fie o bază bună pentru umpluturi, de vreme ce procentul de particule fine recomandat nu trebuie să fie mai mic de 20,0%. Totuşi valorile obţinute ale coeficientului de permeabilitate de 5.5 X 10^{-6} mm/s to 1.2 X 10^{-4} mm/s necesită căptuşala bazei pentru a evita poluarea apelor subterane prin levigare.

Cuvinte-cheie: *nisipuri bituminoase, căptuşală, geotehnic, indice de plasticitate, levigat*

Introduction

Asphalt impregnated sandstones, otherwise referred to as oil sand (tar sand) and active oil seepages occur in southwestern Nigeria within the Eastern Dahomey (Benin) basin, a marginal pull apart (Klemme, 1975) or marginal sag (Kingston et al., 1983) basin. The oil sand outcrops in an E-W belt, approximately 120km long and 4-6km wide, extending from Edo/Ondo-Ogun States (Enu, 1985).

Occurrence of the seepage and tar sand deposit over the Okitipupa ridge in the Dahomey basin provided the initial impetus for oil exploration in Nigeria. From the turn of the century to date, no less than fifteen groups comprising public and private ventures have shown varying degrees of interest. Arising from these, a total of one hundred and fifteen

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Volume ***XIV****, Issue* ***2*** *(****December 2015****), pp.* ***112-116***
*http://dx.doi.org/****10.5775/fg.2067-4635.2015.072.d***

(115) boreholes have been drilled across the basin and have confirmed the presence of oil sands and heavy oil. An intense investigation by Ako et al., (1980) was conducted over 17km^2 area, just north of Agbabu village and this particular study has provided a vast account of information on the oil sand deposits.

The physico-chemical characteristics of the tar sands from outcrops and coreholes in the Agbabu/Ore areas in Ondo state have been extensively reported. The salient aspects of the comprehensive information published within the last two decades covering sedimentological properties, oil saturation, bitumen ultimate analysis, stock-tank properties, calorific values, etc have been published by Adegoke et al (1980); Oshinowo et al (1982); Oluwole et al (1985), Ekweozor and Nwachukwu (1989); Akinmosin et al (2005 and 2006).

Studies carried out on the series of outcrop sections, cores and drilled cuttings obtained from the various exploration Campaign have shown the presence of two horizon-bearing sediments designed as "X" and "Y" horizon, (Fig. 1). "The X-horizon, being the shallower of the two deposits, constitutes the prominent outcropping unit in most areas, though significantly eroded in the north western part of the basin. The thickness varies from 9m to about 22m with an average of 15m.

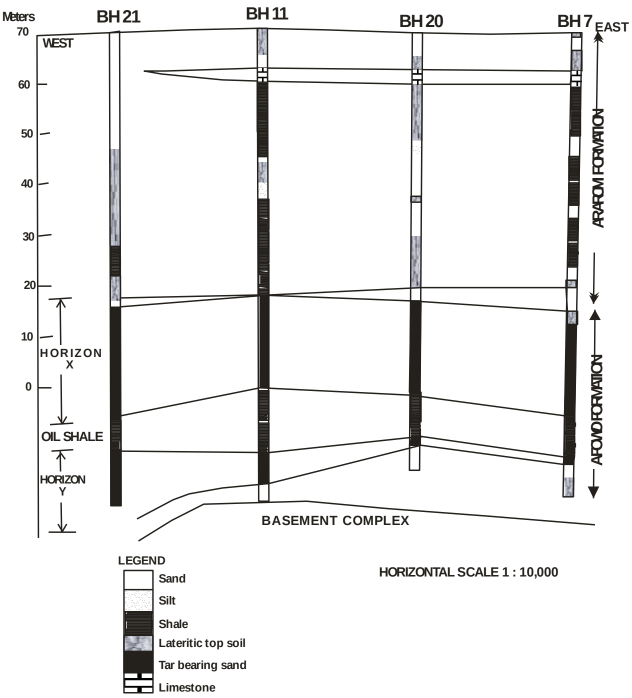

Fig. 1: Schematic geological west-east cross-section showing the stratigraphic sequence and the tar sand horizons in some boreholes (Modified after Ekweozor et al., 1989)

The Y-horizon is the prominent outcropping sequence in the northwestern part of the structure where "X" has been largely eroded. Its thickness varies widely from 3m in the east to 22.6m in the west with an average of about 12m.

A combination of factors has prevented the exploitation of this resource to date, among which are environmental, technological and economic considerations. The most important of which is the environmental effects it may pose to both physical and biological components of the area of occurrence.

The aim of this work is to generate geotechnical properties of some soils in tar bearing area of Southwestern Nigeria which is expected to provide necessary information that will be useful in planning and eventual exploitation of the resource. Moreover this will also help in developing an appropriate environmental management programme to reduce potential negative effects of tar sand mining.

Location of the study area

The study area is Idiobilayo/Idiopopo, a settlement in the South western Nigeria and can be located on topographic sheet 280A, between longitudes 4^{0}34′ and 4^{0}37′ E and latitudes 6^{0}38′ and 6^{0}40′ N. It is accessible by fairly motorable roads and network of footpaths (Fig. 2).

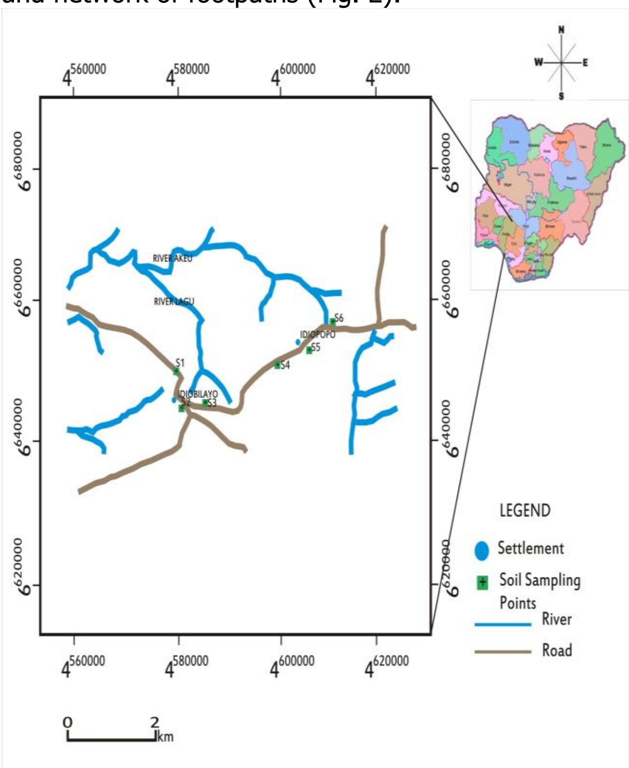

Fig. 2: Map of the study area showing tar sand outcrop locations

The lithostratigraphic units of the Cretaceous to Tertiary sedimentary sequence of eastern margin of Dahomey basin (Fig. 3), are summarized in Table 1.

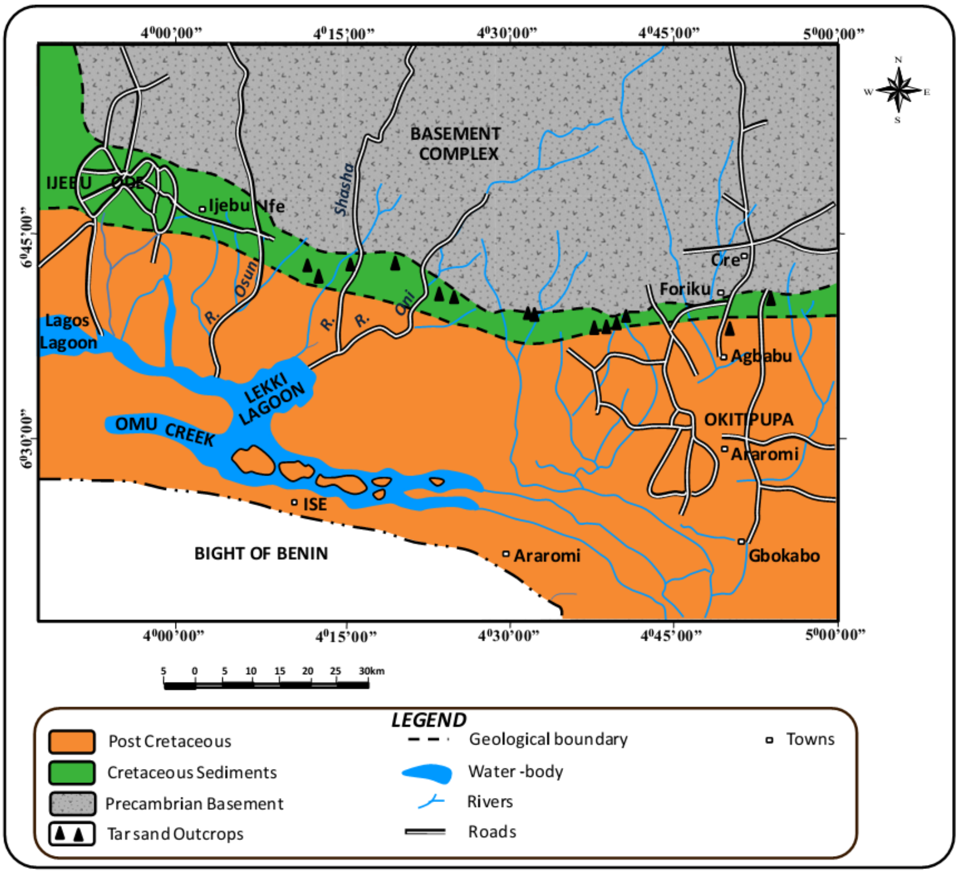

Fig. 3: Generalized geological map of the eastern Dahomey Basin showing Area Extent of the tar sand deposits (modified after Enu, 1985)

Table 1: Regional Stratigraphic Setting of the Eastern Dahomey Basin (after Idowu et al., 1993)

Age		**Formation**			**Lithology**
		Ako et al., 1980	Omatsola and Adegoke, 1981		
Tertiary	Eocene	Ilaro Formation	Ilaro Formation		Sandstone
	Paleocene	Oshosun Formation	Oshosun Formation		Shale
		Ewekoro Formation	Ewekoro Formation		Limestone
Cretaceous	Maastrichtian		**Abeokuta Group**	Araromi Formation	Shale
	Turonian			Afowo Formation	Sandstone/ shale
	Berremian			Ise Formation	Sandstone

Method of study

A total of six sampling locations were established in the study area. Samples were collected by boring pits to depth of about 1.5m below ground surface. Samples of soil both disturbed and undisturbed were obtained from the trial pits to a depth of about 1.5m at 0.5m vertical interval. The disturbed samples collected in polythene bags were obtained using a digger and shovel, while the undisturbed samples were obtained using core cutter (100mmx130mm) with a marshal hammer ramming it into place. The core cutter was sealed on both ends immediately with candle wax melted on the field to prevent loss of moisture. The disturbed samples were subsequently subjected to classification tests such as grain size distribution and consistency limits. However, the undisturbed samples were subjected to permeability test.

Samples were equally collected along the two major slopes in the study area at intervals of 20m from one another in each of the slope. Ten (10) samples were collected all together and carefully packed in polythene bags.

These samples were subsequently subjected to grain size distribution and consistency limit tests.

Results and discussions

Table 2 shows that soil samples in the trial pits at Idiopopo and Idiobilayo have percentage clay size

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 112-116
http://dx.doi.org/10.5775/fg.2067-4635.2015.072.d

range of 3-15%, percentage silt of 15-45%, percentage sand of 44-70% and percentage of gravel of 1-15%. Results obtained in this study showed that the area of study is underlain essentially by sandy soils, with substantial silty content. Clay and gravel content are quite minimal.

Table 2: Grain size distribution of bulk samples

Test Hole Location	Sample Depth(m)	Percentage Clay size particles	Percentage Silt	Percentage Sand	Percentage Gravel
Idiobilayo-A	0.50	15	15	68	02
	1.00	05	39	58	02
	1.50	09	36	50	05
Idiobilayo-B	0.50	03	42	53	02
	1.00	06	38	54	02
	1.50	05	38	55	02
Idiobilayo-C	0.50	09	31	59	01
	1.00	05	40	56	04
	1.50	05	40	53	02
Idiopopo-A	0.50	06	44	45	05
	1.00	05	45	53	02
	1.50	06	44	45	05
Idiopopo-B	0.50	06	41	49	04
	1.00	07	45	44	04
	1.50	09	46	40	05
Idiopopo-C	0.50	03	25	70	02
	1.00	10	25	63	02
	1.50	14	27	67	02

The particle size distribution curves confirmed a general dominance of silt to coarse-grained sand size particles in the soil matrix with minor but complimentary clayey and gravelly materials (Fig. 4 and 5).

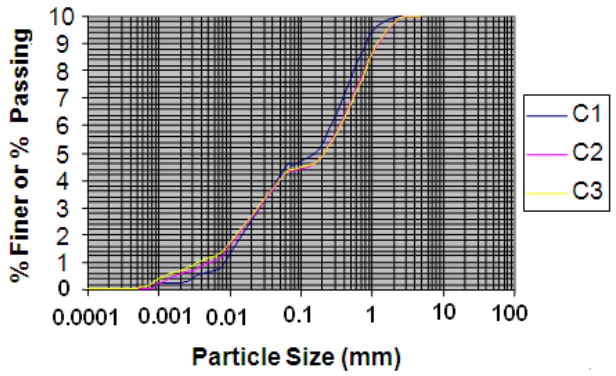

Fig. 4: Grain size distribution curves of sub surface soil samples (Location 2), Idiobilayo

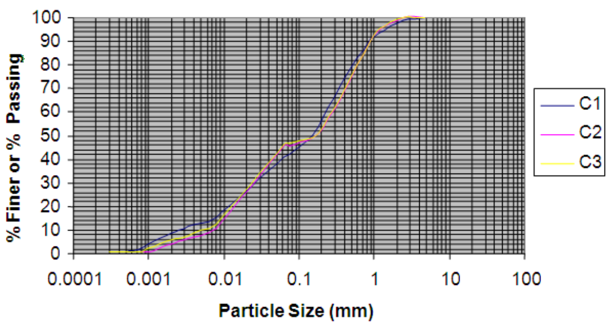

Fig. 5: Grain size distribution curves of sub surface soil samples (Location 3), Idiobilayo

The topsoils in most of the pits are generally loose and silty. With the exception of pits 4 and 5, (Fig. 2) in which some of the horizons are indurated, all the soils are slightly loose with very little evidence of compaction. Amounts of fines in the soils are less than 50% except in trial pts 4 and 5 where they are slightly above 50%. Daniel (1993b) recommends amount of fines of not less than 20% for land fill seals. The soils are thus good for the base of a landfill.

The plasticity index is the measure of the affinity which a soil has for water. Casagrande (1932) did indicate that the higher the value, the poorer would the soil be as an engineering soil. Material with low plasticity do not compress appreciably under load nor do they shirnk extensively when dried so that once they have acquired a firm Consistency near plastic limit; they are quite stable. Plasticity result (Table 3) showed that the plasticity index of soil in Idiobilayo (location A-C) ranged from 2.40 – 20.37 %, while soil in Idiopopo (locations A-C) ranged from 7.72 – 20.37 %. Soils obtained at depths 0.5 m, 1.0 m and 1.5 m in Idiobilayo- A; 1.5 m depth in Idiobilayo B; 0.5 m and 1.0m depths in Idiopopo- A have low plasticity, hence they are good engineering soils and can be used for base of landfill.

Daniel (1993) recommends low plasticity index of between 7 and 10 for landfill seals. Lambe (1951) in classifying soils based on permeability used a permeability co-efficient of 10^{-4}mm/s as a borderline between pervious and impervious soils. The values of permeability coefficient of the soils analysed as shown in Table 4 indicate that all the soils are permeable.

Table 3: Consistency limits of Bulk Soil samples

Test Hole Location	Sample Depth (m)	Liquid Limit %	Plastic Limit %	Plasticity Index %
Idiobilayo-A	0.50	23.0	15.25	7.72
	1.00	25.6	16.13	9.47
	1.50	23.7	13.92	9.78
Idiobilayo-B	0.50	35.3	21.29	14.03
	1.00	44.4	24.06	20.37
	1.50	24.9	22.50	2.40
Idiobilayo-C	0.50	32.5	15.97	16.53
	1.00	42.8	23.11	19.69
	1.50	41.9	25.74	16.16
Idiopopo-A	0.50	23.0	15.25	7.72
	1.00	25.6	16.13	9.47
	1.50	49.8	32.88	16.93
Idiopopo-B	0.50	35.3	21.29	14.03
	1.00	44.4	24.06	20.37
	1.50	31.5	13.70	17.80
Idiopopo-C	0.50	32.5	15.97	16.53
	1.00	42.8	23.11	19.69
	1.50	36.8	16.91	19.89

Table 4: values of Permeability co-efficient of the bulk samples

Test Hole Location	Co-efficient of Permeability (mm/s)
Idiobilayo-A	5.9×10^{-5}
	2.0×10^{-6}
	2.41×10^{-6}
Idiobilayo-B	2.6×10^{-5}
	3.06×10^{-4}
	2.91×10^{-4}
Idiobilayo-C	1.5×10^{-5}
	1.21×10^{-4}
	1.71×10^{-4}
Idiopopo-A	2.0×10^{-6}
	3.0×10^{-6}
	2.5×10^{-6}
Idiopopo-B	9.0×10^{-5}
	2.0×10^{-6}
	2.06×10^{-6}
Idiopopo-C	5.09×10^{-4}
	5.4×10^{-5}
	5.47×10^{-6}

Conclusions

Geotechnical site investigation in a land fill site selection is important to guaranty adequate protection of the environment. Observation and result obtained from all the tests employed in the geotechnical evaluation of the study locations for possible landfill sitting indicate that the soil has suitable characteristics in terms of grading and consistency. However, the obtained values of permeability coefficient of 5.5×10^{-6} mm/s to 1.2×10^{-4} mm/s call for the lining of the landfill base to avoid groundwater pollution by leachates.

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Landscape metrics as a tool for landform pattern delineation. A case study on dune fields

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Abstract

During the recent years, landform detection and mapping has been one of the most active fields of geomorphometry. However, there is still a need for quantitative work addressing the issue of classifying repeating landform types (MacMillan *et al.*, 2004). The main issue in developing an accurate automatic classification algorithm of repetitive landform types is given by the difficulty to integrate contextual information within the analysis (Evans, 2012). Therefore, the motivation of the current approach is strongly related to the importance of context analysis in the field of specific geomorphometry. Introduced in landscape ecology to evaluate the spatial structure of a landscape, the concept of landscape metrics embraces a series of specific indicators for quantifying topological and contextual information. Thus, considering the fact that the assessment of topological and contextual attributes is not possible based on local, statistical and regional land-surface variables, the main objective of this study is to assess the applicability of landscape metrics for the delineation of landform patterns.
The quantification of landscape metrics involved the segmentation and classification of the following morphometric variables: elevation, profile curvature and local relief. Using an unsupervised method, the *Iso Cluster Unsupervised Classification* tool from ArcGIS10® software, a total of 24 classes have been used in order to fulfill the minimum requirement imposed by the concept of landscape metrics and further statistical analysis. In order to test the transferability degree of landscape metrics among different dune fields, a set of statistical analyses was carried out. The proposed methodology has been applied on freely available ASTER GDEM's. This paper provides new prospects regarding the applicability of landscape metrics for the delineation of landform patterns.

Keywords: *geomorphometry, DEM, Landscape metrics, context, dune fields*

Rezumat. Utilizarea metricilor peisajului în descrierea configuraţiei formelor de relief repetitive. Studiu de caz asupra câmpurilor de dune

Clasificarea și cartografierea formelor de relief contituie una dintre cele mai active ramuri din domeniul geomorfometriei. Cu toate acestea, există un număr redus de abordări ce vizează clasificarea formelor repetitive de relief (MacMillan *et al.*, 2004). Dificultatea integrării informațiilor contextuale în procesul de clasificare a formelor repetitive de relief constituie principalul impediment în dezvoltarea unui algoritm de clasificare care să prezinte rezultate cu un grad de acuratețe ridicat (Evans, 2012). Astfel, motivația acestui studiu este puternic corelată cu importanța analizei de context în clasificarea automată a formelor repetitive de relief. Metricile peisajului însumează o serie de indicatori specifici ecologiei peisajului ce vizează evaluarea structurii spațiale a unui ansamblu peisagistic. Luând în considerare faptul că evaluarea atributelor topologice și contextuale nu este posibilă pe baza variabilelor morfometrice locale, statistice sau regionale, scopul acestui proiect este de a evalua aplicabilitatea metricilor peisajului în descrierea configurației spațiale a formelor de relief repetitive.
Cuantificarea metricilor peisajului a impus segmentarea și clasificarea următoarelor variabile morfometrice: altitudinea, altitudinea relativă și curbura în profil. Utilizând algoritmul de clasificare neasistată, *Iso Cluster Unsupervised Classification*, din programul ArcGIS10®, au fost stabilite 24 de clase, acestea având ca fundament o serie de limitări impuse de conceptul metricilor peisajului și de analizele statistice ulterioare. Analizele au vizat evaluarea transferabilității indicatorilor la nivelul altor areale similare. Metodologia dezvolată a avut la bază utilizarea modelelor digitale de elevație de tip ASTER GDEM. Lucrarea prezintă astfel primele demersuri în ceea ce privește aplicabilitatea metricilor peisajului în descrierea configurației spațiale a formelor de relief.

Cuvinte-cheie: *geomorfometrie, DEM, metricile peisajului, context, câmpuri de dune*

Introduction

Recent advances in computer sciences have facilitated an increase in the overall quality of digital elevation models (DEM's) and the development of geomorphometry, the science of digital terrain analysis (Pike, 1995; Wilson, Gallant, 2000; Rasemann *et al.*, 2004). DEM's are complete representations of terrain heights that are used to display landforms and to derive land-surface variables through geomorphometric analysis (Pike, 2000; Hengl, Evans, 2009).

In the scientific literature, there are two overarching modes of geomorphometric analysis: *specific*, treating discrete landforms and *general*, addressing the continuous land surface (Evans, 1972). So far, there is a lack of studies approaching both modes for comparing the results in a specific landscape (Evans, 2012). Therefore, Drăguţ, Eisank (2011) proposed *discrete geomorphometry* as a possible approach to connect general and specific geomorphometry. The main objective of this approach is to produce homogenous objects, determined by discontinuities in land-surface variables (Drăguţ, Eisank, 2011).

Within the context of extracting morphometric objects defined as homogeneous areas based on constant values of morphometric properties and delineated by discontinuities of the properties, Minár, Evans (2008) have introduced the concept of elementary forms. Delineation of such objects should be followed by further analysis in order to relate landforms to context in geomorphological mapping (MacMillan *et al.*, 2004; Bishop, 2009; Eisank, 2010). Therefore, one of the most persistent challenges launched by the scientific community is the description of local conditions based on contextual and topological information (Deng, 2007a; Evans, 2012). Such approaches are utmost important for the classification of repeating landform types (Pike, 2000).

Despite the fact that Pike (1988) has published a seminal research on automatic classification of repeating patterns of landform types by analyzing DEM's, there is still a lack of studies addressing this issue (MacMillan *et al.*, 2004). Pike (2000) and (Olaya, 2009) have suggested that landscape metrics could complement local variables in land surface classification. However, landscape metrics have not been evaluated yet as land-surface variables.

This paper provides new prospects regarding the applicability of landscape metrics as land-surface variables, in the context of delineation of landform patterns. The main objective of the current research is to assess the potential of landscape metrics to differentiate landform patterns and to account for spatial context as a basis for classifying repeating landform types.

Study area and Data

Study area

The test site is situated in the Great Sand Dunes National Park and Preserve (37.78°N, 105.54°W), located in the San Luis Valley, southern Colorado (fig. 1). The National Park covers an area of approximately 168 km^2, with elevations ranging between 2290 to 3900 m. The climate is arid, receiving mean annual precipitation of about 152 mm/y (Forman *et al.*, 2006).

The most predominant feature in the Great Sand Dunes National Park is the 78 km^2 active dune mass that rises more than 200 m above the valley floor (Madole *et al.*, 2008). The sand mass, which is banked against the Sangre de Cristo Mountains, represent a complex of active and sinuous transverse to barchanoid ridges, with a general NNW – SSE orientation (Wiegand, 1977). The 2000 to 12000 years old sand mass was transported to the San Luis Valley, mainly by the Rio Grande, being latter deposited at the base of the Sangre de Cristo Mountain front (Chatman *et al.*, 1997).

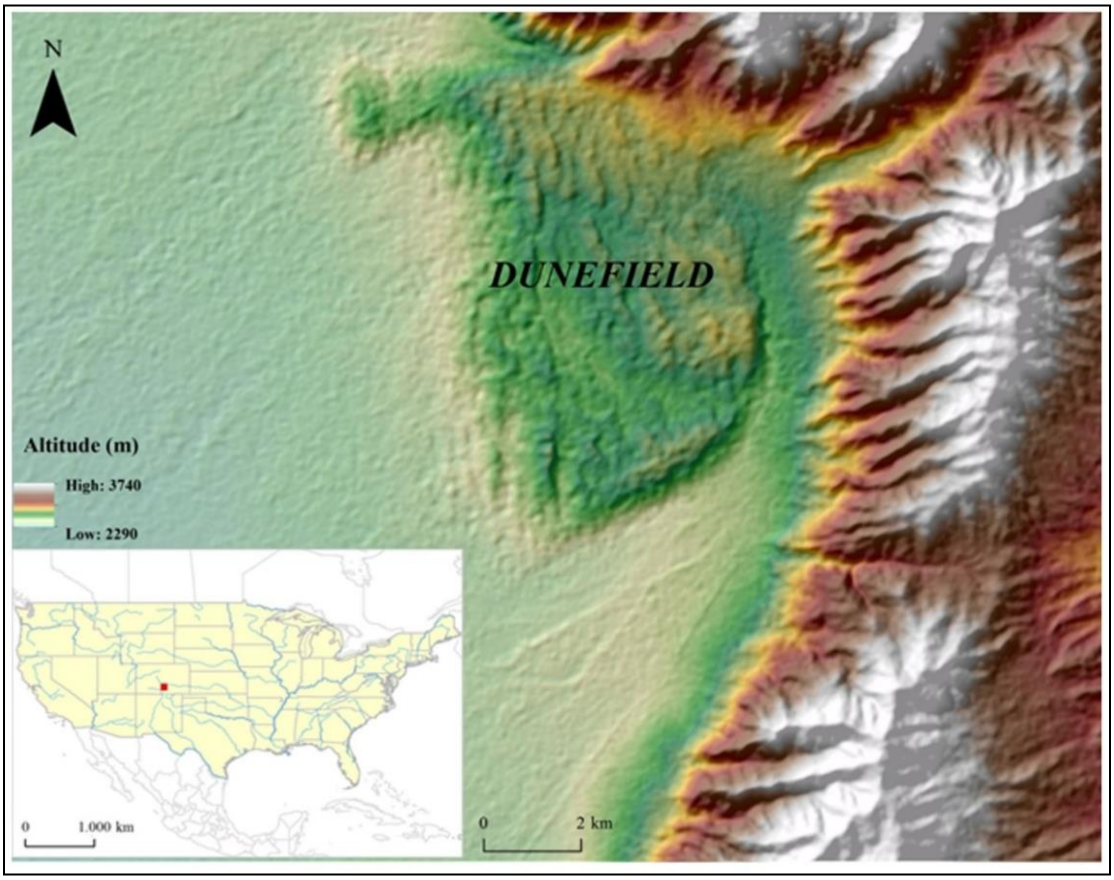

Fig. 1: Location of the study area

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Digital Elevation Model

Previous work regarding the spatial analysis of dunes (Bubenzer, Bolten, 2008; Hugenholtz, Barchyn, 2010; Bullard *et al.*, 2011) have been carried using the global digital elevation dataset, ASTER GDEM (Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model). Given that the current paper aims is to assess the applicability of landscape metrics for the delineation of landform patterns, with a case study on dunefields, data analysis was carried out using the same 30 m resolution ASTER DEM, projected in the national coordinate system, NAD 1983 UTM Zone 13N.

Methodology

Pre-processing

Land-surface variables were derived based on DEM analysis (profile curvature and local relief), using two GIS (Geographical Information System) software's: Landserf 2.3 and ArcGIS10®. Due to the advantage to opt for a multi-scale approach, Landserf 2.3 was used in order to determine the best window size for the derivation of profile curvature (9x9). Mean filtering of elevation, using *Focal Statistics*, implemented in ArcGIS®, was applied, before the extraction of local relief.

Since DEM's consist of continuous data and landscape metrics mostly deal with discrete information (McGarigal, Marks, 1995), the DEM's have been converted into a discrete layer before applying any quantification. The conversion has been carried out through a segmentation process which relies on three different layers: elevation, profile curvature and local relief. For a reliable landscape metrics quantification the creation of meaningful segments, by applying image segmentation algorithms, is utmost important. Therefore, the segmentation processes has been carried out using the ESP2 tool, developed by Drăguţ *et al.* (2013) and implemented in eCognition software (Trimble, 2011). Each of these variables were classified based on mean and standard deviation values, using the *Iso Cluster Unsupervised Classification* tool implemented in ArcGIS10® software. A total of 24 classes have been used in order to fulfill the minimum requirement imposed by the concept of landscape metrics and further statistical analysis.

Quantification of landscape metrics

The concept of landscape metrics was first introduced in landscape ecology to evaluate the spatial structure of a landscape and was thought useful in the field of geomorphometry in order to complement local derivatives in creating geometric signatures of topography (Pike, 2000, Olaya, 2009). Recent advances in computer sciences and GIS analysis have facilitated the development of a large number of landscape metrics. Therefore, choosing the appropriate indicators is a laborious task, imposing both a level of experience, as well as an exhaustive statistical approach (Lausch & Herzog, 2002).

As the patch (landscape element) represents the fundamental element in landscape metrics, the concept of landscape metrics is suitable for the quantification of two fundamental aspects in the analysis of landscape spatial structure: spatial composition and configuration (McGarigal & Marks, 1995). Landscape composition refers to features associated with the presence and amount of each patch type within a given landscape, but without being spatially explicit, while spatial configuration refers to the physical distribution or spatial character of patches within the landscape.

A total number of 21 metrics were quantified within the current approach, using FRAGSTATS software (McGarigal *et al.*, 2012), while statistical analysis was applied in order the delineate the parameters that are most suitable for an accurate delineation of the dune-field.

Statistical analysis

The exploratory spatial data analysis (Anselin, 1995; Anselin, 1999) was used as an alternative method for optimal visualization and clustering of landscape metrics, while the Principal Component Analysis (PCA) approach was applied as a tool for dimensionality reduction (Herzog *et al.*, 2001; Lausch, Herzog, 2002). In order to reduce redundancies, Spearman's correlation coefficients was computed for all 21 metrics. Finally, only one of two metrics was selected if the coefficient between to metrics was higher than 0.9. Thus, the PCA was conducted according to the Spearman's correlation results and based on a series of specific rules (eigenvalue ≥ 1; *Kaiser-Meyer-Olkin* (KMO) ≥ 0.6 and Significance < 0.05) (Szabó *et al.*, 2014).

Test for extrapolation

In order to test the transferability degree of landscape metrics among different dune fields, the proposed approach was tested on two different DEM's representing dune fields from Namib and Oman. The same landscape metrics were calculated for all layers and were used to compute the Wilcoxon Test (Pallant, 2010).

The Wilcoxon Test was used in order to evaluate de differences of Mean related circumscribing circle index (CIRCLE_MN) and Mean fractal dimension index (FRAC_MN) between the tested areas (Study area – Test1; Study area – Test2).

Results

A first analysis of the spatial distribution of the quantified landscape metrics has pointed out that the spatial configuration of the main dune field is best described by the elevation values, thus the remaining morphometric variables (local relief and profile curvature) were excluded from further statistical analysis. The segmentation and classification results of the morphometric objects extracted from DEM are depicted in figure 2.

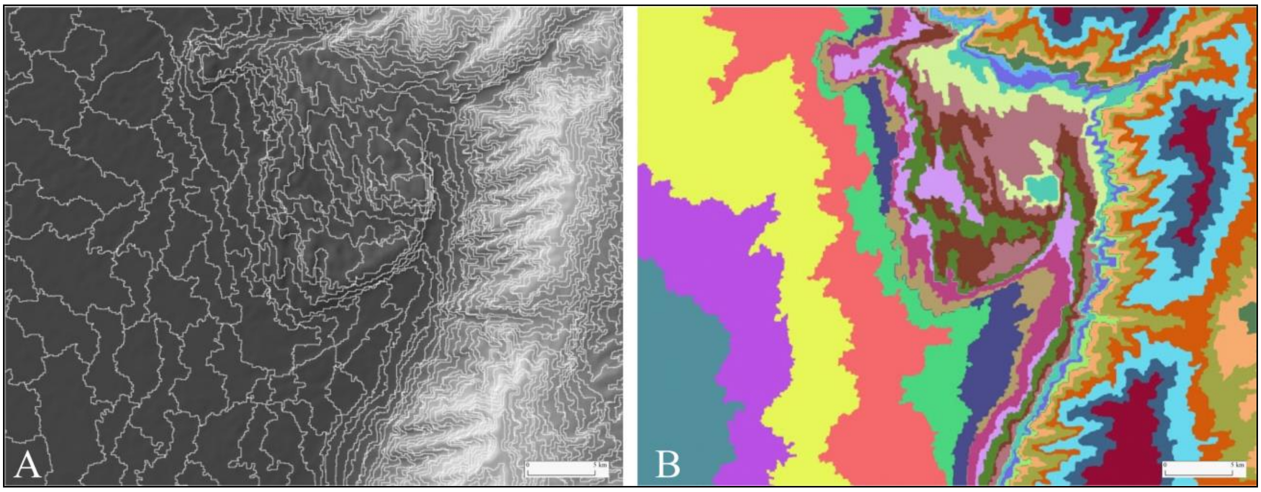

Fig. 2: Results of: A) segmentation process; B) *Iso Cluster Unsupervized Classification* (24 classes)

The exploratory spatial data analysis of landscape metrics confirms the applicability of DEM derived landscape metrics for the quantification of topological and contextual attributes. Thus, a total of 8 landscape metrics were found to be suitable for the automatic delineation of landform patterns (Table 1). The CIRCLE_MN was chosen in order to exemplify the applicability of landscape metrics for the delineation of landform patterns (fig. 3).

Table 1. The selected landscape metrics which are suitable for the automatic delineation of landform patterns

Category	Acronym	Landscape metrics (units)
Shape	FRAC_MN	Mean fractal dimension index (-)
	PARA_MN	Mean perimeter-area ratio (-)
	CONTIG_MN	Mean contiguity index (-)
	CIRCLE_MN	Mean related circumscribing circle (-)
Isolation/proximity	PROX_MN	Mean proximity index (-)
Aggregation	IJI	Interspersion/juxtaposition index (%)
Subdivision	SPLIT	Splitting index (-)
Connectivity	CONNECT	Connectance index (%)

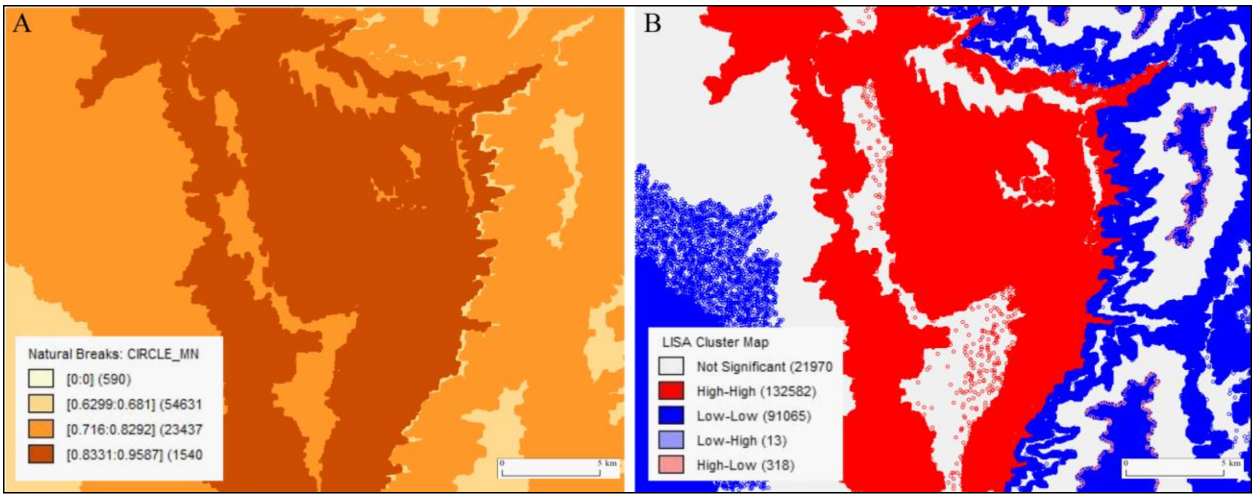

Fig. 3: Spatial distribution of Mean Related Circumscribing Circle: A) Natural Breaks Classification; B) Local MoranCluster Map

Based on the correlation analysis, *Spearman's* coefficient values were determined for all the indicators taken into consideration (Table 2). The obtained values point out a strong negative correlation of -0.999 between the PARA_MN and CONTIG_MN indicators (Table 2). The significant negative correlation outlines an inverse relation, thus an increase in value of one indicator determines a decrease in value of the other one, inducing a series of redundant information that have a negative effect on the overall analysis. Based on these consideration the PARA_MN indicator was eliminated from the principal component analysis.

Table 2. Spearman's correlation coeficients (p < 0, 05)

	CIRCLE_MN	CONTIG_MN	FRAC_MN	PARA_MN	PROX_MN	CONNECT	SPLIT	IJI
IJI	0.570	-0.284	0.415	0.302	0.453	0.510	0.598	1.000
SPLIT	0.370	-0.531	0.361	0.544	0.453	0.535	1.000	
CONNECT	0.365	-0.485	0.245	0.495	0.872	1.000		
PROX_MN	0.304	-0.397	0.207	0.403	1.000			
PARA_MN	-0.122	-0.999	-0.104	1.000				
FRAC_MN	0.888	0.111						
CONTIG_MN	0.135	1.000						
CIRCLE_MN	1.000							

The Principal Component Analysis (PCA) of the dataset has pointed out that the value of the *Kaiser-Meyer-Olkin* (KMO) coefficient was 0.305, lower than the 0.6 limit proposed by Pallant (2010). Therefore, the PROX_MN indicator was eliminated from the dataset, based on the communalities which revealed that the PROX_MN indicator had the lowest value, of 0.208. The elimination of the PROX_MN indicator has resulted in an increase of the KMO coefficient value to 0.608, emphasizing a strong relationship between the indicators included in the PCA (tabel 3). The independence of the data is confirmed by the *sig. 0* value, which is lower than the significance value required (Pallant, 2010) (Table 3).

The PCA results showed that the first two components explained about 77.46 % of the variation in the 6 landscape metrics (Table 4).

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.608
Bartlett's Test of Sphericity	Aprox. Chi-Square	74.068
	df.	15
	Sig.	.000

Table 4. Total variance explained by the first two components

Component	**PC1**	**PC2**
Eigenvalue	2.73	1.91
% of Variance	45.54	31.92

These components were interpreted as a composite of measures of shape and aggregation of similar objects (Table 5). The first component revealed the strongest correlations with CIRCLE_MN and FRAC_MN.

Table 5. Results of principal components analysis and Varimax rotation of the first two components

Landscape metrics	**Category**	**Rotated Component Matrix**	
		PC1	**PC2**
CIRCLE_MN	Shape	0.97	-0.28
FRAC_MN	Shape	0.93	-0.08
IJI	Aggregation	0.73	0.44
CONNECT	Connectivity	0.36	0.67
CONTIG_MN	Shape	0.18	-0.84
SPLIT	Fragmentation	0.04	0.86

Possibilities of extrapolation

The Wilcoxon paired test between the study area and the first test area (Table 6) revealed that there was no significant difference between the FRAC_MN (Sig. = 0.009), while for the CIRCLE_MN a statistically significant difference was indicated (Sig. = 530).

The second test (Table 6) revealed that there was consequential change between the FRAC_MN (Sig. = 0.648) and the CIRCLE_MN (Sig. = 0.346).

Table 6. Wilcoxon Test statistics

	FRAC_MN_Study_area - FRAC_MN_Test1	CIRCLE_MN_Study_area - CIRCLE_MN_Test1
Z	-2.6	-0.629
Sig.	0.009	0.530

Table 7. Wilcoxon Test statistics

	FRAC_MN_Study_area - FRAC_MN_Test2	CIRCLE_MN_Study_area – CIRCLE_MN_Test2
Z	-0.457	-0.943
Sig.	0.648	0.346

Discussions and Conclusions

The current approach confirms the applicability of landscape metrics for delineating the spatial configuration of different landform types. Thus, based on the morphometric objects outlined through the segmentation process, it has been pointed out that only 8 of a total of 21 metrics confirmed the applicability for differentiating landform patterns.

The analysis of the degree of transferability, of the current approach to different dune fields, has pointed out that the segmentation process has a great impact on the overall analysis (fig. 4). Due to the fact that the degree of transferability is strongly dependent on specific local conditions, the utilization of the proposed methodology in dune filed delineation within the test area is strongly affected by the fact that the study site comprises of several dune types (star dunes, transversal and barchan dunes) (Madole *et al.*, 2008) while the test areas comprise mainly of linear dunes. Thus, it can be said that the methodology applied in delineating a complex dune field is not adequate for the delineation of linear dunes, therefore further analyses is still needed for providing a universal solution for the utilization of landscape metrics to differentiate landform patterns.

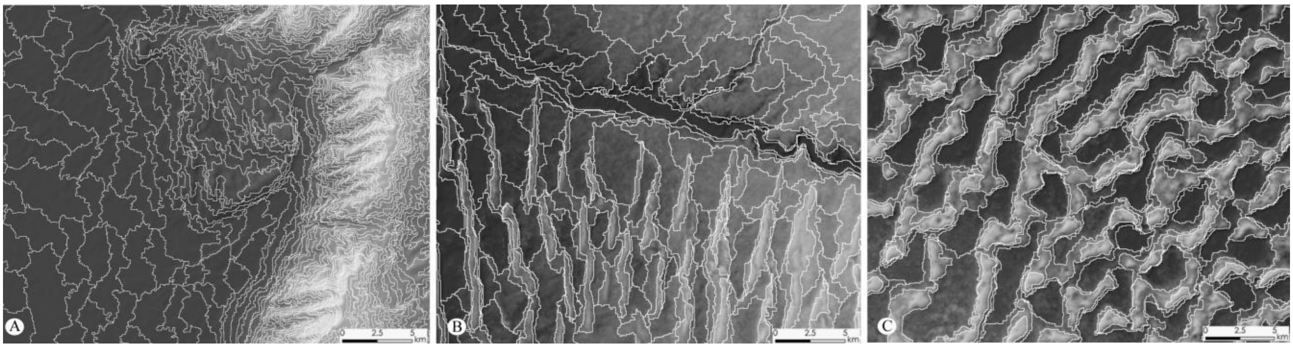

Fig. 4: Segmentation results (grey outline) for the tested areas: A) Study area; B) Test1 and C) Test2

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Near surface thermal characteristics of alpine steep rockwalls in the Retezat Mountains

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Abstract

The characteristics of the near surface thermal regime of two rockwalls with different aspect in the Retezat Mountains were investigated using two miniature thermistors. Three one-year (2012-2013; 2013-2014 and 2014-2015) rock surface temperature time series were available for the north facing rockwall, whereas only two seasons were analyzed for the south facing rockwall. The mean annual rock surface temperature (MARST) values were with 1.5-2°C colder on the northern rockwall compared with the southern steep bedrock face. Due to long daily exposure to sunshine, the south facing rockwall experienced more diurnal freeze-thaw cycles during the cold season compared to the north facing rockwall. Overall, the thermistor with a southern aspect recorded 40 and 55 more freeze-thaw cycles than the northern one. A greater number of effective freeze-thaw cycles were measured on the south facing rockwall. The maximum daily amplitude on the southern rockwall is three times higher than on the north-facing location (39.1°C compared to 13.6°C). Based on our findings it seems that the MARST values recorded on the shaded face of the steep bedrock suggest a quite likely absence of permafrost, whereas the MARST values at TPR indicate a quite certain absence of permafrost.

Keywords: *thermal regime, rockwall, freeze-thaw cycles, permafrost, the Retezat Mountains*

Rezumat. Caracteristicile regimului termic la suprafața pereților de rocă din zona alpină a Munților Retezat

Caracteristicile regimului termic la suprafața pereților de rocă având expoziții diferite au fost investigate cu ajutorul a doi termistori în Munții Retezat. În cazul peretelui cu expoziție nordică au fost disponibile serii temporale care au acoperit trei sezoane (2012-2013; 2013-2014 și 2014-2015), în timp ce peretele cu expoziție sudică a fost monitorizat doar două sezoane. Temperaturile medii anuale ale peretelui sudic au fost mai scăzute cu 1,5-2°C, în comparație cu cele înregistrate de cel nordic. Datorită expunerii mai îndelungate la soare, peretele cu expoziție sudică a fost afectat de mai multe cicluri îngheț-dezgheț față de cel nordic. Per ansamblu, termistorul instalat pe fața sudică a peretelui a înregistrat cu 40, respectiv cu 55 mai multe cicluri față de senzorul instalat pe versantul cu expoziție nordică. De asemenea, numărul ciclurilor îngheț-dezgheț considerate eficiente a fost mai mare în cazul peretelui sudic. Amplitudinea zilnică maximă a fost de trei ori mai mare în condiții de expunere mai îndelungată la soare, față de locația mai umbrită (39,1°C față de 13,6°C). Rezultatele obținute au relevat că în cazul sitului cu expoziție nordică absența permafrostului este probabilă, în timp ce în cazul sitului având aspect sudică absența permafrostului este sigură.

Cuvinte-cheie: *regim termic, perete de rocă, cicluri îngheț-dezgheț, permafrost, Munții Retezat*

Introduction

High mountain systems are among the most sensitive environments to climate change (Barsch, 1996) and react rapidly to air temperature rising (Kääb et al., 2007). The consequences of accelerated climate change on high mountain systems consist also in an increase of slopes instability and related natural hazards (Gruber and Haeberli, 2007). Considering the rapidity of temperature increase and the impact on shifting the snow line or the permafrost occurrence, the monitoring of the geomorphological evolution of the alpine systems represents a priority for scientists.

Compared with unconsolidated coarse blocks, the rockwalls faces react more rapidly to air temperature rising, since the cooling effect of the debris-covered slopes and the insulating snow cover effect are absent. The instability of rock walls is strongly controlled by the freeze-thaw action which induces rock weathering and/or by the warming and thawing of permafrost in regions with perennial frozen rock walls (Gruber et al., 2004). In the latter case high magnitude rock falls events (e.g., rock-ice avalanches, cliff falls, block falls etc.) may occur, involving a volume of materials of 107 m^3 or more (Draebing et al., 2014).

Previous studies conducted in the Southern Carpathians outlined the occurrence of permafrost in rock glaciers within the Retezat, Parâng and Făgăraș Mountains (Urdea et al., 2008; Vespremeanu-Stroe et al., 2012; Onaca et al., 2013a; Onaca et al., 2013b; Popescu et al., 2015; Onaca et al., 2015), whereas the occurrence of permafrost in rockwalls is still questionable. However, negative mean annual rock surface temperatures (MARST) were pointed out in case of two rockwalls in the Făgăraș and the Parâng Mountains (Onaca et al., 2013a; Popescu et al., 2015), indicating that permafrost is likely to occur in the sub-surface of the north facing rockwalls situated above 2200 m.

Since the occurrence of permafrost in the alpine environment of the Southern Carapthians is patchy, it is more likely that the frost weathering induced by efficient diurnal and seasonal freeze-thaw cycles prevail in the Southern Carpathians periglacial zone. Despite several recent contributions (Vespremeanu-Stroe and Vasile, 2010; Onaca, 2013; Vasile et al.,

2014) there is still a lack of knowledge concerning the near-surface thermal characteristics of the rockwalls in the Southern Carpathians and the role of the environmental factors controlling the rock surface temperature (RST) regime. Previous contributions pointed out to the role of lithology, snow cover and elevation, but the importance of aspect on RST regime was poorly evaluated.

In this context, our study aims to: i) evaluate the differences between the characteristics of RST regime on two rockwalls in the Retezat Mountains with different aspect (north versus south); ii) assess the effectiveness degree of the freeze-thaw action on different aspect (north versus south) iii) evaluate the thermal conditions at the surface of the investigated rockwalls as proxy data for permafrost occurrence.

Study area

The Retezat Mountains are the highest range within the Retezat-Godeanu group and one of the highest in the Romanian Carpathians. They are situated in the western part of the Southern Carpathians (45°20’N, 22°23’E) (fig. 1) and cover approximately 450 sqkm.

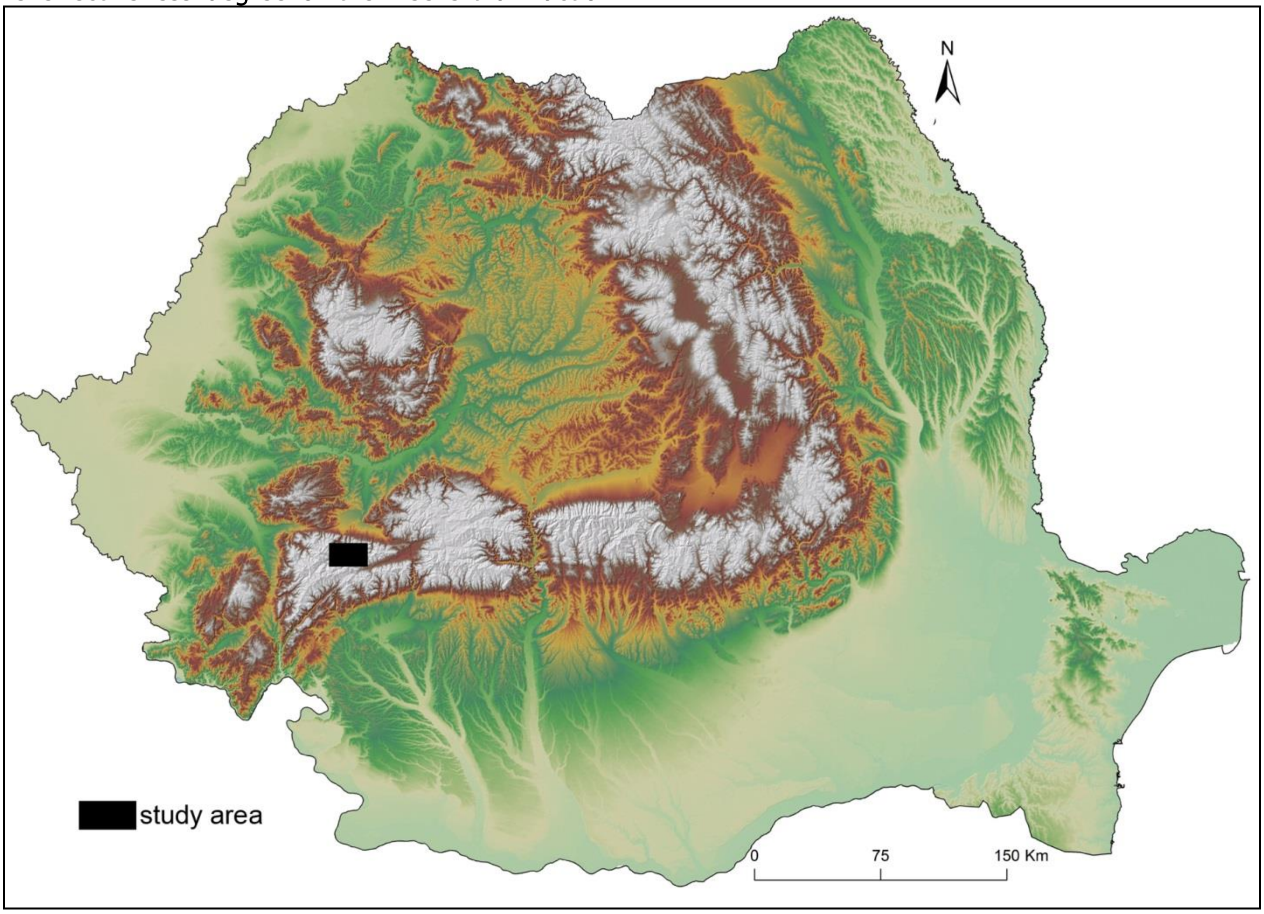

Fig.1: Location map of the studied area (the Retezat Mountains)

The measurements were performed in the central part of these mountains, where the highest peaks occur (Peleaga, 2509 m and Papușa 2504 m). There are more than 55 peaks with altitudes above 2000 m within the Retezat Mountains and around 14% of the total area of this range lies at more than 2000 m (Urdea, 2000). The alpine domain, corresponding to the periglacial environment (cf. French, 1996) occupies the slopes found between 1700 and 2509 m, representing around one third from the total area of this mountainous unit. A large variety of periglacial features were mapped in the alpine domain by Urdea (2000), such as: rock glaciers, talus slopes, debris cones, block streams, screed slopes, debris fields, solifluction lobes and sheets, patterned ground, etc.

The landscape was shaped by small Pleistocene glaciers, which have not reached the foreland. According to Urdea (2004), the largest glacier descended to 1000-1100 m on Lăpușnicu Mare valley, with a maximum length of 18.1 km, but the majority of the Retezat glaciers were three times smaller. After the Făgăraș Mountains, the Retezat Mountains were the most exposed area to glaciation within the Southern Carpathians (with 116 km2) (Mîndrescu et al., 2010). As a result, the relief shows a typical alpine morphology, with glacial cirques and troughs, glacial rock basins, glacial steps and arêtes with very steep walls.

In the central part of the Retezat Mountains, the predominant lithology consists of granodiorites and granites. The tree line is situated around 1650-1700 m, where the +3°C isotherm lies, whereas above 2100 m, negative mean annual temperatures are expected. The nearest meteorological station is found at approximately 30 km to the south-west (Țarcu meteorological station), and the main characteristics of the regional climate are highlighted in table 1.

Table 1 Climatic characteristics of Țarcu high-altitude meteorological station

Altitude (m)	Coordinates	Interval of observations	MAAT (°C)	Precipitations (mm)	Days with snow cover	Days with T≤0	AMinAT (°C)
2180	45°16'50"N, 22°32'00"E	1961-2007	-0.5	959	190	221	-34.4

MAAT – mean annual air temperature; AMinAT - absolute minimum air temperature

Methodology

During the last decade more and more studies addressed the problem of rockwalls thermal regimes using miniature temperature dataloggers (Gruber et al., 2004; Matsuoka, 2008; Vespremeanu, Vasile, 2010; Onaca, 2013).

The data used in this study were collected by 2 miniature thermistors (iButton Digital Thermometers DS 1922L) and one UTL 3 Scientific Datalogger. The thermistors were placed at one or two cm depth inside the rock in order to measure the evolution of its surface temperature. We used silicon rubber to protect the upper part of the thermistor from water infiltration and to avoid direct exposure to air. The thermistors were programmed to perform temperature measurements every hour with a resolution of 0.065°C and a precision of ±0.5°C.

The thermistors were placed on different aspect rockwalls, as follows: one facing north in the Pietrele Valley, below Bucura III peak and the second one facing south in the Bucura Valley, close to the Turnu Porții lake. The precise location and the main characteristics of the sites are specified in table 2. The collected data spreads over a period of three years in the case of the north facing thermistor (BUC) and over a period of two years in the case of the south facing thermistor (TPR).

The third datalogger (AIR) was installed in the Judele glacial cirque to monitor the air temperature evolution between August 2012 and August 2015. In the case of this datalogger (AIR) readings were recorded every hour with a resolution of 0.1°C and a precision of ±0.1°C. A special cubic protection box made by wood was used to shelter the datalogger and to avoid direct exposure to solar radiation. The UTL3 datalogger was placed in the box, but direct contact with air was provided by the lateral holes, which were designed by the authors.

It is important to point out that we considered a season of measurements the interval that starts in a particular day during the warm season and finishes one day before the same day of the next year (e.g. from 01.08.2012-31.07.2013); and not a calendar year starting from the 1st of January to the 31st December.

From the row data we calculated several relevant indicators, such as: mean annual rock surface temperature, the number of the freeze-thaw cycles, the diurnal superficial freezing index, the seasonal freezing index, the daily amplitude of temperatures and the potential depth of frost.

Table 2 Main characteristics of the dataloggers

Location	Type	Coordinates	Monitoring interval	Altitude (m)	Aspect	Code
Bucura III	iButton	45°22'04" N 22°52'12" E	01.08.2012-01.08.2015	2183	North	BUC
Tăul Porții	iButton	45°21'42" N 22°51'46" E	01.08.2012-01.08.2014	2221	South	TPR
Judele	UTL3	45°21'25" N 22°51'26" E	01.08.2012-01.08.2015	2180	South	AIR

Results

Characteristics of the RST regimes

The characteristics of the RST values are strongly correlated with air temperature variation, mainly due to the absence of snow and debris cover and high conductivity of the rock blocks (fig. 2).

Between august 2012 and august 2015, the mean annual temperature values from the north-oriented location (BUC) ranged from 1.3 to 1.9°C (table 3) and are with 1.5-2°C colder than the MARST values recorded on the Turnu Porții rockwall.

The MARST values at the more sun-exposed location (TPR) are thus higher, reaching 3.9°C in 2013-2014 season, but also appear to show larger variations from one season to another compared with the shaded location. The inter-annual variation of MARST was twice as high on the southern exposed rockwall (TPR) compared to the ±0.5°C recorded by BUC between 2012-2013 and 2013-2014 seasons. Compared with the MAAT, the MARST values recorded at TPR site are on average 1.2°C warmer. This finding highlights the influence of the direct solar radiation, since the rock surface temperature is strongly heated on the south facing rockwall compared with the northern one.

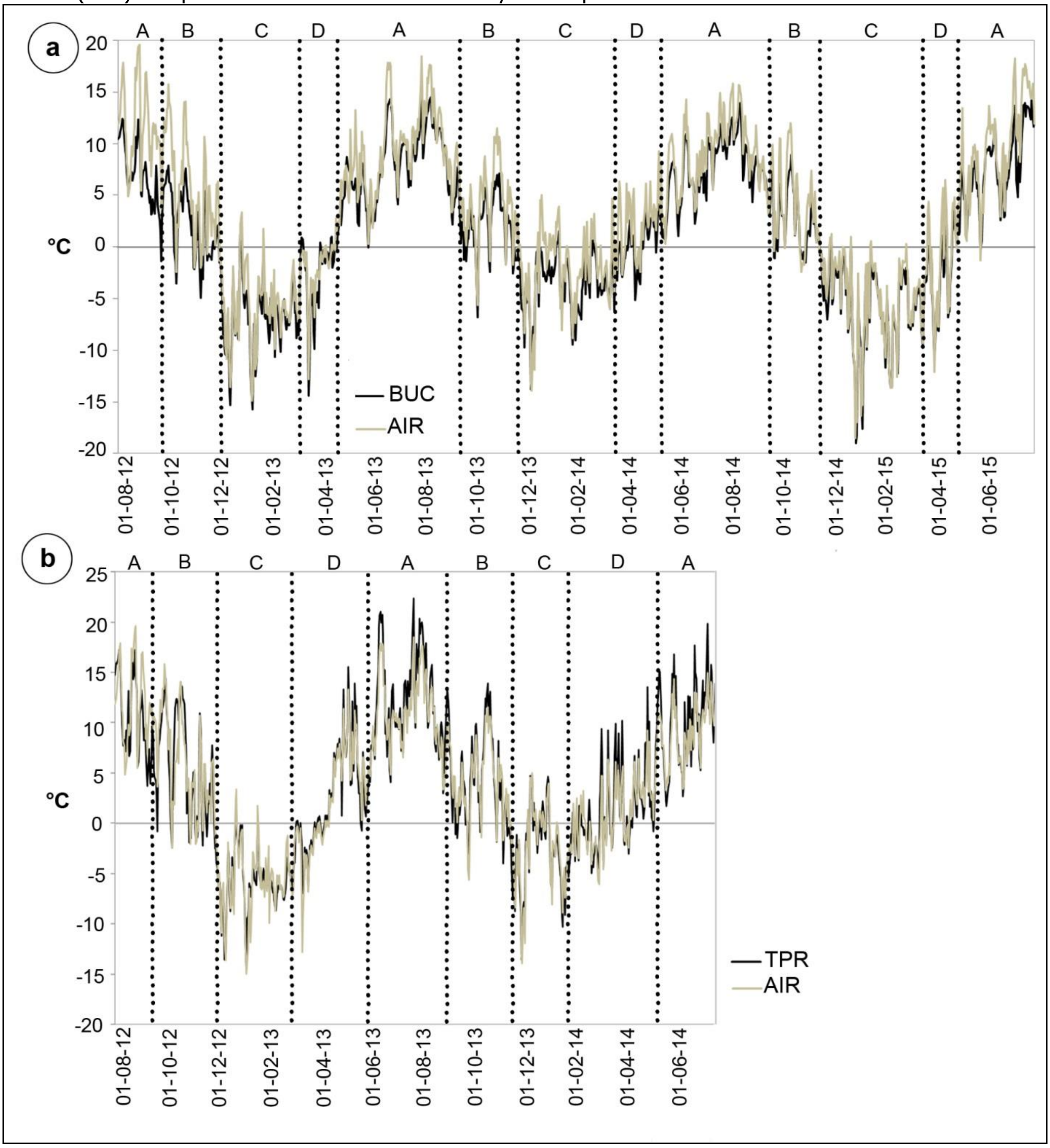

Fig. 2: Mean daily air and near surface rock temperature (a. BUC versus air; b TPR versus air)

Figure 2 gives an overview of the mean daily temperatures evolution on both investigated rockwalls during two and three year measurements period. The characteristics of the four distinct periods of the annual RST regime are discussed to emphasize the differences between the shaded location and the south facing one and the interactions with air temperature variations (Hanson and Hoelzle, 2004).

Table 3 Calculated MARST values for three different seasons

Sensor	MARST		
	2012-2013	2013-2014	2014-2015
BUC	1.4	1.9	1.3
TPR	2.9	3.9	-
AIR	1.7	2.8	2.1

The A period corresponds to the interval with positive temperatures during the summer, characterized by maximum insolation. The duration of this interval appear to be more extended in the case of TPR. Due to intense insolation the maximum mean daily temperatures on the southern rockwall exceed 22°C, whereas on the northern one the highest values reach 14.5°C. The A period of the 2013 summer appears to be considerably warmer than the corresponding interval of the other two seasons. Thus, the highest recorded temperatures were registered on the northern rockwall on 29.07.2013 (20.6°C), whereas in case of the TPR site, the maximum value was reached on 24.05.2014 (40.1°C).

The B period corresponds to the first interval with diurnal freeze-thaw cycles and begins with the first freeze-thaw cycle (in September) and lasts for 2-3 months. It appears to start earlier at BUC site, but it is more extended at the TPR site. The average temperature of this period ranges between 1.3 and 1.7°C at the BUC site and 3.6 and 3.8°C at TPR site. The lowest temperatures recorded during B period reached -10.6°C. At the end of this phase, a significant near-surface cooling was observed at both investigated sites.

However, the most intense cooling occurred either in December or January during the C period, also known as the seasonal/annual freezing. This phase starts at the end of November or beginning of December and lasts until the end of April or beginning of May. However, several thawing events, lasting 1 to 5 days may occur during winter, especially in the case of TPR. The average temperature of this period ranges between -3.6 and -5.8°C at the BUC site and -2.5 and -5°C at TPR site.

After this interval, in spring, there occurs a second period with diurnal freeze-thaw cycles. The amplitude of these freeze-thaw cycles is lower compared with the autumn cycles, but the frequency seems to be higher, excepting the first season. The lowest temperatures recorded in this period were registered by BUC (-7.6°C). The last cycles occur on 2.07.2013 and 4.07.2014 at TPR site, whereas in the case of BUC on 1.06.2013, 1.06.2014 and 28.05.2015.

Freeze-thaw cycles

At both sites the temperature regime at the surface of the rocks revealed short-term frost-thaw events and annual frost cycles. Overall, a greater number of freeze-thaw cycles were recorded by TPR sensor in both seasons (table 4). In case of the BUC thermistor two peaks (one in the autumn and the second one in the spring) with freeze-thaw cycles could be observed in all the three seasons. Generally, a decreasing of the freeze-thaw cycles occurs on the shaded slope during the winter months. However, during the 2013-2014 winter due to a great number of days with positive maximum air temperatures, 24 freeze-thaw cycles were recorded at the BUC site. The relatively warm 2013-2014 winter season is the main reason for the greater number of freeze-thaw cycles compared with the previous one. At both sites the number of freeze-thaw cycles increased by approximately 40% in 2013-2014 compared to 2012-2013. These findings highlight the great inter-annual variability of thermal characteristics at the rock surface in periglacial environment of the Southern Carpathians, as it was pointed out by similar studies (Rödder and Kneisel 2012; Onaca et al., 2015).

Table 4 Total number of freeze-thaw cycles and effective freeze-thaw cycles

	Total freeze-thaw cycles			Effective freeze-thaw cycles		
	2012-2013	2013-2014	2014-2015	2012-2013	2013-2014	2014-2015
BUC	62	88	61	41	51	29
TPR	102	143	-	55	104	-

During the 2012-2013 season, the evolution of the number of freeze-thaw cycles revealed a similar pattern at both sites, with slightly greater values on the southern facing slope of Turnu Porții. The following season the similarities between the behaviour of freeze-thaw cycles at both sites are not as pregnant as in 2012-2013 season. There were recorded more than 20 freeze/thaw cycles per month in December, February, March and April by TPR, whereas at BUC site the maximum was 19 in March. September is the only month when more freeze-thaw cycles were recorded by BUC in both seasons.

The monthly distribution of freeze-thaw cycles at both sites reveal that in the 2012-2013 there are little differences between the activity of the autumn freeze-thaw and spring freeze-thaw regimes, whereas during the following season the intensity of late-winter and spring freeze-thaw activity is considerably higher both at BUC and TPR (fig. 3). It

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **124-133***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.091.d***

is generally accepted that the efficiency of the winter and spring freeze-thaw cycles is greater than the autumn cycles due to a higher moisture content within the cracks.

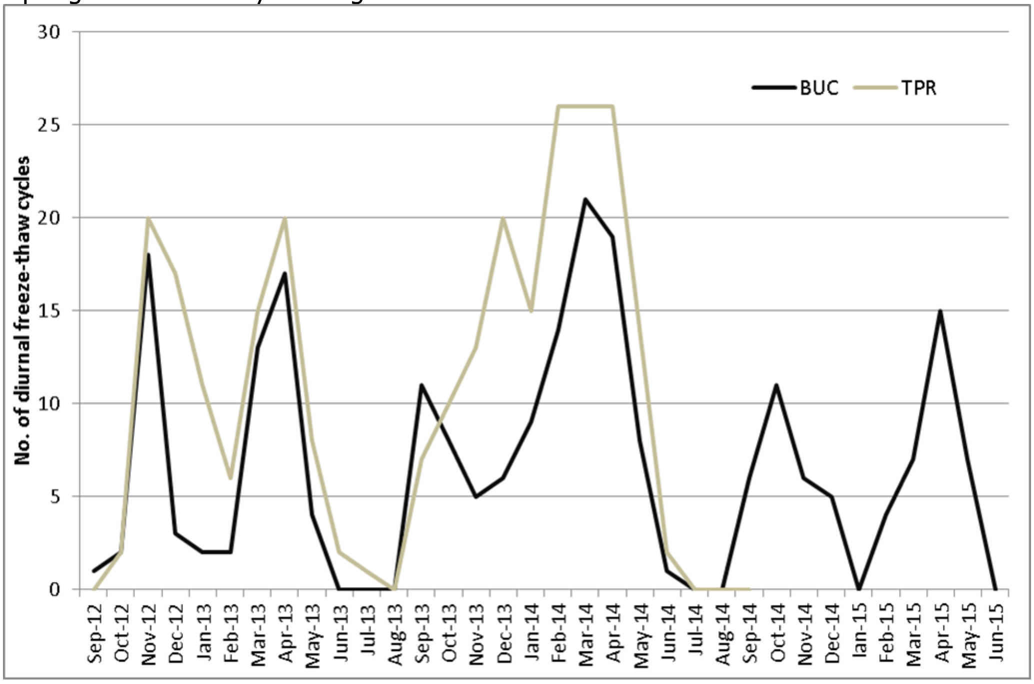

Fig.3: The monthly distribution of freeze-thaw cycles at BUC and TPR sites

In order to assess the effectiveness degree of each freeze-thaw cycle, we have calculated the diurnal superficial freezing index, described by Vespremeanu-Stroe and Vasile (2010). Thus, we have calculated the duration of each freeze-thaw cycle and the amplitude of the frost and considered effective freeze-thaw cycles only those reaching at least -2°C and not less than 12 h (Vespremeanu-Stroe and Vasile, 2010). In the case of BUC, we found that 66% from the total amount of freeze-thaw cycles were considered effective in 2012-2013 season, 57% in the second season and 47% in the last season. Despite the greater number of recorded freeze-thaw cycles in the case of TPR 55% were considered effective in 2012-2013 and 72% in 2013-2014 season. The monthly distribution of effective freeze-thaw cycles is revealed in fig. 4. It appears that more effective freeze-thaw cycles are possible to occur during the spring than during the autumn. The highest mean values of superficial freezing index related to freeze-thaw cycles are specific for the winter months and the beginning of spring.

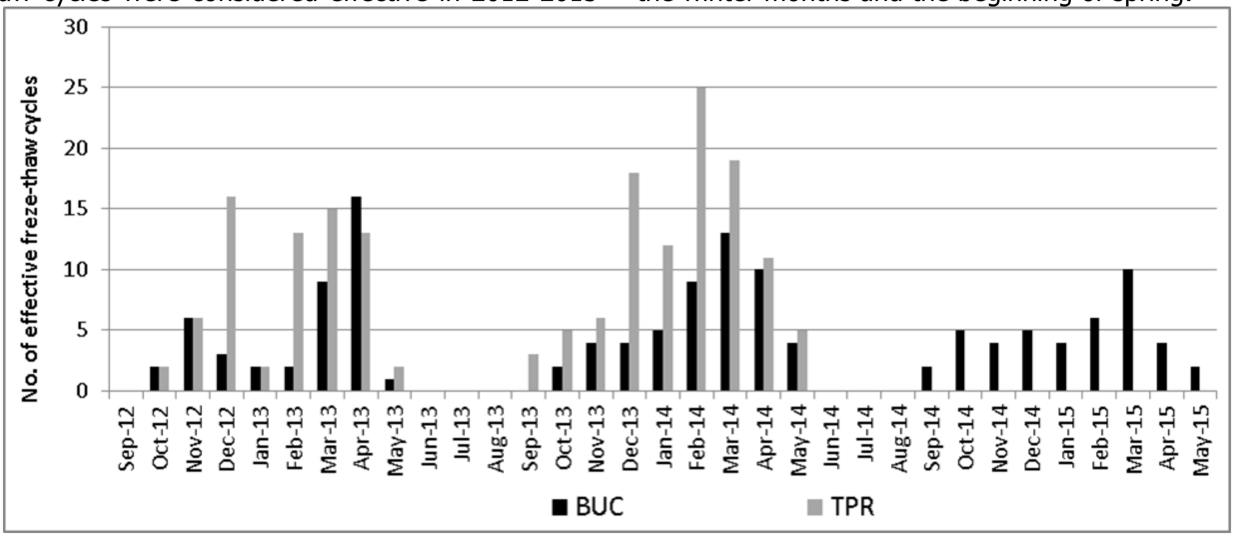

Fig.4: The monthly distribution of effective freeze-thaw cycles between 09.2012 and 05.2015

Seasonal freezing has a long duration (136 days at BUC and 121 at PRT) at both sites during the first season of monitoring, whereas in the second one it seems that it is much shorter at the rock surface, due to a great number of days with positive temperatures.

Considering the fractures pattern identified at both sites, the thermal stress should be a major cause of rock breakdown (Hall et al., 2002). Unfortunately, the resolution of our data is too poor to highlight the amplitude of this process. According to Murton (2007), thermal shocks are efficient when abrupt changes (≥2°C/min) in the RST values occur. The amplitude of the cracking is controlled by the magnitude and frequency of thermal stress episodes. However, diurnal/hourly thermal amplitudes are also used to get more information on the short-term temperature changes at the rock surface. In fig. 5 the evolution of daily amplitudes at both sites is displayed, revealing that on the south-facing rockwall the thermal stress is likely to be more effective. The maximum daily amplitude on the southern rockwall is much higher than on the north-facing location (e.g.: 13.6°C at BUC and 39.1°C at TPR). At BUC site, the daily amplitudes are generally below 10°C, whereas at TPR great variations may occur from one day to another.

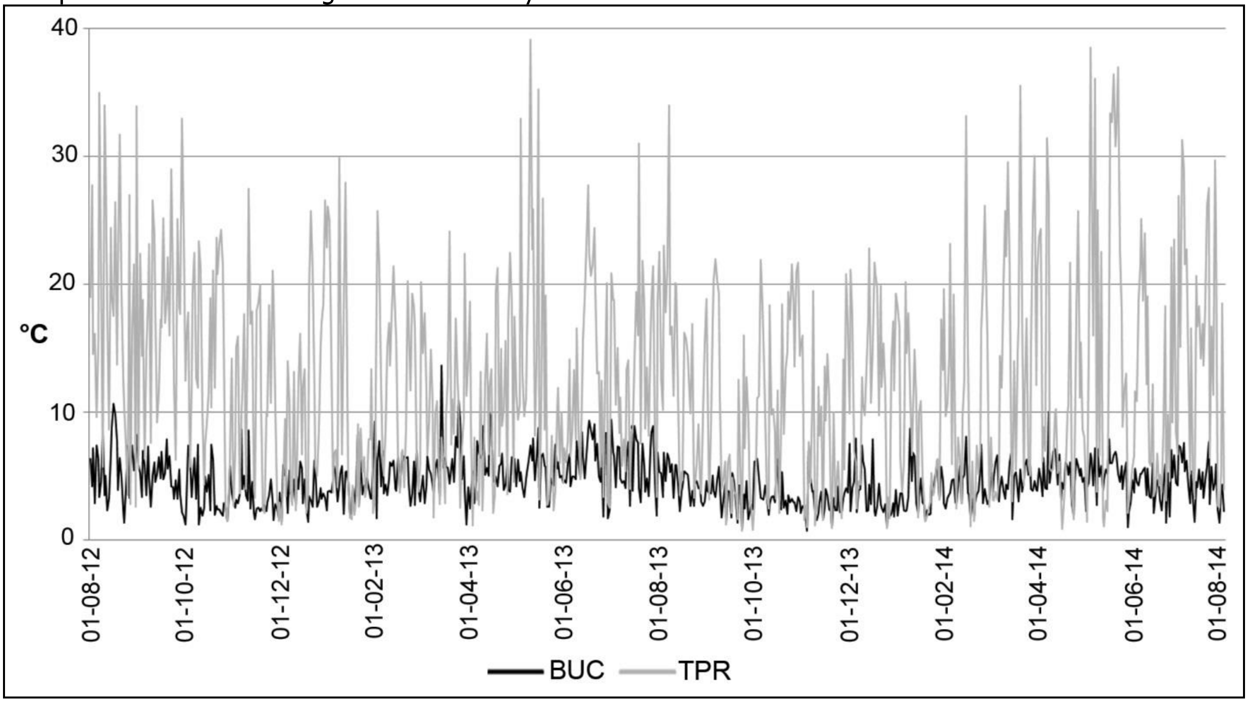

Fig. 5: The evolution of daily temperature amplitudes between August 2012 and August 2014

Permafrost conditions

Due to the absence of snow cover and high porosity boulders mantle, the thermal conditions at the surface of the rockwalls could be used as proxy data for permafrost occurrence. MARST is generally used to assess the certainty degree of permafrost occurrence in the substrate. According to the instructions suggested by the Permafrost Evidences Database (Cremonese, et al., 2011), the MARST values suggest a quite certain occurrence of permafrost, when values lower than -2°C are measured, whereas values of -2 to 0°C suggest that permafrost presence is quite likely. MARST values higher than 2°C indicate a quite certain absence of permafrost, whereas values of 0 to 2°C suggest that permafrost absence is quite likely.

According to this classification, neither of the two analyzed rockwalls fit into the permafrost presence category. Based on our findings, it seems that the MARST values recorded by BUC suggest a quite likely absence of permafrost, whereas the MARST values at TPR indicate a quite certain absence of permafrost.

Another possible indicator of permafrost occurrence in the rockwalls is the multiannual potential depth of freezing, which should be greater than the corresponding depth of summer thawing. To estimate these, we used the modified Berggren equation, which is also capable to estimate the depth to which frost weathering is operative (Matsuoka and Sakai, 1999), by applying the formula:

D = λ(2FiK/Lwρd)1/2,

where D is the depth of frost (m); Fi is the surface freezing/thawing index (°C h); K is the thermal conductivity of the rock (fixed at 1,5x104 Jm-1h-1K-1), L is the latent heat of fusion (fixed at

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 124-133
http://dx.doi.org/10.5775/fg.2067-4635.2015.091.d

3.34 x 105 J/kg); w is the estimated water content (fixed at 0.03%), ρd is the dry unit weight of rock (fixed at 2300 kg/m3), λ is the dimensionless correction factor estimated at 0.95 (Popescu et al., 2015).

The equation allowed computing the potential annual thaw depth of 5.2 m at BUC and 6.1 m at PRT, whereas the annual frost depth ranged between 3.4 m (PRT) and 4.5 m (BUC). These findings indicate that the investigated rockwalls experience seasonal frost/thaw penetration to 3-6 m in depth. These values seem to support the quite likely the absence of the permafrost at BUC and quite certain the absence of the permafrost at TPR. In the Parâng Mountains the potential depth of freezing is greater than the summer thawing above 2350-2400 m, where according to Popescu et al., (2015) permafrost is probably present in shaded rockwalls. This assumption seems to fit fairy well with our findings in the Retezat Mountains.

Discussion

The MARST values at the southern locations are 1.5-2°C higher than the shaded ones and these values are in agreement with similar findings from Swiss Alps, where on the southern slopes the mean annual temperatures were with 1-8°C higher, than on northern faces (Hasler et al., 2011). At the south facing site, direct radiation determined higher daytime temperatures in the early winter than at the north-facing location in both years. The contrasts between BUC and TPR thermal regimes revealed the effect of aspect, as reflected in the daily amplitudes of rock surface temperature in all the four distinct periods of the annual RST regime. Earlier studies showed very clear that the south facing slopes receives substantially greater solar heating than any of the other aspects (Hall, 2004), but the amplitude of the differences between north facing and south facing slopes may vary considerably from place to place. The northern exposed rock surfaces are warmed by indirect solar heating and rising in air temperature (Hall, 2004).

Due to long daily exposure to sunshine the south facing rockwall experienced more diurnal freeze-thaw cycles during the cold season compared to the north facing rockwall. There were 40 and 55 more freeze-thaw cycles recorded at TPR site than at BUC site. A similar situation was described by Onaca (2013) in the Muntele Mic Massif, where on the northern face of a periglacial torr at 1664 m there were recorded only 30 freeze-thaw cycles, with 53% less than on the south facing side of the rockwall. The effectiveness degree of freeze-thaw cycles on the southern rock face seems to be greater than in the case of BUC shaded location, supporting the assumption that nowadays the microgelivation appears to be more active on south facing rockwalls. This superficial frost weathering provides shallow, but intensive fragmentation of rock surface, producing fine debris (Matsuoka, 2001). Conversely, the macrogelivation, capable to provide large boulders occur only when the rock surface is strongly cooled for more than few days in optimal moisture environments (Matsuoka, 2001).

Because of the high inter-annual variability of RST regime, it is difficult to evaluate the influence of local conditions on rock surface temperature characteristics. To avoid misinterpretation, it is highly recommendable to monitor the evolution of rock surface temperatures for longer intervals. Also, a high temporal resolution of the sampling data gives the possibility to assess more carefully the amplitude of thermal stress episodes and the duration and amplitude of freeze-thaw cycles. In previous studies performed in the alpine environment of the Southern Carpathians, the thermal regime of rockwalls showed similar characteristics, but most of the studies only recorded the evolution of surface temperatures for one season. More than 100 freeze-thaw cycles/year were recorded at 2501 m in the Bucegi Mountains at one south-facing slope (Vasile et al., 2014), whereas in the Retezat Mountains, but on the northern rockwall of Turnu Porții, the total number of diurnal frost cycles was 24 (Vasile et al., 2014).

The number of freeze-thaw cycles on south-facing rockwall is very similar to the number of air diurnal cycles, whereas on the north exposed rockwall there are far fewer diurnal freeze-thaw cycles. However, the mean amplitude and duration of the freeze-thaw cycles on the southern rockwall are lower than the corresponding values recorded on the southern slopes. These findings bring more light into the role of aspect on MARST regime.

According to previous studies (Ikeda, 2006), it is not a simple task to place exactly the MARST boundary between the presence and absence of the permafrost, mainly because of great inter-annual variation in the RST regime and pronounced influence of thermal conductivity of different types of rocks. However, according to the „rules of thumb”, MARST values lower than 0°C indicate that permafrost is likely to occur in the substrate (Nötzli et al. 2003). So far, the permafrost occurrence in rockwalls in Southern Carpathians was assumed only in two cases. Onaca et al. (2013) previously pointed out that shaded rockwalls situated above 2200 m in Căldarea Pietroasa are likely to host permafrost, since subzero MARST were measured for two consecutive years (Onaca, 2013). In the Parâng Mountains, Popescu et al., (2015) placed the altitudinal boundary between permafrost presence and absence at 2350-2400 m. However, if these rockwalls correspond to a zone of permafrost and the MARST is higher than -1°C, the stability of the rockwalls could be extremely low, due to ice-filled joints melting out during the summer (Davies et al, 2001).

The existing MARST values recorded in the last few years in the Southern Carpathians at more than 2000 m are synthesized in fig. 6. Based on the classification suggested by the Permafrost Evidences Database (Cremonese, et al., 2011) we placed the RST points into the categories „presence” or „absence” of permafrost with differing degrees of certainty, as described earlier. This synthetically representation of the existing findings provides baseline information on assessing the certainty degree of permafrost occurrence in the substrate in different rockwalls (fig. 6).

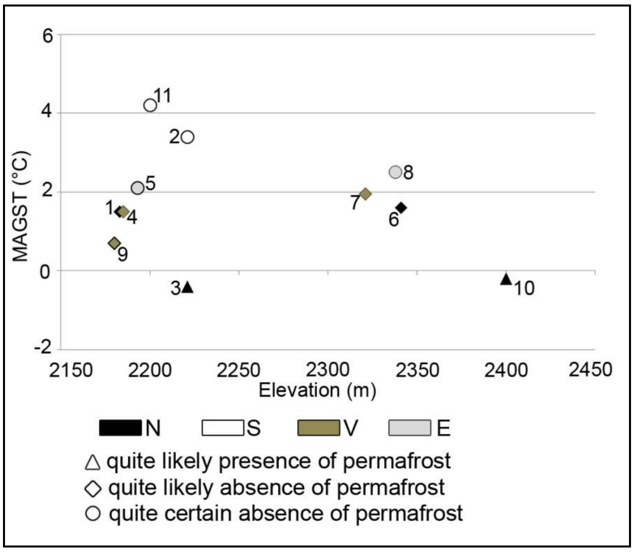

Fig.6: Classification of RST points into the categories „presence” or „absence” of permafrost with differing degrees based on MARST values (1. BUC; 2. TPR; 3. Pietroasa N; 4. Pietroasa W; 5. Pietroasa E; 6. Văiuga N; 7. Văiuga W; 8. Văiuga E; 9. Căleanu W; 10. Gruiu N; 11. Baba Mare S) (source: Onaca, 2013; Popescu et al., 2015; Vasile et al., 2014)

The relationships between the geomorphologic evolution of rockwalls above 2000 m, RST regime, permafrost occurrence, and climatic changes are extremely complex acting at various spatial and temporal scales. To elucidate the existing uncertainties, future approaches should consider assessing the influence of lithology, chemical and biological weathering, the role of thermal shocks, the depth at which weathering acts and the moisture distribution within the substrate. For fulfilling these goals long-term recordings of RST at different depths are required, as well as monitoring the seasonal rates of weathering, by quantifying the mass of dislocated materials. In addition, a better understanding of the role of rock properties (thermal conductivity, porosity, moisture content etc.) on RST regime and rockwalls destabilization would be extremely helpful.

Conclusions

The analyses of the rock surface temperature time series at two field sites in steep bedrock revealed the effects of site aspect on the characteristics of RST regime. The results demonstrated that considerable differences of annual mean temperatures, number of freeze-thaw cycles, the percentage of effective freeze-thaw cycles, daily temperature amplitudes, the potential depth of freezing/thawing may occur between the radiation-exposed face and the shaded rock face. For the south facing rockwall, the mean annual temperatures are with 1.5-2°C colder, but the total number of freeze-thaw cycles is larger. Based on our findings, we assume that due to a greater effectiveness degree of freeze-thaw cycles on the southern rock face, the microgelivation appears to be more active at the more sun-exposed location. The greater thermal amplitudes measured on the southern face support the assumption that here the surface of the steep bedrock is more exposed to intensive heating and the potential thermal stress is higher.

The positive MARST values recorded suggest the quite likely (in case of north facing site) and the quite certain (at the south facing location) absence of permafrost in the substrate.

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The North Atlantic Oscillation Influence on the Climate and Flow Variability of the Lower Danube Valley, between the Towns of Olteniţa and Călăraşi, Romania

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Abstract
As previous international research has identified, the large-scale NAO atmospheric circulation pattern dominates climate variability in the northern hemisphere**.** In this study we investigate the impact of the North Atlantic Oscillation (NAO) index on annual/winter precipitation and river flow regimes for a sector of the lower Danube Valley. An important goal was to test the relation between the NAO pattern and the occurrences of extreme events. We assume that precipitation variability and river flow are harder to assimilate into a modified anthropogenic environment as the situation of the Danube in the study area. During the communist regime, this valley sector was transformed from a wetland environment into a farming area.
Understanding NAO – rainfall and NAO – river flow relationships were based on monthly data in the time period between January 1977 and December 2010 for the NAO index, the river basin average precipitation over the Danube and the Danube river flow measured at Oltenita and at Calarasi Stations. Results showed that the large inter-annual variability in the precipitation regime and flows of the Danube is largely modulated by the NAO phenomenon. The four-time series in study are weak stationary, which means that the natural events vary moderately along a constant mean and the extreme events do not have the power to propagate, vanishing after few time steps.

Keywords: *NAO, Lower Danube Valley, precipitation, river flow, extreme events*

Rezumat. Influenţa Oscilaţiei Nord Atlantice la nivelul aspectelor climatice şi a variabilităţii scurgerii Dunării Inferioare între Olteniţa şi Călăraşi
Cercetări la nivel internațional arata că Oscilația Nord-Atlantica (NAO) influentează variabilitatea climatică în emisfera nordică. În acest studiu se investighează impactul indicelui NAO asupra regimului precipitațiilor și al debitelor fluviale anuale și hibernale pentru un sector al Văii Dunării Inferioare. Un obiectiv major este acela de a testa relația dintre direcțiile și modul în care variază NAO și apariția evenimentelor exteme in sectorul studiat. Ipoteza de la care pornim este aceea că un mediu puternic modificat antropic, precum este Dunărea în zona de studiu, care a fost transformată în perioada comunistă dintr-o zonă umedă într-o zonă agricolă, se adaptaza mai greu unor variatii mari. Înțelegerea relației NAO - precipitații și NAO - debit fluvial s-a bazat pe datele lunare ale indicelui NAO din perioada ianuarie 1977 - decembrie 2010, precipitațiile medii la nivelul bazinului Dunării și debitele Dunării măsurate la stațiile Oltenița și Călărași. Rezultatele arată că variabilitatea inter-anuală în regimul precipitațiilor și al debitelor Dunării este modulată de fenomenul NAO. Cele patru serii de timp analizate în zona de studiu sunt slab staționare, ceea ce înseamnă că evenimentele naturale variază moderat de-a lungul unei medii constante, iar evenimentele exteme nu au puterea de a se propaga, dispărând după o scurtă perioadă.

Cuvinte-cheie: *NAO, Valea Dunării Inferioare, precipitaţii, debite, fenomene extreme*

Introduction

Discovered since 1864, the North Atlantic Oscillation (NAO) climatic phenomenon in the North Atlantic Ocean has increasingly awoken the interest of researchers in recent years, through climatic influences entailed in the northern hemisphere. The majority of studies focus on the link between the variability of the North-Atlantic Oscillation and the diverse climatic parameters, such as: temperatures, precipitations, winds, droughts or phenomena related to snow, etc. (Bojariu 1997, Mareş et al. 2000, Bojariu and Gimeno 2003, Osborn 2006). Rîmbu et al. (2002), for example, indicate that NAO is responsible for the generation of large amplitude anomalies at the sea surface temperature, influencing the weather in the Northern hemisphere (temperatures, precipitations, wind speed). A positive NAO index indicates a low pressure in Iceland and a high pressure in the Azores and is associated with strong winds from the West, rain above the Atlantic and Europe and winters with high temperatures in Northern Europe and North-Eastern America. A negative NAO index determines zonal storms with the maritime air moving toward the Mediterranean and North Africa and winters, which are much colder than normal in Northern Europe and North-Eastern America (e.g., Hurrell, 1995, Hurrell et al., 2003, Rîmbu et al. 2001, Bojariu, 2002, Jurcău, 2012).

Grosfeld et al. (2007) show that warming of the North Atlantic, as was the case in 1860-1880 and 1940-1960, is related to the negative NAO phase, represented by a weak Icelandic low.

In contrast, the cooling of the North Atlantic, as was the case in 1905 - 1925 and 1970 -1990, corresponds to a NAO positive phase and a deeper than normal Icelandic low. Antunes et al. (2010) demonstrate, based on the analysis of the variability of the front atmospheric pressure at the level of North Atlantic, the existence of a cyclic phase of about 8-9 years between the positive and negative phases of NAO. Other studies focus on the correlation between NAO phases and river flows *(*e.g., Bouwer et al. 2006). Recent research has been looking at the influence of topography, human activities or NAO influence on ecosystems (e.g., Marshall et al. 2001, Bojariu 2002, Bojariu şi Giorgi 2005, Hurrell & Deser 2009).

At the European level, research on NAO's climatic phenomenon aims at both analysis and correlations for recent time periods (in recent decades) and for extended periods (referring to the last 150 years and as far back as 300 years) (Jones et al. 1997, Jurcău 2012).

In Romania, the interest in the NAO phenomenon has significantly increased after 1990 (e.g., Bojariu 1996, 2009; Rîmbu et al. 2002; Stefan et al. 2004; Rîmbu et al. 2004; Bojariu and Giorgi 2005; Bogdan et al. 2007; Cheval et al. 2010; Mareş et al. 2008, 2010; Manea et al. 2010; Lucarini et al. 2011; Nikolova and Boroneanţ 2011; Busuioc 2012; Nikolova et al. 2012; Sandu 2013; Busuioc et al 2014).

Regionally, most work addresses the southern part of Romania, focusing on the province of Southern Moldova (Mareş et. al, 2008), the Danube Valley and the Black Sea coastal area. The issue relates to variations in the climate (Bogdan et al. 2007, Bojariu 2009, Vespremeanu – Stroe et al. 2012)*,* river flows (Ştefan et al. 2004) and coastal dynamics (Vespremeanu –Stroe and Tătui 2011), with particular attention on the Danube in recent works such as Rîmbu et al. (2002, 2004), Pătruţ (2010), Mareş et al. (2008, 2009), Manea et al. (2010), Nikolova and Boroneanţ (2011), Pinto and Raible (2012).

In this paper**,** we assess the impact of the North Atlantic Oscillation (NAO) index on annual/winter precipitation and river flow regimes for the lower Danube Valley between the towns of Olteniţa and Călăraşi (Fig. 1). An important goal was to test the relation between the NAO pattern and the occurrences of extreme events in the study area. We used the NAO index defined by Jones et al. (1997) as differences in anomalies of the sea level pressure calculated from Gibraltar and SW Iceland.

We assume that precipitation variability and river flow, when considered as primary energy flows in fluvial systems**,** are harder to assimilate into a modified anthropogenic environment as the situation of the Danube between Olteniţa and Călăraşi. In this sector, after 1960**,** the authorities have resorted to creating a radical transformation of the floodplain from a wetland environment into a farming area with intensive and extensive agriculture. Sudden changes usually determined by NAO in precipitation and river flow have repercussions on the environment, especially on water resources and ecosystems, influencing the agricultural economy of the region. We presume that a rigid and un-adaptable environment created by cutting the coupling riverbed-floodplain (Fryirs et al. 2007, 2009), could accentuate extreme impacts. In addition, extreme events can have major environmental and economic consequences, as shown by recent floods in 2006.

Study area

The study area stretches from Olteniţa Town and the Argeş River in the West to the town of Calarasi and the Borcea branch of the Danube in the East. In the North, the floodplain is bordered by the Danube terraces. The contact is marked by the alignment of the localities Ulmeni - Spanţov - Mănăstirea – Dorobanţu – Ciocăneşti – Bogata - Race - Grădiştea - Călăraşi along the national highway DN31 (Fig. 1).

The relief heights are between 10 and 17 m, with an average altitude of 12.4 m. The morphometric data for the Danube floodplain are given in Table 1.

Until 1960**,** the Danube floodplain had a natural evolution. In this sector, the floodplain was up to 14 km wide West of Călăraşi; there were many large lakes, such as Iezerul Călăraşi, which was surrounded by smaller lakes and swamps (Fig. 2). In the twentieth century, and especially after 1960, the landscape was significantly changed due to human intervention for agricultural planning purposes.

The majority of the lakes were drained and only two have remained up to the present day.

In the sector analyzed in this study, the present annual precipitation value is around 500 mm / year, while the mean annual evaporation varies between 450 and 650 mm/ year (Rîmbu et al., 2002). Rainfall in the summer represents 30-35% of annual quantities, the spring rainfall 25-28%, the autumn rainfall 22 - 24%, and the winter rainfall about 20% of the total annual quantities (Nikolova, Boroneanţ, 2011). Vraciu (2007) recorded, in an environmental report for Călăraşi County, the frequency of arid years is very high. Excess rainfall and periods of droughts occur on large areas and for periods of between 2 to 3 years.

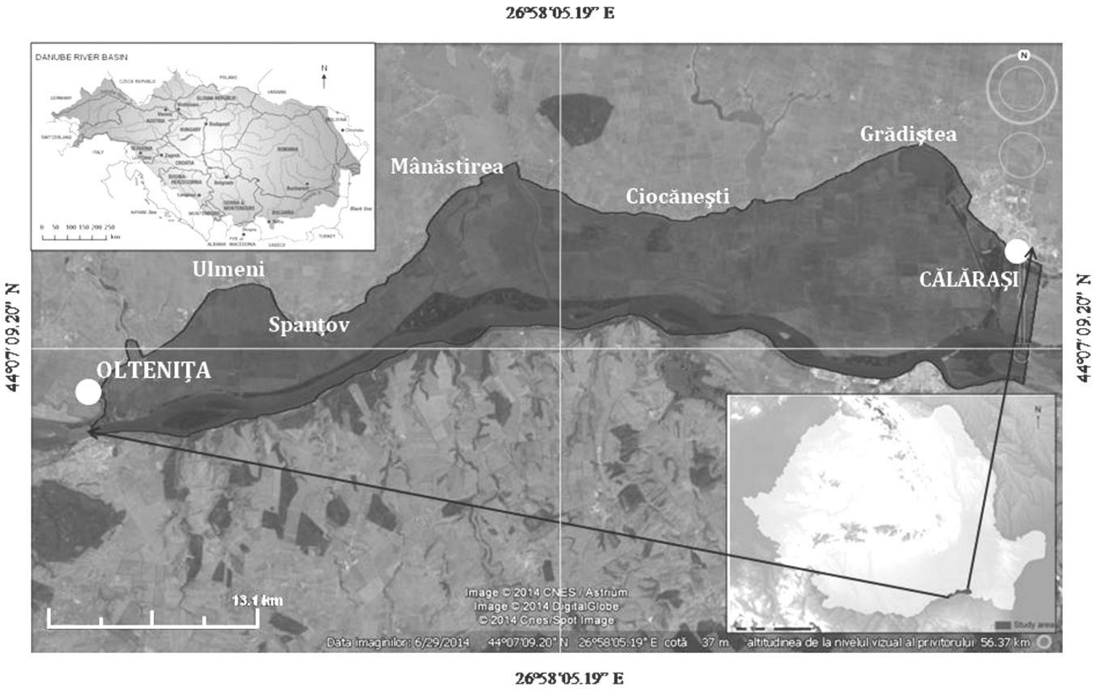

Fig. 1: Location of the Danube floodplain in the sector under study (Olteniţa – Călăraşi localities)

Table 1: Morphometric data

Floodplain	Surface (km^2)	Perimeter (km)	The maximum length (km)	The maximum width (km)	Minimum width (km)	Maximum altitude (m)	Minimum altitude (m)	The average altitude (m)
	421	157	58	13	3	22	6.3	12.4

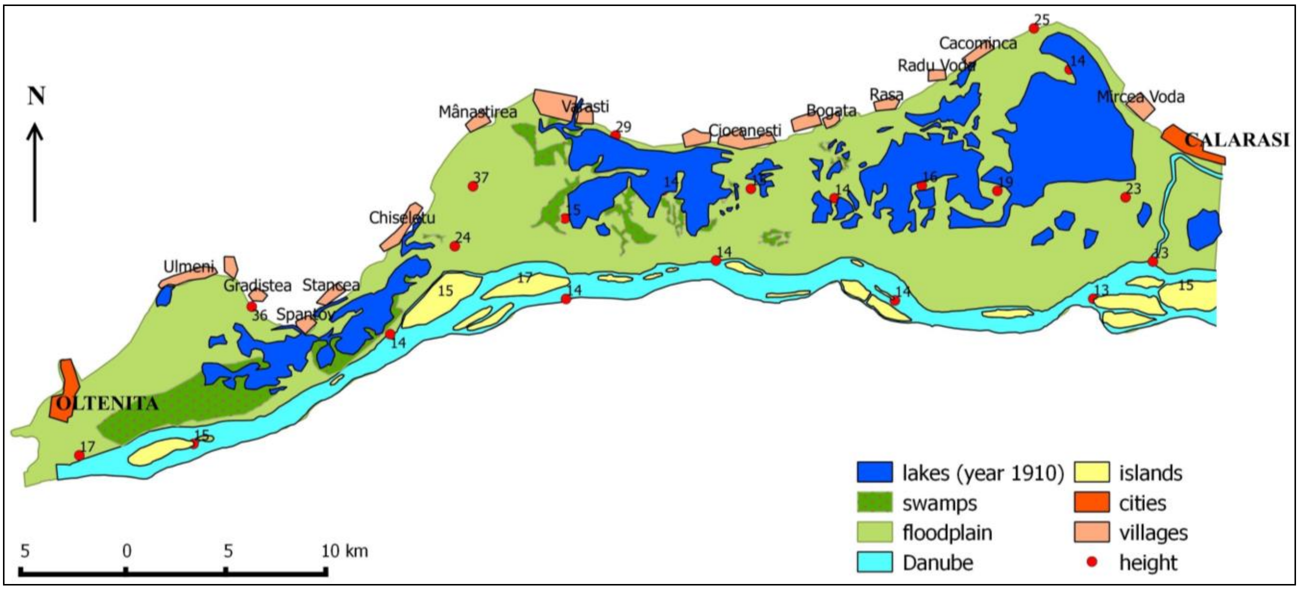

Fig. 2: Lakes in the Danube floodplain in the year 1910

The rainfall and the evaporation processes are main determinants of the Danube River flow. On the Romanian segment of the Danube, the flood flush occurrence is a frequent phenomenon in spring, summer and winter, but maximum flow reaches high values, especially during spring high water levels.

Scientific literature (Rîmbu et al., 2002, 2004; Mareş et al., 2009; Pătruţ, 2010) records the fact that the Danube flow in its lower basin tends to be lower than normal when NAO is in the positive phase and higher than normal when NAO is in the negative phase.

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Results

Complete Data Set

For this research, 4 time series were mainly used: the NAO index (nao), compiled by the Climate Research Unit of the University of East Anglia (http://www.cru.uea.ac.uk/cru/data/nao/), the river basin average precipitation (precip) over the Danube and the Danube river flow measured at Olteniţa (Olteniţa) and at Călăraşi (Călăraşi) Stations. We have monthly data for the time period between January 1977 and December 2010, which gives a total of 408 observations for each time series.

The first step in the study of our data set consists of a basic exploratory analysis. The graphic representations of the time series are illustrated below in figure 3 and the descriptive statistics are given in table 2.

The time series are seasonal and present no linear deterministic trend. From the Jarque Bera normality test, we observe that NAO variable follows a normal distribution while the other three do not, since they are left-skewed (the skewness is greater than zero) and leptokurtic (the kurtosis is greater than three). For the NAO index, the minimal negative value for the skewness denotes that the negative extreme events are more frequent that the positive ones, but this is insufficient to deviate significantly from the normal distribution, thus confirming the expected natural trend.

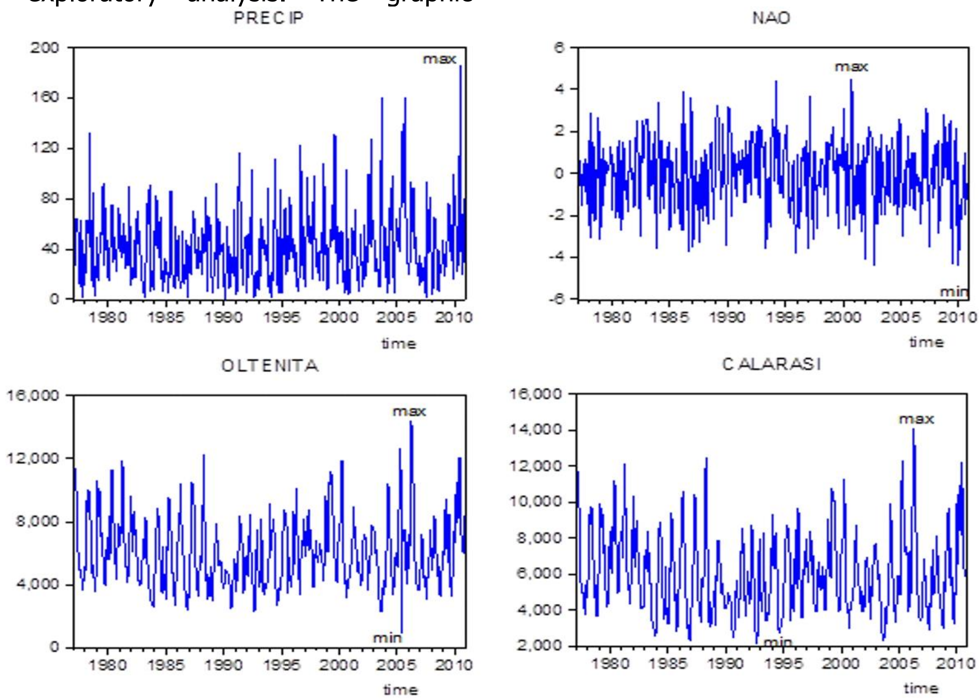

Fig. 3: Graphical representation of the 4 time series

When the distribution is left-skewed the standard deviation overestimates risk (extreme events), because extreme positive deviations from expectation increase the estimate of volatility. Conversely, when the distribution is negatively skewed, the standard deviation will underestimate risk.

In the case of the NAO index, the maximum and the minimum values were registered in October 2000 and December 2010, respectively. The maximum value for Precipitation time series occurred in July 2010. The maximum flow of the Danube River was observed in April 2006 and the minimum value in September 1992 for Călăraşi Station, and in April 2006 (max) and June 2005 (min) for Olteniţa Station. All these extremes are reflected in climatic or hydrologic events which will be described later in this paper.

Table 2: Descriptive statistics and normality test for the 4 time series

	NAO	PRECIP	OLTENIŢA	CĂLĂRAŞI
Mean	-0.025980	41.72181	6036.078	6018.409
Median	0.200000	37.70000	5715.000	5690.000
Maximum	4.500000	185.2000	14400.00	14083.00
Minimum	-5.500000	0.000000	960.0000	2170.000
Std. Dev.	1.715549	29.50766	2213.868	2217.623
Skewness	-0.218571	1.270456	0.712152	0.729369
Kurtosis	2.795227	5.409892	3.277359	3.183087
Jarque-Bera	3.961418	208.4849	35.79465	36.74448
Probability	0.137971	0.000000	0.000000	0.000000

Since the time series show some seasonality and volatility (at least graphically, ref Fig. 3) we have run some unit root tests in order to establish if the variables were stationary or not. This will help us to decide if the strength of the correlation between the NAO index and the other climate variables has changed over time (i.e. they are non-stationary).

We say that a time series, $y(t_1), y(t_2), \ldots, y(t_k)$, is weak stationary if the mean and the variance are constant and the covariance only depends on the lag and does not depends on time, that is:

$E(y_t) = \mu, \forall t$, $\operatorname{var}(y_t) = \sigma^2 < \infty, \forall t$ and $\operatorname{cov}(y_t, y_{t-k}) = \gamma_k, \forall t$.

In order to analyse the stationarity of a time series, a unit root test should be employed. The most common of which is the Augmented Dickey Fuller test (ADF), that is

$$\Delta y_t = \alpha + \beta t + \phi y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \varepsilon_t ,$$

Where the null is $H_0 : \phi = 0 \ vs \ \phi < 0$, that is, unit root (non-stationarity) *vs.* stationarity.

From Table 3 (ADF unit root test) we can observe that for each one of the time series, we reject the null for any significance level, since the t-statistics test is lower than the associated critical values. In consequence, all the time series are weak stationary.

In practice, weak stationarity means that the natural events vary moderately along a constant mean. The extreme events do not have the power to propagate over a period of time; instead they vanish after only a few steps. The hypothesis that the covariance is constant with time is advantageous for forecasting purposes.

We also estimate the correlation coefficients (Pearson) for the considered time series, in order to capture the linear relationship between variables (note that we can estimate these coefficients, since the time series are stationary and linear). Table 4 shows these values for the entire time period. As expected from the scientific literature, we observe a negative correlation between the NAO index and the precipitation time series and between the NAO and the Danube river flow. A positive linear correlation coefficient was obtained for the relation between precipitation and flow.

Figure 4 illustrates the monthly/seasonal behaviour of the four time series. In other words, a month is fixed (for example January) and we consider the values associated with this month in each one of the years. The same has been done for all other months. The red line highlights the mean value. We observe that the inverse (negative) correlation between NAO and precipitation is obvious again, since the lowest value of the NAO index, that occurs in June (in mean and seasonally), corresponds to the highest precipitations value, that occurs also in June (in mean and seasonally).

Table 3: ADF unit root test for the time series

		t-Statistic	Prob.*
Null Hypothesis: PRECIP has a unit root			
Augmented Dickey-Fuller test statistic		-16.10951	0.0000
Test critical values:	1% level	-3.446201	
	5% level	-2.868422	
	10% level	-2.570501	
Null Hypothesis: NAO has a unit root			
Augmented Dickey-Fuller test statistic		-18.55209	0.0000
Test critical values:	1% level	-3.446201	
	5% level	-2.868422	
	10% level	-2.570501	
Null Hypothesis: OLTENITA has a unit root			
Augmented Dickey-Fuller test statistic		-3.476341	0.0091
Test critical values:	1% level	-3.446608	
	5% level	-2.868601	
	10% level	-2.570597	
Null Hypothesis: CALARASI has a unit root			
Augmented Dickey-Fuller test statistic		-3.183647	0.0217
Test critical values:	1% level	-3.446608	
	5% level	-2.868601	
	10% level	-2.570597	

Table 4: Correlation analysis for the 4 time series for the period 1977- 2010

	PRECIP	NAO	OLTENIŢA	CĂLĂRAŞI
PRECIP	1.000000	-0.178866	0.192323	0.207223
NAO	-0.178866	1.000000	-0.065328	-0.071268
OLTENIŢA	0.192323	-0.065328	1.000000	0.980966
CĂLĂRAŞI	0.207223	-0.071268	0.980966	1.000000

The highest and the lowest flow values of the Danube River can be observed in April and September, respectively. The highest NAO index value is observed in March. From Figure 4, by comparing the highest values (in mean) of the Danube River flow, for both Olteniţa and Călăraşi Station (in April) and the highest NAO index values (in March, in mean), we can deduce that there exists a positive correlation between flow and lag one NAO index, that is, the effects of the NAO index are better reflected in the next months flow. The Precipitation time series assume the maximum in

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume XIV, Issue 2 (December 2015), pp. 134-147
http://dx.doi.org/10.5775/fg.2067-4635.2015.111.d

June, which means that in mean, June is the month with the highest precipitation quantity in the last 40 years. It follows also that February is the driest month of the year (in mean).

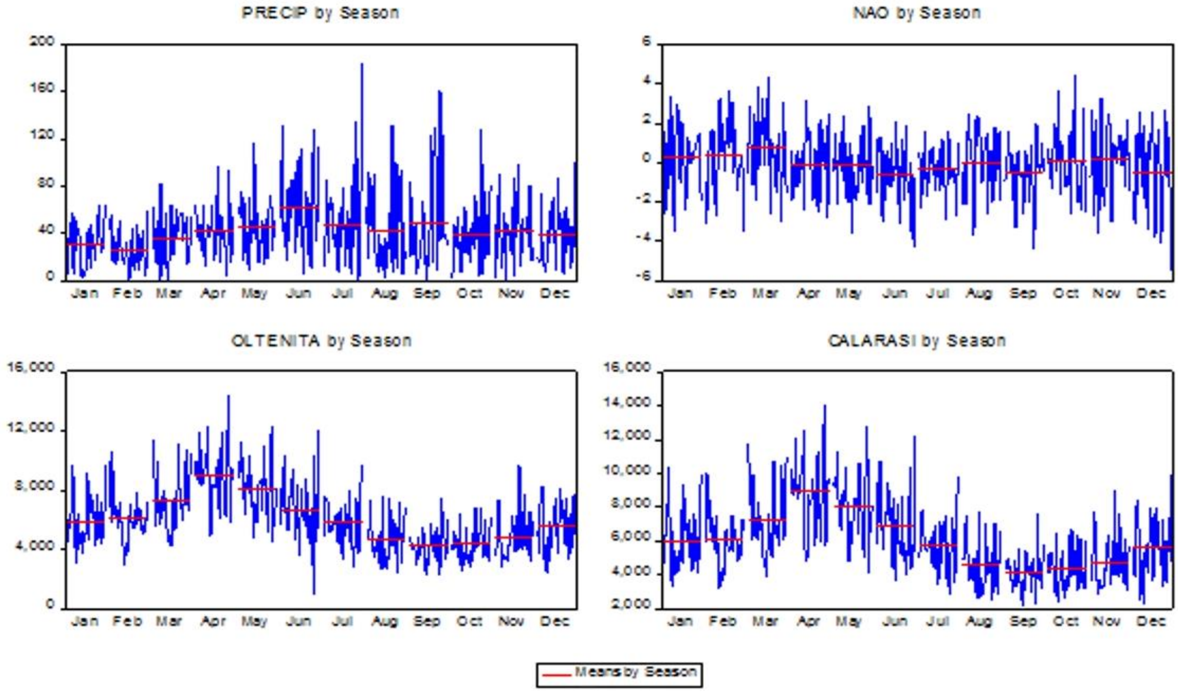

Fig. 4: Monthly / Seasonal behaviour of time series

Winter data set

Following on from this, the impact of the North Atlantic oscillation (NAO) will be assessed on winter precipitation and river flow regimes for the Danube River.

Under consideration is the data that corresponds to the winter season in the time period January 1977 - December 2010, which gives a total of 102 observations/time series. Of particular interest are the months December, January and February for the winter season. The time series in the study are presented in Figure 5.

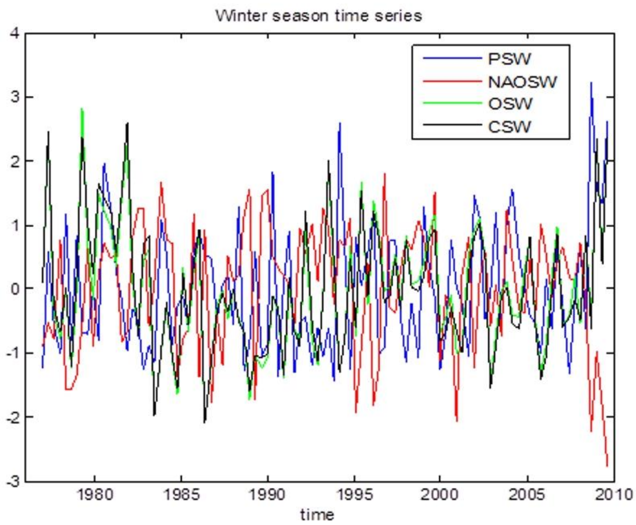

Fig. 5: Winter season time series

The data was standardized, dividing the difference between each time series and the associated mean by the corresponding standard deviation (the mean and standard deviation of each time series are presented in Table 2). The abbreviate names of the time series are: PSW – standardized precipitations for the winter season, OSW and CSW – the Danube flow measured at Olteniţa and Călăraşi stations standardized for the winter season and NAOSW – standardized NAO index for the winter season.

Results show that the large inter-annual variability in the flows of this river is greatly modulated by the NAO phenomenon. River flow tends to be lower (or higher) when the NAO index is in its positive (negative) phase.

Figure 6 illustrates each one of the time series and the standard deviation line. Of note are some extreme values that occur for the data in the study.

Table 5 shows the monthly correlation coefficient values between the NAO index, the river basin average precipitation and the flow of the Danube River, for the winter seasons. Once again, we observe a negative correlation between the NAO index and the precipitation time series and between NAO and the Danube River flow, with a higher value than for the entire time series. A higher positive linear correlation coefficient was obtained also for the relation between precipitation and flow, since other seasons were taken off.

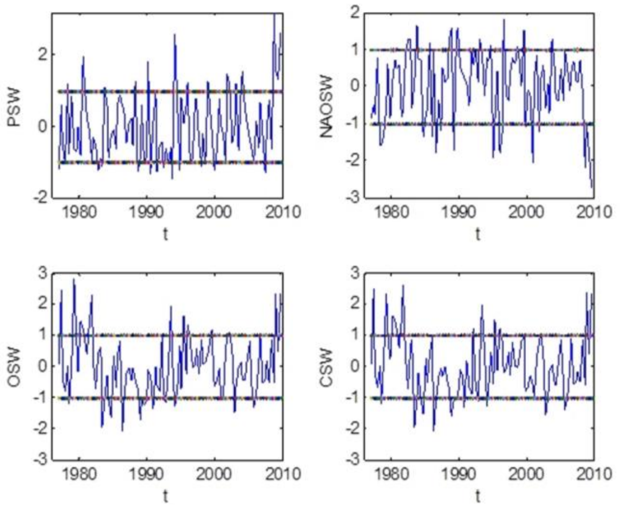

Fig. 6: Winter season time series and standard deviation

Table 5: Winter season time series correlation

	PSW	NAOSW	OSW	CSW
PSW	1	-0.3359	0.1953	0.2126
NAOSW	-0.3359	1	-0.0592	-0.0996
OSW	0.1953	-0.0592	1	0.9561
CSW	0.2126	-0.0996	0.9561	1

Analysis for the NAO extreme values in relation to extreme events

Following standard scientific literature procedure (see for example, Trigo et al. 2002), the extreme events representing high (low) NAO index conditions were produced using a monthly (not seasonal) criterion. Thus, extreme events were obtained by taking only those months where the NAO index is higher than the standard deviation +1 (high NAO) or those where the NAO index is lower than minus standard deviation −1 (low NAO). The number of months with low NAO index (71) is slightly greater than those characterized by a high NAO index (59), for the entire period considered. The remaining months (278) are characterized by `near-normal' values of the NAO index. Once again the variables were standardized. We proceeded in the same way in order to obtain the extreme events for Precipitation and Flow time series.

Table 6: Frequency of low and high values of the NAO index

Year	Low NAO	High NAO	Year	Low NAO	High NAO
1978	5	1	1995	4	2
1979	1	0	1996	4	0
1980	3	0	1997	5	1
1981	1	0	1998	1	0
1982	1	5	1999	2	2
1983	2	3	2000	3	2
1984	1	1	2001	3	0
1985	3	1	2002	3	4
1986	3	6	2003	2	1
1987	4	0	2004	1	3
1988	2	0	2005	1	1
1989	1	4	2006	2	1
1990	1	4	2007	1	2
1992	0	5	2008	2	1
1993	2	3	2009	4	3
1994	0	3	2010	5	0

A summary of the frequency of High and Low NAO values per year, for all seasons, is presented in Table 6 and illustrated in Figure 7 below.

We can observe an increasing trend for the negative extreme events and a decreasing trend for positive extreme events.

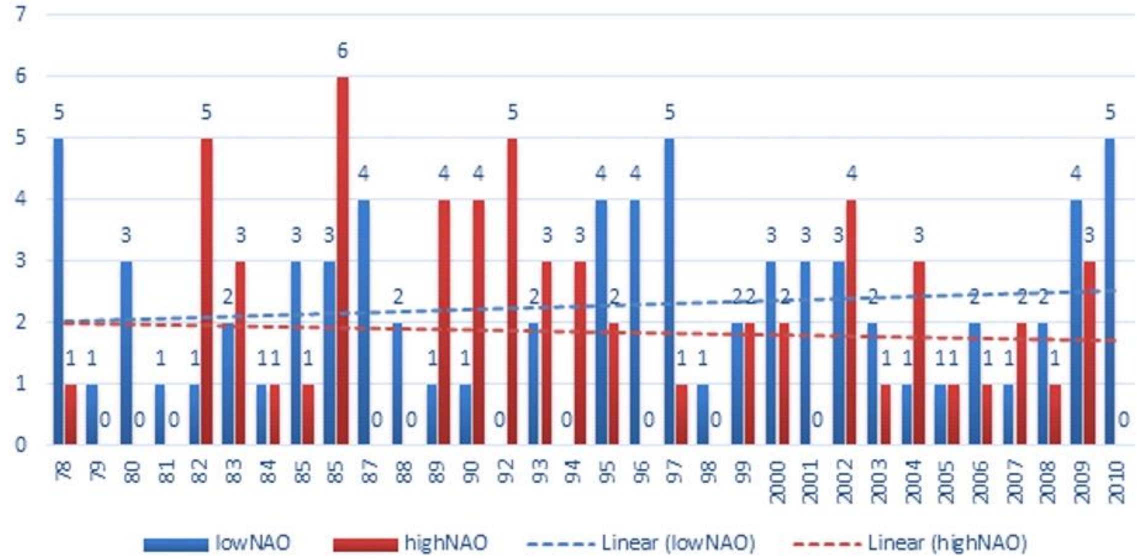

Fig. 7: Frequency of extreme events for the NAO index

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 134-147
http://dx.doi.org/10.5775/fg.2067-4635.2015.111.d

In the time period 1982-2003 there were the highest number of positive extreme events, namely 47 (in 59), which correlates to very dry years. The years 1986, 2002 and 2009 are characterised by the highest number of extreme events (high and low), respectively 9, 7 and 7.

Figure 8 illustrates the NAO index and the extreme events for the NAO index considering only the winter season. There are 17 low NAO and 16 high NAO index values. The remaining months (69) are near-normal. The inverse (negative) correlation between NAO and Precipitation extreme events time series can be observed. The minimum values for NAO corresponds to the maximum values of Precipitation time series, and inversely.

Below the common extreme events are analysed between NAO index and flow, and NAO index and precipitation, for the entire time period during the winter season.

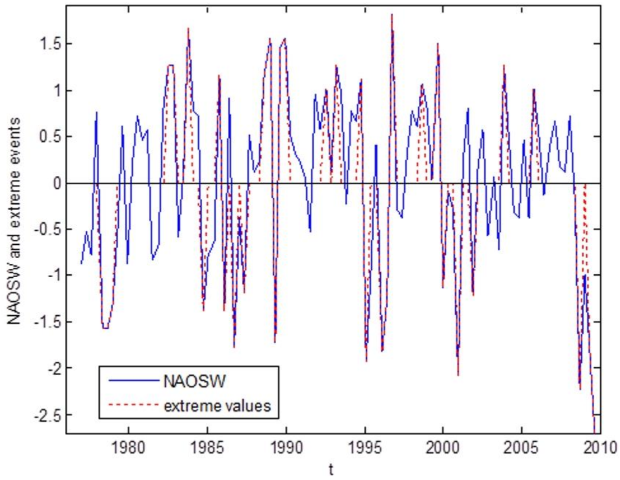

Fig. 8: NAO index and NAO extreme values for Winter Season

Figure 9 illustrates the common significant NAO index values and the extreme events for the precipitation time series in the period 1977-2010, for the winter season.

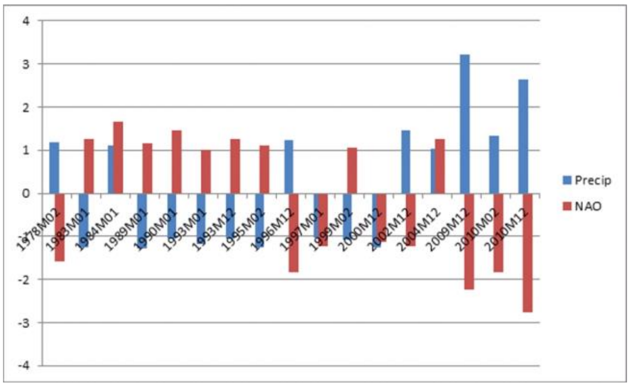

Fig. 9: NAO index and precipitation common extreme values

There are 9 high NAO and 7 low NAO values in common with extreme precipitation values. It can be observed that December is the month with highest precipitation quantity (and lowest NAO index, December, 2000, 2002, 2009, 2010) during winter and January is the driest one (January, 1983, 1984, 1989, 1990, 1993). A growing tendency in the quantity of precipitations is observed in most recent years. The negative correlation Pearson coefficient was evaluated in this case and takes the value -0.6721.

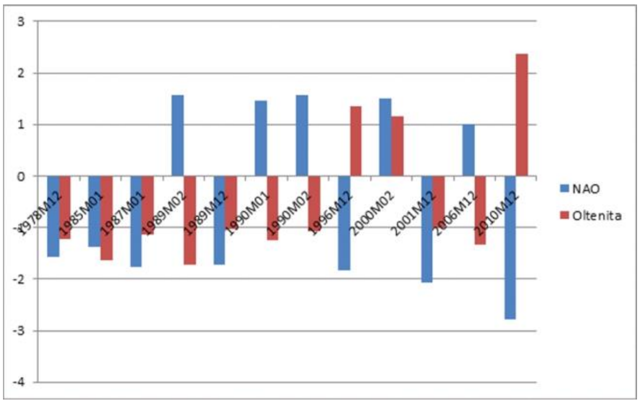

Fig. 10: NAO index and the Danube flow common extreme values

Figure 10 illustrates the common significant NAO index values and the extreme events for the flow time series (measured at Olteniţa station) in the period 1977-2010, for the winter season. There are 5 high NAO and 7 low NAO values in common with extreme precipitation values. A negative correlation can be observed between common extreme events for the flow and NAO time series, which was evaluated to -0.3093. The highest flow is in December 2010 which corresponds to the lowest NAO index. December of the year 1996 was also characterized by an extreme high flow of the Danube River. The other extreme values mostly show low flow of the Danube River. In particular, in February, 1989, was measured the lowest flow.

Extreme positive events between NAO and Precipitation

High NAO index and Precipitation Extreme Events can be observed in the following dates: 11-1978, 01-1983, 03-1983, 05-1986, 11-1986, 01-1989, 01-1990,03-1990,08-1992,11-1993, 12-1993, 06-1994, 02-1995, 02-1997, 02-1999, 10-2000, 02-2002, 04-2004, 08-2005, 12-2006 and are illustrated in Figure 11.

Figure 12 shows all High NAO values in the time period between 1978-2010, common and non-common, with extreme precipitation values measured in the same time period. It can be observed that the highest positive values of the NAO index frequently appear in March and October.

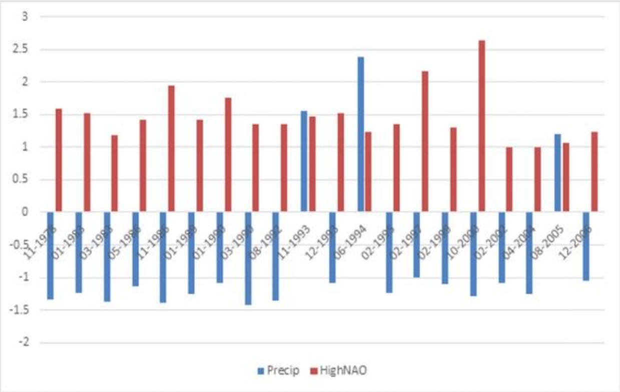

Fig. 11: Extreme precipitation and high NAO index

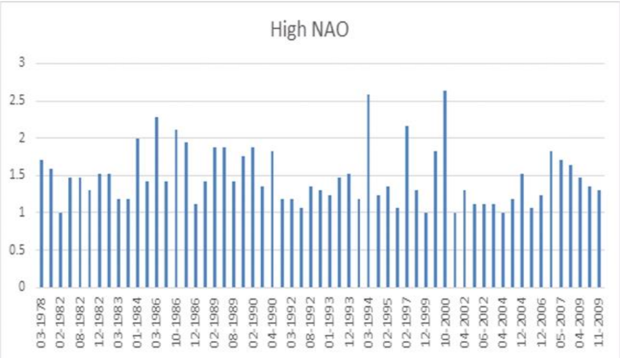

Fig. 12: High NAO index

This fact is emphasised in a study carried out by Manea & Nikolova (2010), which demonstrates that the driest months during 1961 - 1990, for the Lower Danube basin in its central segment (segment, which includes, Olteniţa - Călăraşi study area) are March and October.

From the analysis of specialist literature, the period 1982 – 1994, belongs to a period of intense drought (Nikolova, Boroneanţ, 2011; Sandu 2009, 2013). Nikolova & Boroneanţ (2011) specify the fact that this period of intense drought was confirmed by both by the Rainfall Anomaly Index (RAI) and the Index of Cumulated Anomaly of precipitations (the CA index). The authors' analysis reveals that the driest period was between 1982 and 2003. During these two decades, NAO was predominantly in a positive phase, recording the highest values in the following months: January 1984 (1.997 NAO), March 1986 (2.28846 NAO), December 1986, and a maximum value for this period was recorded in March 1994 (2.57992124 NAO).

Therefore, the graph shows that 2000 is the driest year for the lower Danube basin area, followed by 1992 and 1990 (Nikolova, Boroneanţ 2011; Busuioc et al. 2012; Sandu 2009). In 2000, the month of October, the NAO index being in a positive phase, had a value over 2.6 (2.63821 NAO).

The 2000 - 2003 interval it is also characterised by extremely dry years and the predominance of the NAO index in the positive phase, with few exceptions, namely in December 2001 and September 2002, when the NAO index is in the negative phase.

A study regarding the frequency of warm winters in the decade of 1999 -2009 carried out by Marinică et al. (2014), demonstrates the exceptions recorded in the above mentioned years.

Marinică et al. (2014) indicate that warm winter months were recorded in the following years: February 2000, February 2002 and December 2004. Comparing these situations with NAO index values a positive anomaly was observed in February 2000, when the index value was 1.89; in February 2002 and in the following months of April, May, June, when NAO was in a positive phase (e.g. the warm winter has brought a dry spring and in December 2004 the index was 1.53).

The winter of 2006 - 2007 was the warmest winter from the commencement of recording meteorological observations in Romania (Bogdan et al., 2007). In December 2006, the NAO index was in the positive phase (the value being 1.23) and will continue throughout 2007, without significant deviations.

Extreme negative events between NAO and Precipitation

Low NAO index and Precipitation Extreme Events can be observed in the following dates: 05-1980, 09-1983, 11-1983,03-1984, 06-1985, 04-1995, 06-1995,11-1995, 01-1997, 04-1997, 10-1997, 09-1998, 08-1999, 07-2000, 12-2000, 09-2001, 10-2002, 08-2003, 10-2004, 06-2009, 07-2009, 12-2009, 12-2010 and are illustrated in Figure 13.

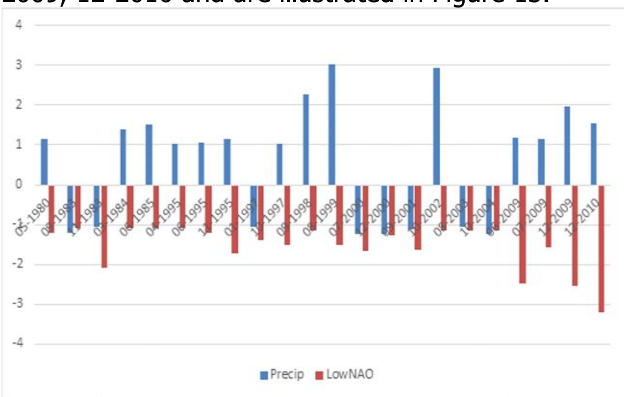

Fig. 13: Extreme precipitation and low NAO index

Figure 14 shows all Low NAO values in the time period between 1978-2010, common and non-common with extreme precipitation values measured in the same time period. It can be observed that the lowest negative values of NAO index frequently appear in May and December. June and August are also characterized by frequent low NAO values.

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **134-147***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.111.d***

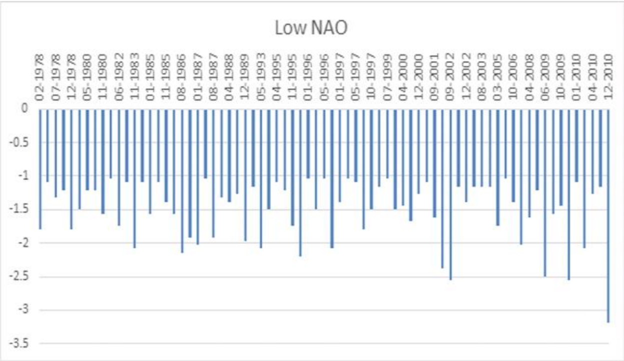

Fig. 14: Low NAO index

The period 1971 – 1980 is considered by many authors as being a period of high precipitation (Stefan 2004; Sandu 2009, 2013; Nikolova, Boroneanţ, 2011; Busuioc et al. 2012). Following the NAO values closely for the analysed sector, after 1994 (a year when the prolonged drought period came to an end) it was noted that the NAO index changed from the positive phase to the negative phase. Throughout 1995 and 1996, the NAO index would maintain a negative phase, with extreme values in December months, in December 1995 its value was -2.24, while in December 1996 its value was -2.12.

The situation pertaining to 1995 and 1996 is strongly related to an unusual event, both for the area and the entire country, according to Oprea (2012), when the blizzard from November 1995 marked the earliest date of winter commencement and lasted until 4/16/1996, when the last snow fell. The 1995-1996 winter registers a climatic record, being the winter with the longest continuous period of snow layer (in some parts of Romania this layer lasted for 170 days). This winter overlaps with the year of minimum solar activity, which favoured exceptionally well a long interval of snow on the ground. In the same month of November, 7 blizzards were recorded, which affected the entire country and proved to be a very unusual phenomenon for this month. The continuous layer of snow, which had become compacted and icy, affected 500 000 ha of crops in Romania.

Sandu (2009, 2013) and Nikolova şi Boroneanţ (2011) recorded 1997 as being an excessively rainy year. According to the standard values for 1997, for the study area, the NAO was in the negative phase for almost the entire year. Among the months of winter with cold weather (and negative NAO) Marinică et al. (2014) indicated the following: December 2001, as mentioned above, 2001 belongs to the period of arid years with the exception of one month - December, when NAO was in a negative phase and explained by the exceptionally high NAO negative value of –2.41; December 2002 falls also in the category of cold winter months, when in the study area, NAO's value is –1.41 (in the anterior months its value was -2.5, in September and in October was -1.18); During February and March 2005, NAO was also in the negative phase: -1.77 recorded in February 2006, followed by March, when NAO's values was -1.06.

2004, 2005 and 2006 registered as being extremely rainy years (Sandu 2009, 2013; Nikolova, Baroneanţ 2011; Busuioc 2012) are also years when NAO was in a negative phase. It should be noted that these years also experienced heavy rainfall which determined very destructive floods in the study area, as will be presented in the next sub-chapter.

The relation extreme NAO index and the Danube River flow

Figure 15 shows the common extreme values between NAO index and the Danube River flow measured at Olteniţa and Călăraşi Stations.

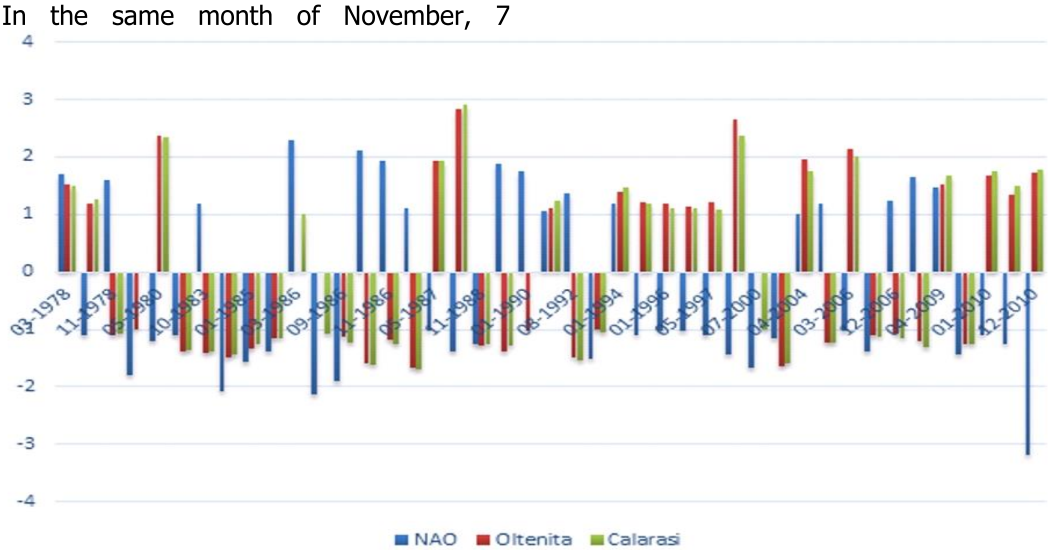

Fig. 15: Extreme flow and extreme NAO index

We computed the correlation coefficient and came to the conclusion that the extreme values of NAO index and Olteniţa (Călăraşi) flow are negatively correlated with a strength equal to -0.2264 (-0.1585). It therefore follows that high NAO is associated with low flow, and inversely. These relations are also revealed in literature for the Danube by Rîmbu et al. (2002, 2004).

In the study area, the highest flow was observed in May 1980, May 1987, April 1988, April 2000, March 2006, December 2010.

The beginning of the 1980s is characterized by heavy rainfall and a negative NAO phase, with flow rates exceeding values of 11,000 m^3 / s at both gauging stations. Extreme positive events were registered at Oltenita station in February, 1979, and at Calarasi in January, 1982, respectively.

During 1982 – 1993, a period which was predominantly dry and with NAO in a positive phase, the Danube flow rates between Olteniţa and Călăraşi were registering low values, with extreme negative events for both stations in December, 1986, with flows lower than 4000 m^3/s.

The years 2005 and 2006 were mainly in the negative phase of the NAO index, were marked by extreme phenomena (flooding) and unusually high flow rates over 10000 m^3/s.

The floods from 15 March to 30 June 2006 had the highest flow rate recorded in the period 1840-2006 (Fig. 16). The duration of the flash-flood was the longest from the entire period of historical data recording, having a probability of being exceeded once in 100 years (Sălăjan, 2010) (Fig.17). The maximum flow for the Olteniţa - Călăraşi sector was recorded on April 24, which is 15610 m^3 / s, and the maximum level of 737 cm.

The 2006 floods on the Danube were due to the prevailing meteorological and hydrological situation in the catchment area during the previous months (February, March, April), but also due to the sudden melting of snow in the upper and middle Danube basin from the last 10 days of March (Sălăjan, 2010). The largest levels of rainfall were recorded in the Western and central parts of the study area, exceeding 200 l / sqm and 140 l / sqm (Olteniţa - Ulmeni - Spanţov - Stancea - Chiselet - Mânăstirea).

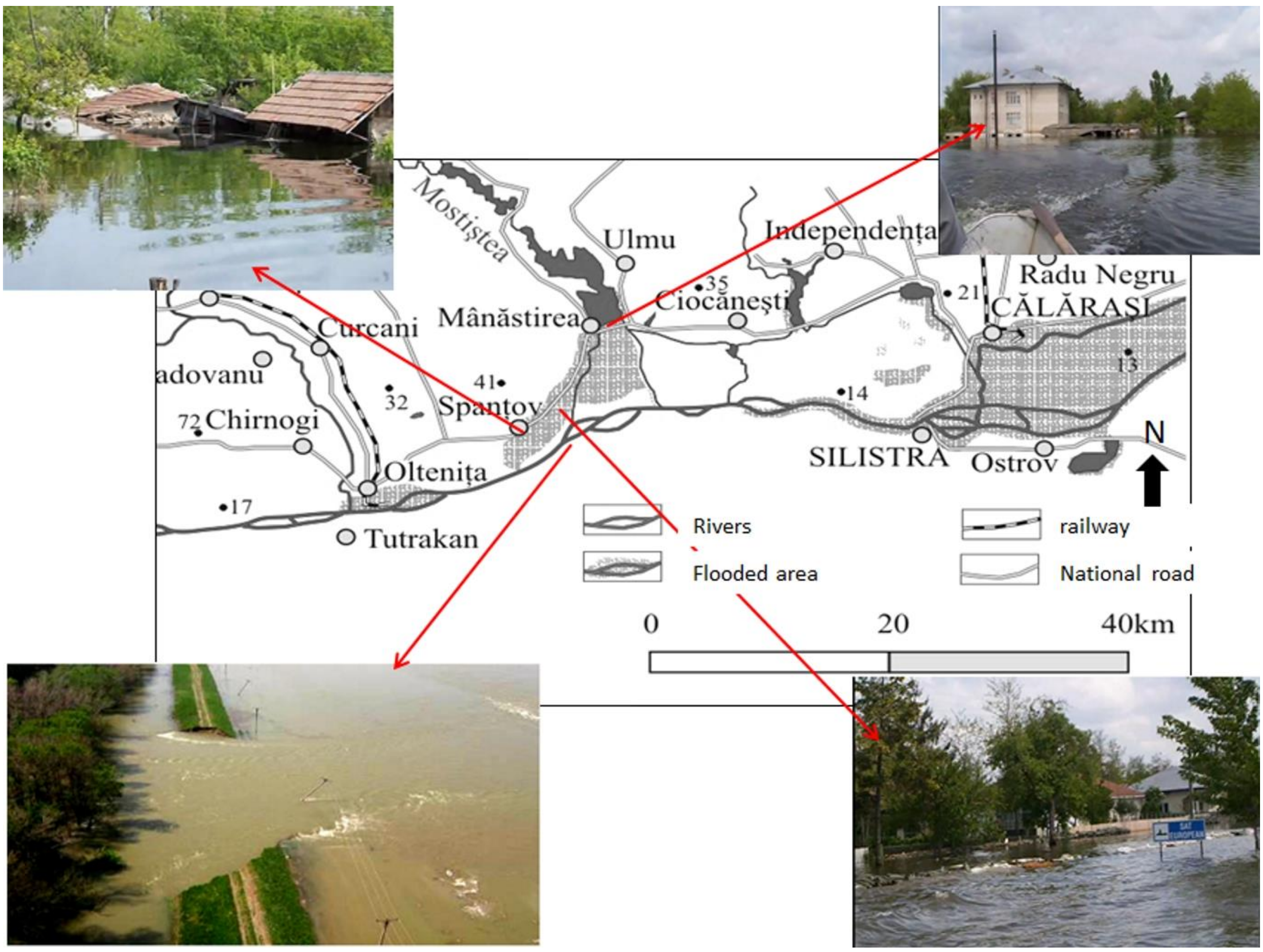

Fig. 16: Flooded areas in 2006

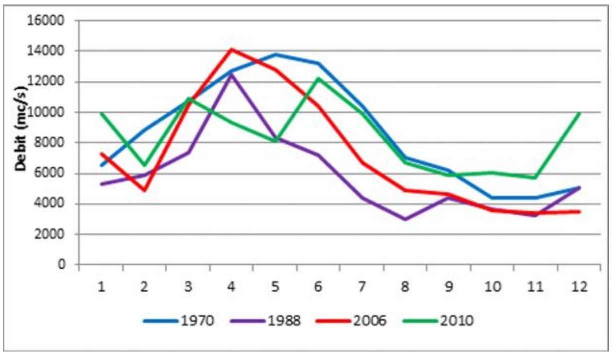

Fig. 17: Average monthly flow rates on the Danube at Călăraşi hydrometric station during the flood-flush of 1970, 1988, 2006 and 2010 (*Source: 1970 - Hydrological Yearbook of RSR, 1988 - INHGA, 2006 and 2010 - SGA Călăraşi*)

On the other hand, the winter of 2006 - 2007, being a milder winter registered since the beginning of meteorological data recording (Bogdan et al., 2007), was characterised by a low flow of 3488 m³ / s. The river water levels were below the lowest navigable water level between October and December.

Conclusions

The paper assessed the impact of the NAO index on annual/winter precipitation and river flow regimes for the lower Danube Valley between the towns of Oltenita and Calarasi, a sector which experienced major environmental changes after 1960, being transformed into a farming area.

The four time series in study (NAO index, the Danube flow at Calarasi and Oltenita Station, precipitations) are weak stationary, which means that the natural events vary moderately along a constant mean and the extreme events do not have the power to propagate, vanishing after few time steps. Extreme events were obtained by taking only those months where the NAO index is higher than the standard deviation +1 (high NAO) or those where the NAO index is lower than minus standard deviation −1 (low NAO). We can observe an increasing trend for the negative extreme events and a decreasing trend for positive extreme events, but no propagation in time of extreme events, respecting the weak stationarity property.

Results showed that the large inter-annual variability in the precipitation regime and flows of the Danube is largely modulated by the NAO phenomenon. On the one hand there is a direct correlation between dry years and warm winters with the positive NAO index phase, on the other hand there is a direct correlation between rainy years and cold winters with the negative phase of the index.

Understanding NAO – rainfall and NAO – river flow relationships will continue to be of interest in the light of human impact on the sensitive wetland environment of the Danube Valley and further studies will be needed to monitor these trends in the general context of climate change.

Acknowledgements

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Evaluation of rainfall extremes. Northeast and West coast regions of India as case study

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Abstract

The response of climate change is the increase in the frequency and intensity of extreme weather events. An attempt has been made to study the trends in heavy rainfall amount and the highest rainfall value in 24 hours over Northeast region (NER) and West coast region (WCR) of India with the period ranging from 1901-2009. A standard statistical analysis concludes that the majority of the stations in NER and WCR indicates increasing trend in annual and monsoon rainfalls. Further, the increasing trends in heavy rainfall were investigated and the associated synoptic conditions were identified. The study reveals that the increase in heavy rainfall over the WCR can be attributed to the synoptic systems namely monsoon trough, cyclonic circulation, depressions and lows.

Keywords: *climate change, monsoon rainfall, trend analysis, synoptic systems*

Rezumat. Evaluarea precipitaţiilor extreme. Studiu de caz: regiunile de coastă nord-estice şi vestice ale Indiei

Ca urmare a schimbărilor climatice, frecvența și intensitatea fenomenelor meteorologice extreme a crescut. Lucrarea de față își propune să analizeze tendințele în evoluția cantității de precipitații torențiale și a cantității de precipitații căzute în 24 ore în Regiunea Nord-Est și Regiunea costieră din vestul Indiei, în perioada 1901-2009. Analiza statistică standard indică faptul că la majoritatea stațiilor meteorologice din cele două regiuni există o tendință de creștere a cantității de precipitații anuale și musonice. Mai mult, tendințele de creștere au fost investigate, fiind identificate condițiile sinoptice. Studiul de față indică faptul că sistemele sinoptice, respectiv musonul, circulația ciclonică, ariile depresionare, contribuie la creșterea cantității de precipitații torențiale în Regiunea costieră din vest.

Cuvinte-cheie: *schimbări climatice, precipitații musonice, analiza tendințelor, sisteme sinoptice*

Introduction

One of the anticipated effects of climate change is the increase in the frequency and intensity of extreme weather events such as cyclones, floods and droughts, heat and cold waves, etc. Public awareness of extreme climatic events has increased in the recent years due to the media reporting catastrophic nature of floods, droughts, storms and heat waves or cold spells. Occurrences of extreme events claim thousands of lives as well as cause extensive damage to national and regional economy. Therefore, possible long term changes in the intensity of such events are of great concern notably in a country like India. About 70% of its population is agrarian; the impact of extreme weather event is a serious matter.

In India, the highest-ever-recorded rainfall in a day was reported at Cherrapunjee (Meghalaya) on the 15–16th of June in 1995 with the rainfall amount of 156.3 cm followed by 116.8 cm at Amini Devi on the 5–6th of May 2004. In Mumbai, on the 26-27th of July 2005, Santa Cruz (Mumbai) received a record-high of 94.4 cm rain. In this event, 927 people perished with loss and damage of property amounting to Rs. 450 crores (Tongdi et al. 2008). There is an alarming concern that extreme events may be changing in frequency and intensity as a result of human influences on climate (IPCC, 2007).

Trends in extreme rainfall days have decreased significantly throughout South Asia, Western and Central south Pacific (Manton et al. 2001). Several studies have revealed an increasing trend of extreme precipitation events in USA and Australia (e.g., Easterling et al., 2000; Haylock and Nicholls, 2000; Groisman et al., 2001; Kunkel, 2003), South-East Asia and Central Pacific (Griffiths et al., 2003). Haylock et al. (2006) have recently addressed the trends in extreme rainfall over South America and their links with sea surface temperatures. Moberg and Jones (2005) found significant increasing trend in extreme daily precipitation in Central and Western Europe while Klein Tank et al. (2006) reported increase in the amount on very wet days in central and south Asia. Recent regional studies on southern South America reported positive trends in the frequency of heavy rainfall (Re, 2009). Further, Choi et al. (2009) found significant trends in extreme precipitation events at fewer than 30 percent weather stations in Asia Pacific region.

Sen Roy and Balling (2004) found increasing trends in precipitation extremes over India. Francis and Gadgil (2006) reported that probability of intense rainfall events is high during mid-June and mid-August over the WCR. They established that organized convection over a large scale zonal belt, off-shore convective systems, mid-tropospheric cyclone (MTC) and an off-shore vortex were the

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features that caused heavy rainfall events. The orographic features over the west coast and northeast India, and the movement of synoptic scale systems from the Bay of Bengal region to the central parts of India (Sikka, 2006; Pattanaik, 2007) contribute to heavy rainfall events. In a warming environment there is a significant rising trend in the frequency and magnitude of extreme rain events over central India (Goswami et al. 2006). A study by Sen Roy (2009) reveal an increasing trend in extreme hourly precipitation over north-western Himalaya, Indo-Gangetic basin and northern parts of WCR. However, the southern west coast has been associated with a declining trend. Kishtawal et al. (2009) concluded that increasing trend in the frequency of heavy rainfall events over Indian monsoon region is likely where urbanization is faster. There is an increasing trend in heavy rainfall during summer monsoon (Ghosh et al. 2009) and its contribution to the seasonal rainfall shows significant increasing trend (Pattanaik et al. 2010). Guhathakurta et al. (2011) found decreasing trend in frequency of heavy rainfall events over major parts of central and north India while they are increasing in peninsular, east and north east India.

Looking at the extreme weather events, India stands prominently and has witnessed many such episodes. For a country that has more than 70% of its population relying on agriculture directly or indirectly, the impact of extreme weather event is critical. In India, a significant number of persons live on the bank of the rivers, low lying areas and coastal regions that are vulnerable to meteorological disasters. Furthermore, unplanned urbanization and growth of slums due to migration from rural to urban areas aggravate the problems. In the context of climate change, it is pertinent to ascertain whether the trends in heavy rainfall and the highest rainfall in 24-hour over these regions are also changing. Whether the extreme weather events are becoming more frequent or are region specific. In order to seek answers to the above-mentioned questions, it is necessary to examine the annual and monsoon extreme in rainfall over the study areas by using 26 stations during the last century.

Research Methods

In the NER, it was not possible to include a greater number of stations due to paucity of data series. As a result, two stations from the neighbouring state of West Bengal were included in this study. The daily rainfall data during the period ranging from 1901-2009 were acquired from the Indian Meteorological Department (IMD) Pune (Table 1.a, 1.b). There are two types of data; one data signifying the highest rainfall value in 24 hours in a month (26 stations) while the other data (16 stations) signifies the threshold amount of rainfall ranging from 6.5 to 12.5 cm, 12.5 to 25 cm and 25 to 9999.9 cm.

Table 1.a. Meteorological stations along with the data period (data period signifying the highest rainfall value in 24 hours in a month)

NER	Data period	Elevation (m)	WCR	Data period	Elevation (m)
Pasighat	1958-1992	157 m	Mumbai	1901-2006	11 m
Dibrugarh	1970-2000	111m	Alibag	1939-2002	7 m
Lakhimpur	1955-1992	102 m	Harnai	1970-2002	20 m
Tezpur	1939-1998	79 m	Ratnagiri	1901-2005	67 m
Guwahati	1903-2000	54 m	Panjim	1964-2003	60 m
Dhubri	1946-1993	35 m	Marmagoa	1970-2001	62 m
Silchar	1951-1993	29 m	Karwar	1915-2003	4 m
Gantok	1970-2000	1812 m	Honavar	1939-2002	26 m
Shillong	1903-2000	1500 m	Mangalore	1901-2001	22 m
Cherrapunjee	1903-2000	1313 m	Calicut	1901-2000	5 m
Imphal	1954-1998	781 m	Cochin	1970-2000	3 m
Kailashahar	1959-1996	29 m	Alleppey	1944-2000	4 m
Agartala	1970-2000	16 m	Trivandrum	1901-2004	64 m

Table 1.b. Meteorological stations along with the data period (data period signifying heavy rainfall ranging from 6.5 - 12.5, 12.5 - 25 and >25 cm)

NER	Data period	Elevation (m)	WCR	Data period	Elevation (m)
Agartala Aero	1953-2005	14 m	Bombay Coloba	1901-2006	4 m
Cherrapunjee	1902-2005	1313 m	Bombay SC	1950-2006	11 m
Mohanbari Aero	1949-2005	110 m	Karwar	1882-2005	4 m
Gantok	1971-2005	1812 m	Ahmadabad Aero	1901-2006	53 m
Alipur	1901-2005	14 m	Ratnagiri	1901-2006	67 m
Dumdum	1951-2005	11 m	Trivandrum	1901-2005	64 m
Guwahati	2003-2005	54 m	Trivandrum Aero	1955-2005	4 m

Note: Aero-aerodrome, SC-Santa Cruz

The extreme value has been computed focusing on monsoon season and annual scales. In order to determine the trend, linear regression coefficients and Student's t-test was applied to find out its significance at 0.05 and 0.01 level. Time series were plotted for the entire record.

Linear regression has been used by various climatologists (Sen Roy and Balling, 2004; Ali et al., 2007) for studying the rainfall and temperature patterns. This method (linear trend), i.e., the slope of the simple least square regression line with time as the independent variable, is found to be very useful in studying the secular trend in rainfall and temperature data. This is a simple model which is expressed in the form of an equation:

$$Y = a + bx$$

Where:
- Y is the dependent variable
- a is the intercept
- b is the slope or regression coefficient
- X is the independent variable (or covariate)

The equation will specify the average magnitude of the expected change in Y given a change in X. Statistical significance was determined by the t-test in the following way.

$$t = \sqrt{\frac{r^2(\mathrm{N}-2)}{1(1-r^2)}}$$

Where 'r^2' is squared correlation coefficient and 'N' is the number of observations. The obtained value of 't' is compared with its table value. If the computed value is greater than table value at the desired level of significance then the correlation is significant. The results are presented in the forthcoming paragraphs.

In the light of the above discussions two extreme regions in the country namely the west coast and northeast region of India (Fig. 1) have been selected to study the trend in extreme rainfall. These two regions have some unique physical characteristics different from the rest of the country. Both regions have rugged terrain, receiving copious rainfall but vary in distribution patterns. More than 80% of the rainfall over the west coast is concentrated during the four months of the southwest monsoon while for northeast 25% of the annual rainfall occurs from March to May and 65% during the south west monsoon period. There is a general increase in precipitation with altitude in northeast region while precipitation in west coast region increases from the coast towards the interior. The mountain ranges of the northeast (Himalayas, Meghalaya plateau and Purvanchal ranges) and the west coast regions receive heavy rainfall due to the orographic effect. Both regions receive mean annual rainfalls of more than 100 cm. With this in view, an attempt is being made to investigate the changing patterns of this climatic element over these two regions.

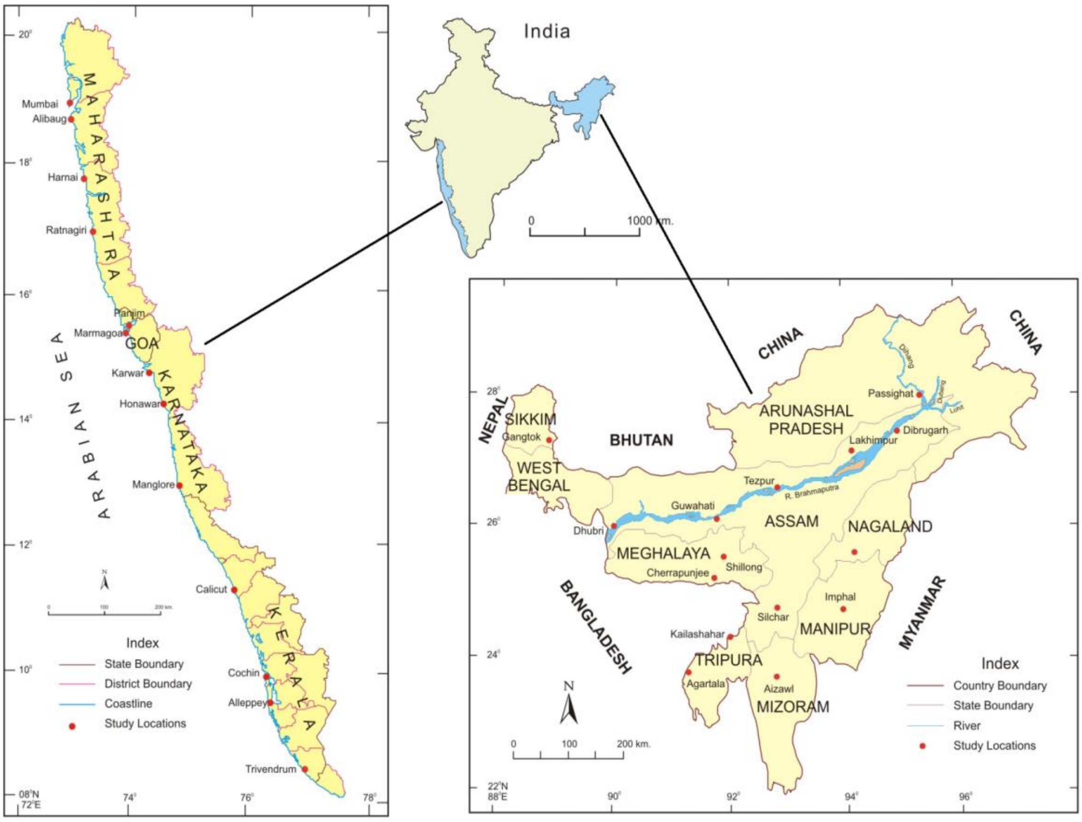

Fig. 1: Study Area

Source: Jamir et al., 2015, Geoadria, 20/1, 1-11

Results

Trends in extreme rainfall (6.5 - 12.5 cm, 12.5 - 25 cm and >25 cm)

The trends in the extreme rainfall for the study regions are shown in Table 2. Therefore, to assess long-term trends, heavy rainfall events that exceed certain thresholds for 7 stations representing the NER were used.

Table 2 Trends in heavy rainfall

Stations	6.5 to 12.5 cm		12.5 to 25 cm		25 to 9999.9 cm	
NER	**Annual**	**MON**	**Annual**	**MON**	**Annual**	**MON**
Agartala Aero	**-1.428x**	**-1.574x**	**-0.703x**	**-0.673x**	~	~
Cherrapunjee	**-4.586x**	**-4.147x**	**3.427x**	0.575x	**7.039x**	**5.752x**
Mohanbari Aero	**1.776x**	**1.956x**	**1.073x**	0.117x	~	~
Gantok	**5.667x**	**1.956x**	~	~	~	~
Alipur	**1.042x**	**0.716x**	**-0.526x**	**-0.741x**	~	~
Dumdum	**2.032x**	0.148x	**1.288x**	**1.046x**	~	~
Guwahati	**0.743x**	**0.148x**	**0.261x**	**0.155x**	~	~
WCR						
Bombay Coloba	**1.689x**	**1.774x**	**1.542x**	**1.411x**	**1.119x**	**1.119x**
Bombay Santa Cruz	**-1.701x**	**-1.934x**	**-0.285x**	**-1.188x**	0.585x	0.585x
Karwar	**4.609x**	**4.165x**	**0.736x**	**0.621x**	0.048x	0.048x
Ahmadabad Aero	**0.617x**	**0.533x**	**0.257x**	**0.144x**	~	~
Ratnagiri	**2.667x**	**2.541x**	**2.969x**	**2.912x**	**0.737x**	0.162x
Trivandrum	0.069x	**0.384x**	**-0.206x**	**-0.291x**	~	~
Trivandrum Aero	**0.814x**	**0.703x**	~	~	~	~

Note: MON-monsoon, Aero-aerodrome, ~-few occasions; Bold-significant

From the above table, it can be concluded that, for the NER, there is a significant increase in rainfall at Mohanbari Aero, Gangtok, Alipur, Dumdum and Guwahati. However, two stations namely Agartala and Cherrapunjee show significant decrease in rainfall. The rate of increase in annual amounts varies from 5.66 cm/year at Gangtok to 0.74 cm/year at Guwahati. While the rate of decrease ranges from -1.42 cm at Agartala Aero to -4.58 cm at Cherrapunjee. Further, the study was extended to examine, whether the contribution of monsoon rainfall to annual shows any significant trend. The results suggest that the increase/decrease during the monsoon seasons except for Dumdum is not significant. The rate of decrease during the monsoon season is high at Cherrapunjee (-4.14 cm/year) whereas the maximum rate of increase is observed at Gangtok and Dibrugarh Aero (1.95 cm/year).

Whereas, for the WCR (Table 2), the stations - Bombay Coloba, Karwar, Ahmedabad Aero, Ratnagiri and Trivandrum Aero indicate significant increase in rainfall. The same situation is noticed during the monsoon season also. However, Bombay-Santa Cruz shows significant decrease in annual amount as well as during the monsoon season. The rate of increase in annual amounts varies from 0.06 cm/year at Trivandrum to 4.6 cm/year at Karwar. Among the stations selected for this study only Bombay Santa Cruz show decrease at the rate of -1.70 cm/year. During the monsoon season, the rainfall varies from -1.93 cm/year at Bombay Santa Cruz to a high of 4.16 cm/year at Karwar. Thus, it can be said that maximum stations experiencing significant increasing trend in rainfall for both regions during annual as well as monsoon season. The increase in rainfall over the NER and WCR is consistent with Sinha Ray et al. (1999), on their study on frequencies of heavy rainfall > 7cm show increasing trend in the WCR. Our findings are also in agreement with Sinha Ray and De (2003); Sen Roy and Balling (2004). Among the stations in the NER used for the study of heavy rainfall trend only Agartala Aero and Cherrapunjee show significant decrease in rainfall. The decrease in rainfall shows similarity with the finding of Sontakke and Singh (2001), their study concluded that there is a decreasing trend in monsoon rainfall at Cherrapunjee. The summer monsoon rainfall was decreased by 8 mm/year significant at 10% level. Similarly, orographic lifting over the northeast parts of the country causes heavy rainfall events over the region (Rao, 1976).

For the trends in extreme rainfall of 12.5 cm to 25 cm in the NER (Table 2), the stations Mohanbari Aero, Alipur, Dumdum and Guwahati report significant increase in annual rainfall while during the monsoon season it is not significant at Mohanbari Aero. Only one station viz., Agartala Aero shows significant decrease in annual and monsoon rainfall. The rate of increase/decrease in annual amounts varies from -0.70 cm/year at Agartala Aero to 3.42 cm/year at Cherrapunjee. During the monsoon season, the rainfall rate range from -0.67 cm/year at Agartala Aero to 1.04 cm/year at Dum

Dum. Gangtok rainfall data was insufficient and hence it was not used. The rainfall above 25 cm for the NER reveals that, Cherrapunjee reported significant increase in annual and monsoon rainfall, the rest of the stations reported less rainfall amount so the data was not analysed. The rate of increase in annual is 7.03 cm/year to 5.75 cm/year during the monsoon season.

For the WCR, annual rainfall over Bombay Coloba, Karwar, Ahmedabad Aero, Ratnagiri and Trivandrum witnessed significant increase (Table 2). The increase in annual rainfall is attributed by significant increase in monsoon rainfall. Only two stations that is, Bombay Santa Cruz and Trivandrum show decrease in annual rainfall but it is significant only at Trivandrum however during the monsoon season it is significant at 95% and 99%. The rate of increase in annual rainfall varies from 0.25 cm/year at Ahmedabad Aero to 2.96 cm/year at Ratnagiri. While the rate of decrease at Bombay Santa Cruz and Trivandrum is almost the same that is -0.20 cm/year at Santa Cruz to -0.28 cm/year at Trivandrum. The rate of increase during monsoon is high at Ratnagiri (2.91 cm/year) to -1.18 cm/year at Bombay Santa Cruz. The stations that receive rainfall above 25 cm for the WCR reveal increasing trend in annual rainfall at Bombay Coloba, Bombay Santa Cruz, Karwar and Ratnagiri; however it is significant at Bombay Coloba and Ratnagiri. The increase in annual rainfall is attributed to the increase in monsoon rainfall. The rate of increase in annual rainfall is 1.11 cm/year at Mumbai Coloba to 0.04 cm/year at Karwar whereas during the monsoon season it varies from 0.04 cm/year at Karwar to 1.11 cm/year at Mumbai Coloba. However, the station Karwar does not show statistical significance. The rest of the stations reported fewer rainfall amounts which are not possible to compute. IPCC (2007) also stated that there will be substantial increase in heavy precipitation (95th Percentile) in many land regions.

The above studies concluded that there is an increasing trend in heavy rainfall over both the regions however significant at majority of the stations. As these are the two regions in the country that receive copious rainfall throughout the year, in the following paragraph, the highest rainfall in 24 hours in a month in all the 26 stations for both the regions will be examined. Therefore, it makes sense to assess the heavy rainfall frequency at the regional level, because these events are more likely to be revealed by several observations than by a single station.

Trends in the highest rainfall in 24 hours

The trends in extreme rainfall for the NER are examined and the results are shown in Table 3.

Table 3 Trends in rainfall extremes

NER			WCR		
Stations	**Annual**	**MON**	**Stations**	**Annual**	**MON**
Pasighat	2.037x	1.08x	Mumbai	**0.832x**	**0.836x**
Dibrugarh	2.259x	1.574x	Alibag	**1.313x**	**1.374x**
Lakhimpur	0.677x	0.982x	Harnai	-0.729x	-0.729x
Tezpur	0.362x	0.353x	Ratnagiri	**0.573x**	**0.619x**
Guwahati	0.106x	0.018x	Panjim	1.685x	**1.733x**
Dhubri	0.102x	0.631x	Marmagoa	1.881x	1.830x
Silchar	-0.497x	-0.211x	Karwar	0.443x	**0.455x**
Gantok	-0.739x	0.024x	Honavar	**1.472x**	**1.356x**
Shillong	0.188x	0.167x	Mangalore	**0.303x**	**0.473x**
Cherrapunjee	0.766x	0.855x	Calicut	0.087x	-0.028x
Imphal	0.161x	0.326x	Cochin	-0.621x	0.468x
Kailashahar	0.385x	0.096x	Alleppey	-0.395x	-0.312x
Agartala	-2.849x	0.541x	Trivandrum	-0.075x	-0.086x

Note: MON-monsoon; Bold-significant

Although there is a predominant positive trend in annual as seen from the Table 3 at the majority of the stations in the NER, it does not exhibit any statistical significance while Silchar, Gangtok and Agartala depict decrease in the extreme values. Thus, in order to detect the presence of trends monsoon rainfall was analysed. During the monsoon season, ten stations reported increasing trend significant only at Lakhimpur. The rate of increase in annual amounts varies from 0.10 cm/year at Dhubri and Guwahati to 2.03 and 2.25 cm/year at Pasighat and Dibrugarh. The rate of decrease varies from -0.49 cm/year at Silchar to -2.84 cm/year at Agartala. The rate of increase/decrease during the monsoon season, varies from -0.21 cm/year at Silchar to 1.57 cm/year at Dibrugarh. Thus, considering the annual results it can be stated that monsoon rainfall influenced annual trend.

The results for the WCR are shown in the Table 3. When analysed on the annual basis, nine stations show increasing trend statistically significant at Mumbai, Alibag, Ratnagiri, Honavar and Mangalore while Harnai, Cochin, Alleppey and Trivandrum report decrease in extreme rainfall. The rate of increase ranges from 0.08 cm/year at Calicut to 1.88 cm/year at Marmagoa. The rate of decrease varies from -0.07 cm/year at Trivandrum to -0.72 cm/year at Harnai. During the monsoon season, the rate of decrease ranges from -0.02 cm/year at Calicut to 1.83 cm/year at Marmagoa. The seasonal trend reveals that during the monsoon season, ten stations demonstrate significant increase at five stations, viz., Mumbai, Alibag, Ratnagiri, Honavar and Mangalore at 95% and 99% levels of significance, respectively. Three stations – Harnai, Alleppey and Trivandrum show decreased rainfall. Therefore, it can be concluded that in this region extreme rainfall have increased over the last century.

The increase in rainfall trend over the WCR shows similarities with the finding of Francis and Gadgil (2006); Pattanaik et al. (2010), which show increase in extreme rainfall events over the WCR during the monsoon months.

Extreme rainfall events and associated synoptic conditions

When considering the highest rainfall in the months that were available, the trends of annual and seasonal heavy rainfall in both the region were by large positive during the study period. Similarly, changes in the frequency of rainfall over certain thresholds (6.5 cm to 12.5 cm, 12.5 cm to 25 cm and 25 cm to 9999.9 cm) were predominantly positive in majority of the series. These two copious rainfall receiving regions of India have witnessed positive changes in rainfall extremes; however, statistical significance was reported only from the West coast region. It is difficult to justify the direct causes of the changes in rainfall extremes, but some attributes have been put forward in this study. It is not the intention of the article to identify all the physical causes of the observed upward trends in the indices of heavy precipitation. For establishing the physical causes in the increase in heavy rainfall over the west coast for all the stations during the last century, it is beyond the scope of this paper. However, the issue deserves a brief discussion in the context of synoptic system for some main events during the monsoon season in the WCR during the period 1901-2005.

So, in this section, extreme rainfall events in the WCR were investigated with the help of synoptic systems which may be useful to explain the corresponding changes in the rainfall pattern. This paper attempts to find out the synoptic component associated with heavy rainfall occurring at certain places and accordingly the synoptic system had been identified. For this, data related to extreme rainfall events during the last 105 year (1901-2005) over the WCR were acquired from IMD (Indian Meteorological Department), Pune. The data related to synoptic systems were noted from IMD publications - Mausam and Indian Daily Weather Report. WCR witnessed increasing trend in heavy rainfall amount significant at the majority of the stations in annual as well as during the monsoon season. It is a well-known fact that the extreme rainfall were caused either by cyclonic circulations, lows, cyclones and depressions, monsoon troughs, north-south troughs, east-west troughs, etc. In order to understand the causative factor for these trends in heavy rainfall the data related to various synoptic systems were collected and their frequencies during the last 104 years have been worked out. The date of occurrence, duration and amount of rainfall in mm were taken into account.

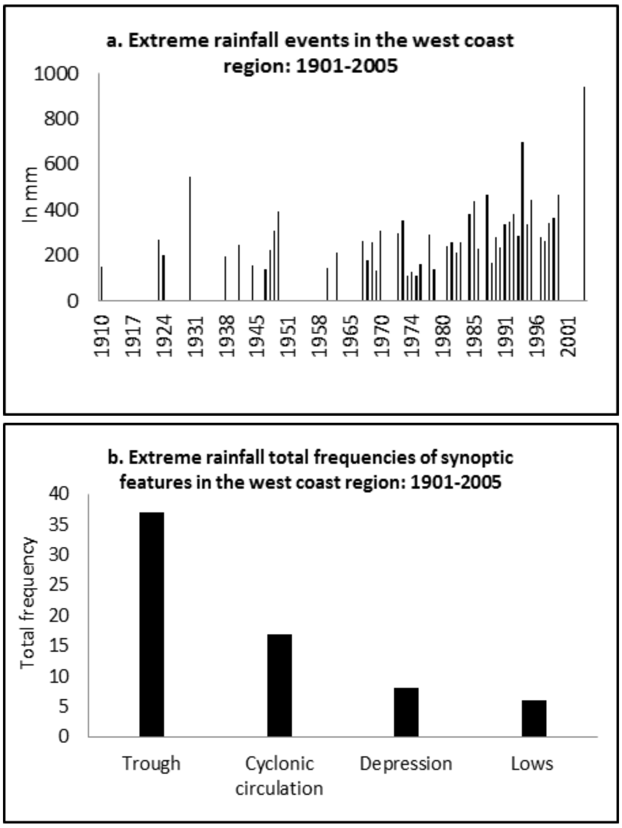

Fig. 2 Extreme rainfall events and frequencies of synoptic features in the west coast region: 1901-2005

Fig. 2 (a and b) concludes that heavy rainfall in the WCR were caused by monsoon trough (37), followed by cyclonic circulations (17), depressions (8) and lows (6); wherein 54% of heavy rainfall events were caused by monsoon trough, 25% by cyclonic circulation, while 12% and 9% were contributed by depressions and lows. The above figure (2 a and b) clearly indicates that synoptic conditions over the Arabian Sea during the study period were the main factors leading to the heavy rainfall.

Nearly half of active to vigorous monsoon situations in Konkan and three quarters of such occasions in CK are associated with troughs off the west coast region (Rao, 1976). In their study on intense rainfall events over the WCR, Francis and Gadgil (2006) found that the probability of intense rainfall events is high between the period mid-June and mid-August over the WCR. They attributed the cause in heavy rainfall to organized convection over a large scale zonal belt, off-shore convective systems, mid-tropospheric cyclone (MTC) and an off-shore vortex. Investigating on the Indian summer monsoon rainfall during the recent years Jadhav (2006) found that the west coast trough becomes more prominent. Even though the systems are not intensifying, they give sufficient rainfall over southern part of the country. Jenamani et al. (2006) investigated the Mumbai rain of 2005, and they found that the rain band/low pressure system positioned over the Western Ghats interacted with meso-scale processes to create the heavy rain event. Vaidya and Kulkarni (2006) independently confirmed a similar conclusion and found that a cloud burst phenomenon was the main reason for the heavy rain. Kishtawal et al. (2009) found very heavy and extreme rainfall events showed increasing trends over urban centres of Indian where the pace of urbanization is faster.

Conclusion

This study reveals noticeable changes in the extreme rainfall events that occurred over the WCR in the past century. The non-parametric test as well as the linear trend analysis identified increasing trends in the heavy rainfall amount and extreme rainfall over the study regions. However, the significance is higher for the WCR on annual and monsoon scale with a threshold of 6.5 - 12.5 cm, 12.5 - 25 cm. The majority of the stations over the WCR, namely, Konkan/Goa and Coastal Karnataka reported significant increase in annual and monsoon rainfall extremes (the highest rainfall in 24 hours) but not significant for the NER. Further, the synoptic systems associated with this rainfall were identified and it was found that the extreme rainfall events for the WCR were due to the increased formation of the synoptic systems like monsoon trough, cyclonic circulations, depressions and lows.

Our results are in general agreement with the increase in extreme precipitation events over the country (Goswami et al. 2006) in a global warming environment given with the increase in greenhouse gases over the study areas (Tongdi Jamir and De. 2012). Further, an increase in the frequency of intense precipitations events in many parts of South Asia for the period 2080-2099 with the control period 1980-1999 is well documented by IPCC 2007. Hence, changes in heavy rainfall events will increase proportionally in the future. The result of this analysis shows that regional planning and preparedness should be initiated as there is greater risk of flood related events over the study regions.

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Assessing flood inundation extent and landscape vulnerability to flood using geospatial technology: A study of Malda district of West Bengal, India

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Abstract

Assessment of flood risk zonation and landscape vulnerability to flood are fundamental aspects in flood risk management. Landsat 8 Operational Land Imager (OLI) and ASTER DEM data were used to assess landscape vulnerability to flood inundation and flood risk in Malda district of West Bengal state, India. Flood inundation map was prepared on the basis of water and non-water pixels on images (before and during the flood event). Flood risk map was prepared using equal interval of separation based on elevation and inundated flooded area. Flood inundation map was overlaid on the pre-monsoon land use/land cover map to produce landscape vulnerability to flood. The results revealed that 19% area of the district was flooded during monsoon flood event in 2014 and the agricultural area was most affected land use, sharing 62% of the total flood affected area, followed by river bed (21%), built up (7%) and vegetation (5%). The flood risk map of the district shows that temporary river islands, sand banks along the Ganga river course lie in low flood plain and were considered under high risk zone. The flood plain alongside minor stream drainage in southern, north-western and in between them comes under medium flood risk zones. Flood risk is low in areas which are away from the rivers. Non flooded areas were identified in high lands of eastern region of the district. Landscape vulnerability map shows that the blocks located along the Ganga river namely Kaliachak I, Kaliachak II, Kaliachak III, Manikchak, Ratua I were highly vulnerable to flood. The study suggests that efforts should be made to remove the sediments for increasing the depth of river. Spurs and bed bars should be constructed to avoid great loss of prime agricultural land, property and lives of people.

Keywords: *flood, risk, landscape vulnerability, Malda District, remote sensing and GIS*

Rezumat. Evaluarea extensiunii inundaţiilor şi a vulnerabilităţii peisajului la inundaţii folosind tehnologie geospaţială: studiul districtului Malda din Bengalul de Vest, India

Evaluarea zonării riscului la inundaţii şi a vulnerabilităţii peisagistice la inundaţii sunt aspecte fundamentale în managementul riscului la inundaţii. Landsat 8 Operational Land Imager (OLI) şi ASTER DEM data au fost utilizate pentru a estima vulnerabilitatea peisajului la inundaţii şi evaluarea riscului la inundaţii în districtul Malda din statul Bengalul de Vest, India. Harta inundaţiilor a fost obţinută pe baza pixelilor water şi non-water de pe imagini satelitare (înainte şi în timpul fenomenului). Harta riscului la inundaţii a fost realizată utilizând intervalul egal de separaţie bazat pe elevaţie şi zone inundate. Harta inundaţiilor a fost suprapusă peste hărţile de utilizare/acoperire a terenurilor ante-muson pentru a obţine vulnerabilitatea peisajului la inundaţii. Rezultatele au demonstrat că 19% din suprafaţa districtului a fost inundată în timpul inundaţiilor din 2014 şi că suprafeţele agricole au fost cele mai afectate (62% din totalul suprafeţelor calamitate), urmate de albiile râurilor (21%), zone construite (7%) şi zone cu vegetaţie (5%). Harta riscului la inundaţii a districtului arată că insulele temporare, bancurile de nisip de-a lungul râului Gange se află în lunca inundabilă joasă şi sunt considerate a fi expuse unui risc crescut. Luncile joase aparţând reţelei hidrografice situate în sud, nord-vest şi între acestea sunt expuse unui risc mediu la inundaţii. Zonele neinundabile au fost identificate în ţinuturile mai înalte din partea de est a districtului. Harta vulnerabilităţii peisajului arată că blocurile situate de-a lungul râului Gange, mai precis Kaliachak I, Kaliachak II, Kaliachak III, Manikchak, Ratua I sunt foarte expuse la inundaţii. Studiul sugerează că sunt necesare eforturi pentru îndepărtarea sedimentelor astfel încât adâncimea râului să crească. Contraforturi şi bancuri de nisip ar trebui folosite pentru a preveni pierderile de terenuri agricole, proprietăţi şi vieţi omeneşti.

Cuvinte-cheiel: *inundaţii, risc, vulnerabilitatea peisajului, Districtul Malda, teledetecţie şi SIG*

Introduction

Flood as a common hydrologic extreme is a regular phenomenon in India. The rainfall received in India is erratic in nature and unevenly distributed both in time and space. Nearly 40 million hectares of area gets inundated every year in India (NRSC, 2015). West Bengal is one of the highly vulnerable states to flood. It is affected by severe floods during monsoon every year, causing irreparable loss to property and life. Out of the total geographical area, about 42% is susceptible to flood in West Bengal (Government of West Bengal, 2014). Flood inundation and flood vulnerability maps are significant components of flood risk management and mitigation. These maps can provide accurate geospatial information about the extent of floods and can be used as planning tools to assess flood risks and landscape vulnerability (Jung et al., 2013; Turner et al., 2013; Gilles et al., 2012). Flood inundation mapping, using remote sensing and GIS techniques is an intuitively useful tool for monitoring flood extent and assessing its impact on land use and land cover. Landsat Thematic Mapper is widely used for detecting flood extent globally (Bhavsar, 1984; Ruangsiri et al., 1984). Surface elevation data (ASTER DEM) can effectively be utilized for flood zonation mapping by overlaying flood inundation map in GIS environment.

Various studies have demonstrated effectiveness of remote sensing data for monitoring and analyzing flood hazard and flood mapping. It has been efficiently utilized for mapping flood extent in a coastal floodplain using Landsat TM and DEM data (Wang, 2010); the use of digital elevation models for flood hazard mapping (Leenaers&Okx, 1989); micro landform classification and flood hazard assessment (Ho, 2011); flood risk zonation and mapping (Mohan et al., 2011); flood hazard zonation and flood vulnerability assessment (Sanyal&Lu, 2005); flood hazard mapping (Venkata&Rajib, 2004); evaluation of flood water depth using radiometric remote sensing (Lyon and Hutchinson, 1995); uncertain flood inundation models (Horritt, 2006); remote sensing and GIS based mapping of flooded areas (Brivio et al., 2002); calibration of uncertain flood inundation models using remote sensing (Mason et al., 2009), application of remote sensing in flood management (Sanyal&Lu, 2004).

This study aims to assess flood inundation and its impact on landscape. Evidence is given from Malda district, India. This study also attempts to explore the effectiveness of remote sensing and GIS tools for suggesting an appropriate methodology for flood inundation mapping and landscape vulnerability.

Study area

Malda district, where 80% of annual precipitation is received in four wet months from June to September, is traditionally identified as one of the flood-prone areas in India (Nihar et al., 2014). The Ganga river is known to have undergone several shifts of its course in the vicinity of the Malda region because of a combination of several fluvial and topographical features. With rapid growth of population, the banks of Ganga and its tributaries marked residential, commercial and industrial development (Thakur et al., 2011). Excessive rainfall within a short duration of time very often causes flood during monsoon in the district. Apart from the monsoon climate, shifting course of river, porous soil profile, collapse of bank in chunks and consequently submergence of bank into water are claimed to be the major causes of flood in the study area (Iqbal, 2010).

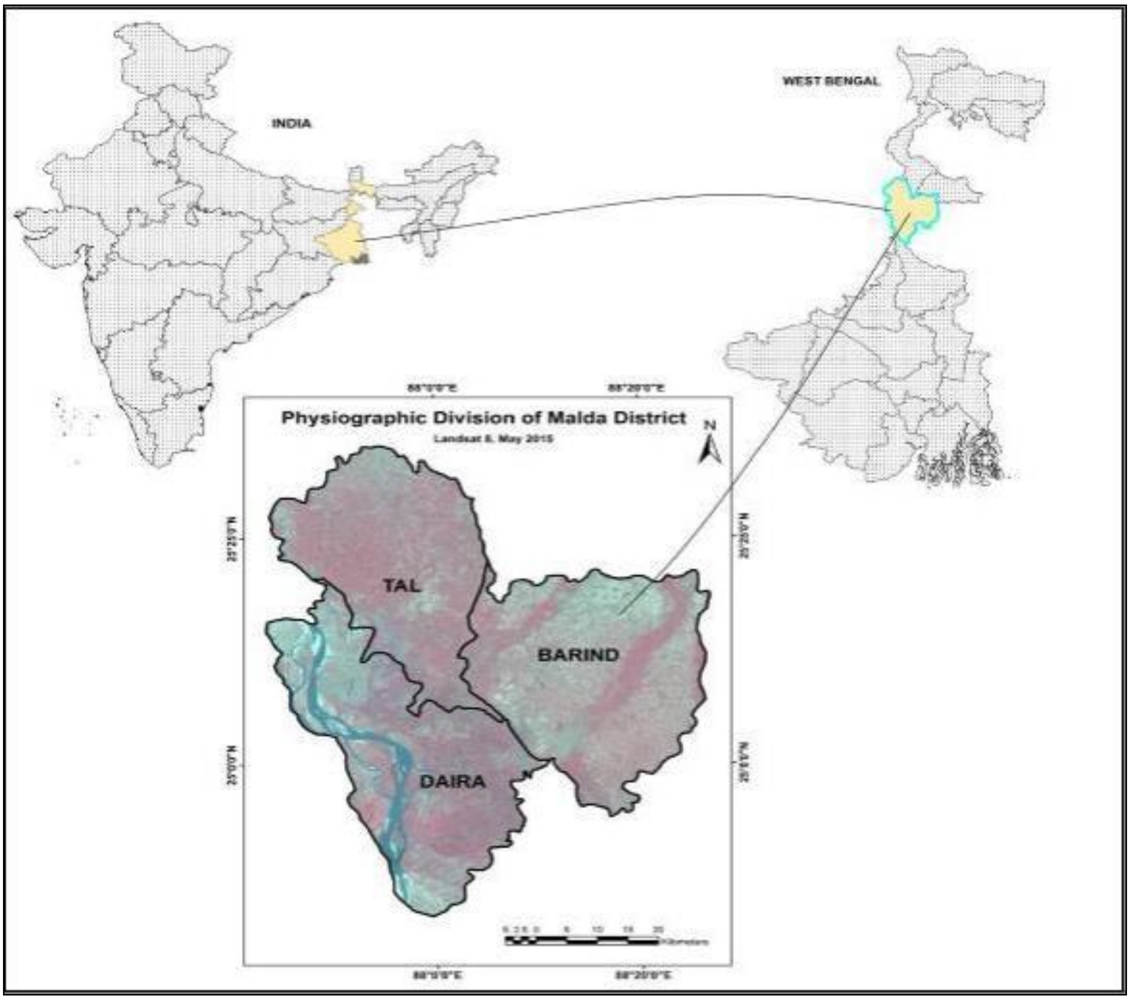

Fig. 1: Location of the study area

Flooding brought by the Ganga and the Mahananda not only causes huge damage of crops and infrastructure, but also leads to massive siltation of reservoirs (Sanyal, 2005). This situation reduces capacity of the existing dams to store water and creates problems to control floods. Farakka Barrage was constructed to divert the Ganga water towards the Bhagirathi and the Padma rivers and to release the sediment load into the deeper part of estuary (Rudra, 2004; Sinha 2012). The main objective of constructing the barrage was not let the water drain into the Hugli river. Due to this obstruction the river made new course in upstream of Farakka barrage affecting Malda and Murshidabad districts (Banerjee and Chakroborty, 1983; Banerjee, 1999). Change in the Ganga river course and river bank erosion are main causes of flood in the district. Flood occurrence has become a regular phenomenon and its magnitude has increased over the decades (Rudra, 2004; Rudra, 2010; Banerjee, 1999; Mukhopadhyay, 2003. Manikchak, Kaliachak-II, Kaliachak-III and Ratua-I blocks (administrative divisions) of the district were more subjected to erosion and flood.

Malda district has two distinct subdivisions, (English Bazar and Chanchal) which are divided into 15 blocks spreading over 3,733 square kilometers area. The district is situated between 24º40′20″ N to 25º32′08″ N latitudes and 88º28′10″ E to 87º45′50″ E longitudes (Fig. 1). The district consists mainly of low-lying alluvial plains sloping towards the south. The North Eastern part of the district contains a few elevated tracts. The river Mahananda flows from north-east to south-east and divides the district into eastern and western regions. Further, the river Kalindri divides the western region into northern and southern regions. The eastern part is comparatively high and undulating while western part is low and fertile. Three broad sub-regions can be identified physiographically within Malda district on the basis of nature of topography and soil, i.e. Barind, Diara and Tal. The Barind region of mature alluvium lies on the eastern margin of the Mahananda River. The Diara is a relatively well-drained flatland formed by the fluvial deposition of newer alluvium in the transitional zone between the Barind upland and the marshy Tal tract of the Ganges (West Bengal Development and Planning Department, 2007).

Database and methodology

Landsat 8 OLI data of pre-monsoon and monsoon (2014) were used for flood inundation mapping and ASTER DEM data was used to assess the landscape vulnerability to flood and flood risk in Malda district. The study area was extracted using Survey of India (SOI) topographical sheet (RF 1:50,000). The methodology adopted for flood inundation and landscape vulnerability to flood is presented in Fig. 2 and described as follows:

Land use and land cover map

Land use and land cover maps of the study area for pre-monsoon and monsoon (2014) were generated by supervised classification and maximum likelihood method was used for this classification. Final grouping of spectral classes was done on the basis of land cover classes. The generalized images were reclassified to reduce classification error and to improve the accuracy of the classification. Finally land use/land cover maps of pre monsoon and monsoon period were prepared.

Normalized difference water index

Normalized difference water index (NDWI) was derived to identify water related surface. The main advantage of NDWI is that near infrared (NIR) is highly sensitive to moisture content in the soil and the vegetation canopy. The Normalized Difference Water Index (NDWI) was employed to reach the goal of isolating water and non-water features. McFeeters's NDWI equation was used to separate water cover area from non water area. This equation is designed to maximize the reflectance of a water body by using green wavelengths and minimize the low reflectance in near infrared (NIR) of water bodies. Consequently, the water body information was enhanced and the background (vegetation and soil features) information was restricted in McFeeters's NDWI equation (McFeeters, 1996). Thus water body was identified by applying a threshold to McFeeters's NDWI images:

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

where NIR is the reflectance or radiance in a near infrared band (0.85-0.88 μm OLI and 0.76-0.90 μm for TM) and Green is the reflectance or radiance in a visible channel (0.53-0.60 μm OLI and 0.52-0.60 μm TM).

Flood mapping using Landsat 8 images

Water versus non-water areas were delineated on Landsat image before and during flood events and were compared to determine flooded areas. After identifying water and non-water areas on both images (one acquired before the flood event and the other during the flood) using the above criteria, determination of areas that were flooded was made. The area indentified as dry or non-water on the May (pre-monsoon) image was classified as water on the August (monsoon) image and considered to be flooded. The area identified as dry on both May and August images was considered non-flooded.

Flood risk zonation

A flow accumulation model was created using the ASTER GDEM 2 and the inundated flood map was reclassified into high risk, moderate risk, low risk, and non-flooded area using equal interval of separation based on elevation. The overall accuracy of GDEM 2 for flood risk zonation was around 17 meters at the 95% confidence level and a horizontal resolution on the order of 75 meters. The vertical (root mean squared error) accuracies generally varied between 10 and 25 meters.

Landscape vulnerability to flood inundation

The inundated flood map was superimposed on the pre monsoon land use classes to examine the landscape vulnerability.

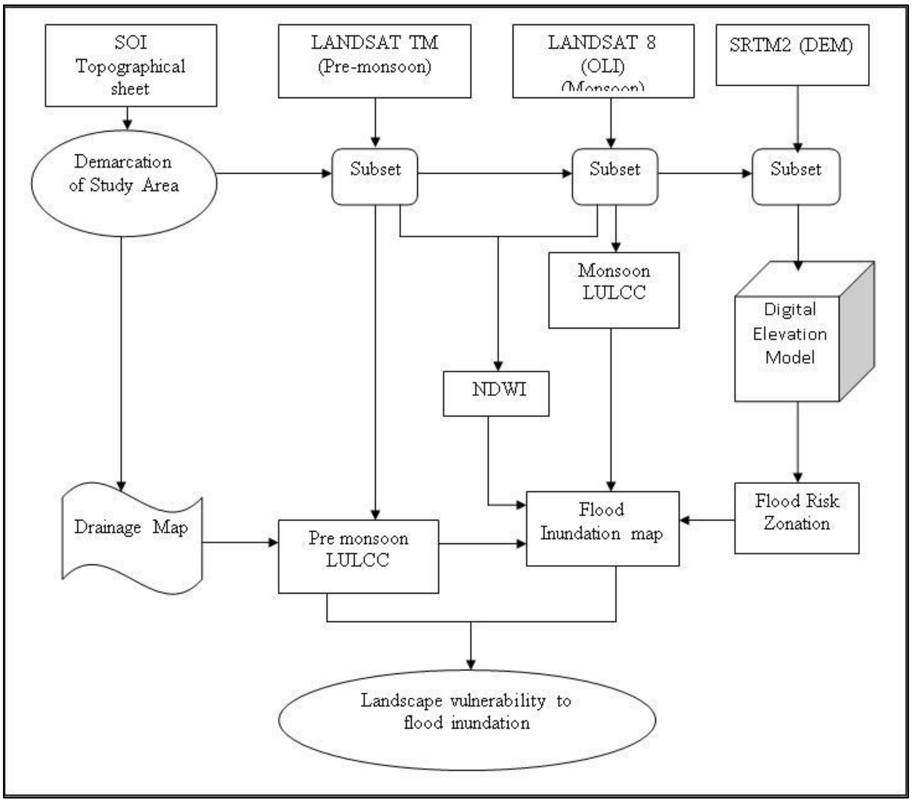

Fig. 2: Flow chart of the methodology

Result and discussion

Flood inundation

The mean value of the NDWI during flood was 0.492 for the flooded areas and 0.2264 for the non-flooded areas. The NDWI values <0 indicate non flooded area and values between 0 and 0.3 indicate moist soil while values >0.3 indicate water on the map (Fig. 3).

Of the total area of the district, 19% area was affected by flood. Ratua I, Manikchok and Kaliachok I, Kaliachok II, Kaliachok III were affected by the flood brought by river Ganga. Habibpur block in south eastern part of this district experienced flood caused by the Tangan river. Among physical divisions of this district, Daira physical division was mostly affected by flood (Fig. 4).

Flood risk zonation

Four flood risk zones (high, medium, low and non-flooded) were delineated in the district (Fig. 5). The stabilized river islands occupied by vegetation and agricultural crops were clearly identified with the help of remote sensing satellite data. These islands lie in low floodplain and were considered under high risk zone. Sand banks and temporary river island are flooded during the rainy season every year. The flood plains alongside minor stream drainage in southern, north-western and in between them fall under low and middle level flood plains and were identified as medium risk zones. Low level and middle level flood plains get submerged every year during monsoon season. Flood risk is low in areas which are away from the rivers. Non-flooded area is identified in the eastern region comprising Barind region.

A vast portion of the lowlands (ground elevation lower than 30 m) is located near the river Ganga and in the eastern and southern zone experiences frequent and deep inundation. The high risks areas in the plain correspond well with the areas that experienced a high flood level (24 m) and were submerged during flood of August due to monsoon rainfall. Very low and low hazard areas also coincide well with the non-inundated areas shown in flood inundation maps prepared from ASTER DEM and

Landsat 8 data in 2014 (Fig 4 and 5). Moderate hazard risk areas were identified mainly at elevations between 30 and 50 m near the outlet for flood water from the upper parts of the rivers.

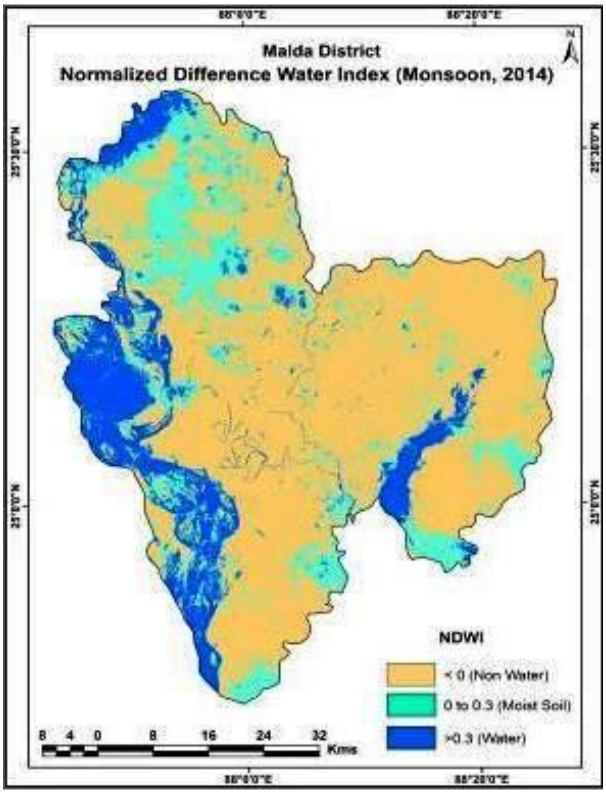

Fig. 3: NDWI (monsoon), 2014

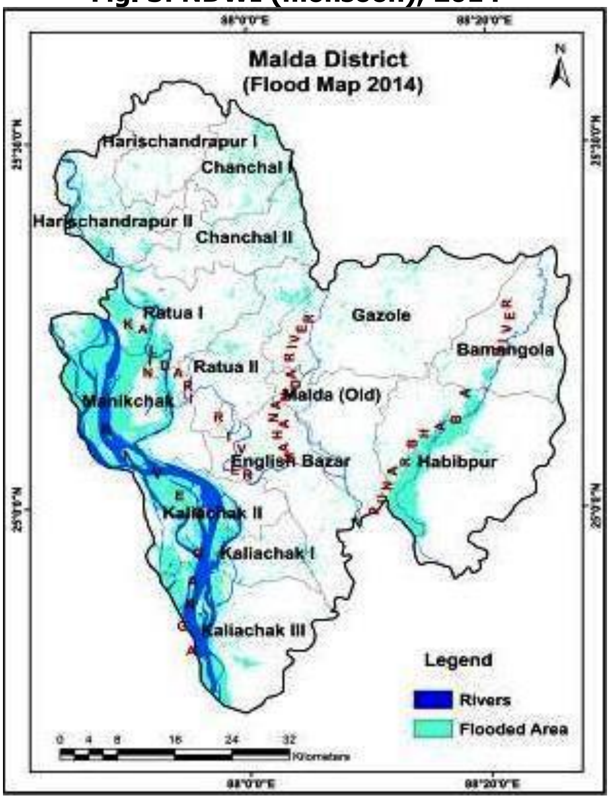

Fig. 4: Extent of flood, 2014

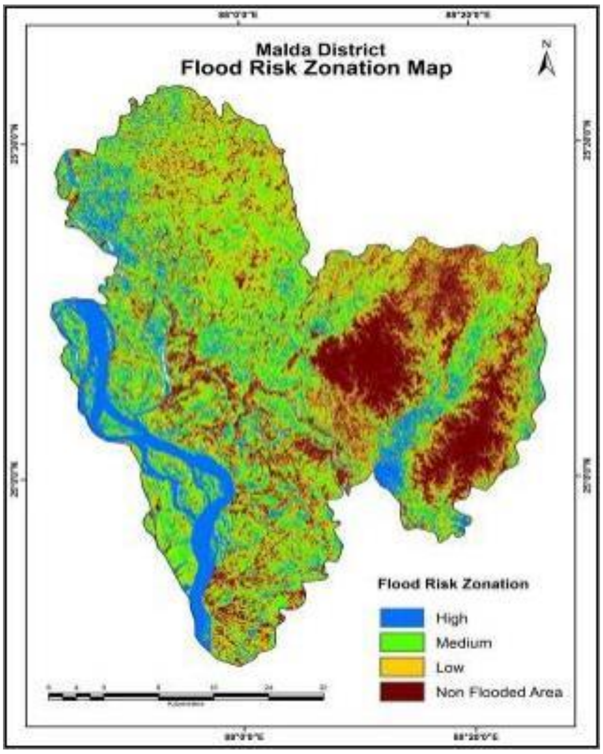

Fig. 5: Flood risk zonation

Pre-monsoon land use and land cover

Land use and land cover map of Malda district during pre-monsoon season, 2014 was prepared to overlay flood inundation map and to assess landscape vulnerability to flood (Fig. 6).

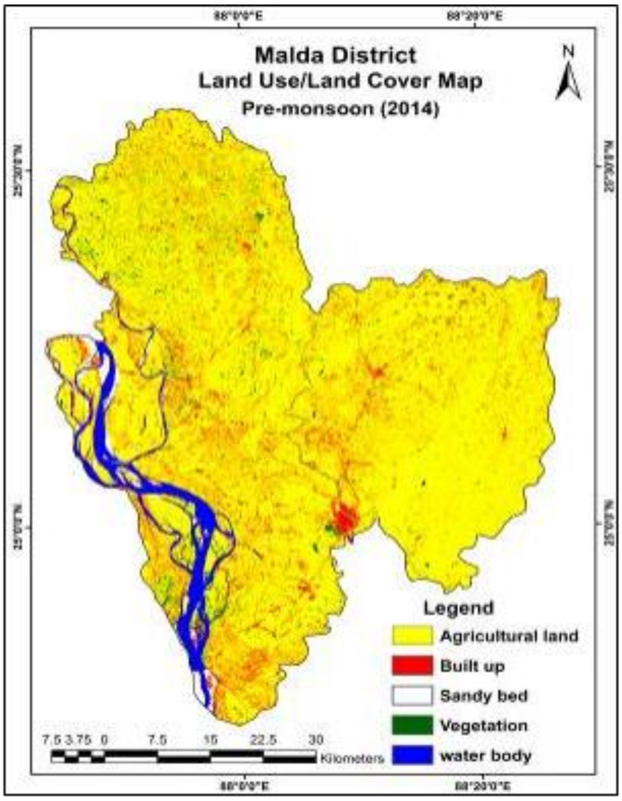

Fig. 6: Pre-monsoon land use land cover

Forum geografic. Studii și cercetări de geografie și protecția mediului
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Areas under various land use categories and their percentage is presented in Table 1. Five land use categories were identified viz. built-up, sandy bed, agriculture, vegetation, and water body in the study area. Table 1 revealed that agriculture occupied the largest area (82%) followed by built up area (9.2%).

Table 1: Land use/land cover in Malda district (before flood event)

Land use/land cover classes	Area in hectares	Area in percentage
Built up	35,657	9.2
Sandy bed	3,830	1.0
Vegetation	12,268	3.2
Agriculture	3,19,529	82.4
River bed	16,397	4.2

Landscape vulnerability to flood inundation

Of the total agricultural area (82.42%) nearly 14% area under paddy was vulnerable to flood thus affecting the crop production in the district. About 30% vegetation cover was flooded resulting in the degradation of ecosystem and 15% built up area was exposed to flood rending many people homeless. The high and moderate risk areas were lying between flood plain areas and low slope gradients along the Ganga river. The flooded areas along the Ganga River and along the tributary of the Mahananda River were primarily agricultural land and vegetation area (Fig. 7)

Figure 8 shows the area of each land use/land cover class affected by flood. It revealed that about 45,953 hectares of agriculture, 5,361 hectares of built up, 3,726 hectares of vegetation cover area of their respective total areas was affected during the flood in the district. Patches of flooded areas in the north, north-west and south-west of the image were identified mainly in southern river bed, fallow land and cultivated land.

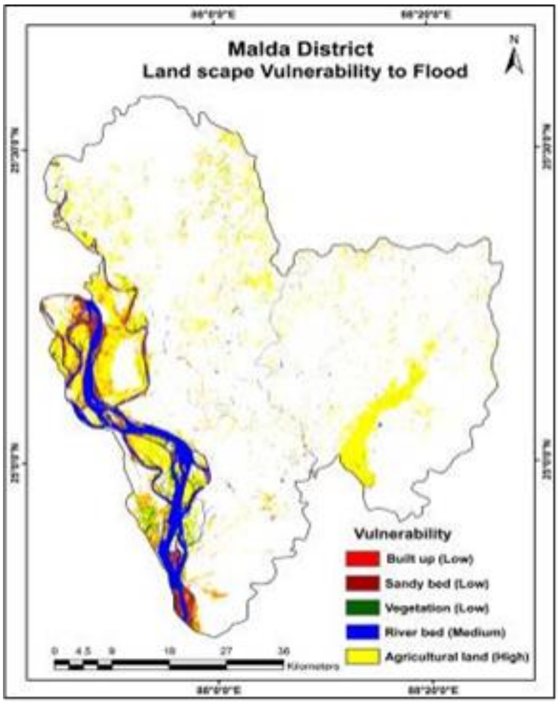

Fig. 7: Flood risk zonation

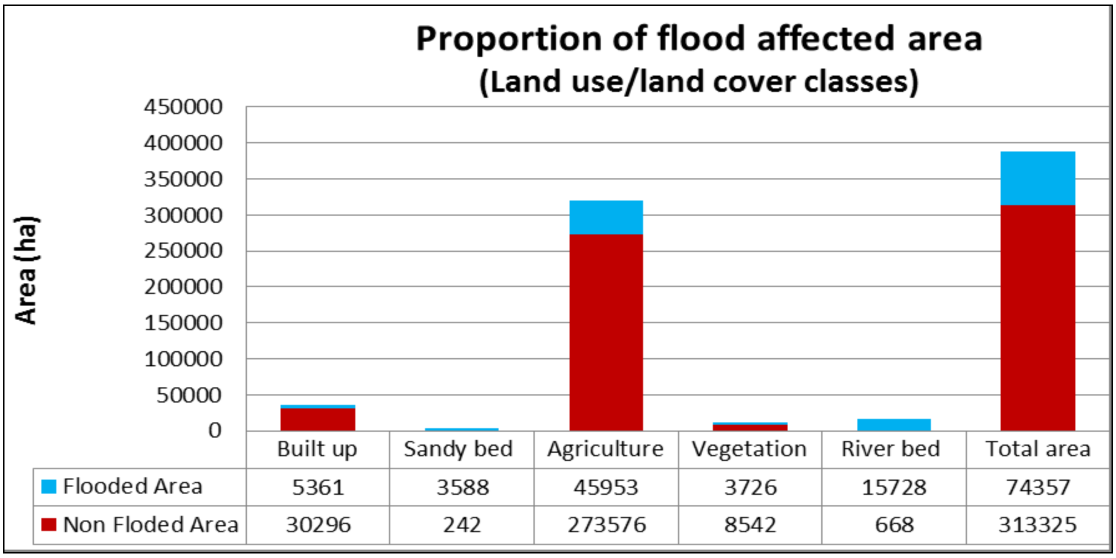

Fig. 8: Percentage of land use classes affected by monsoon flood

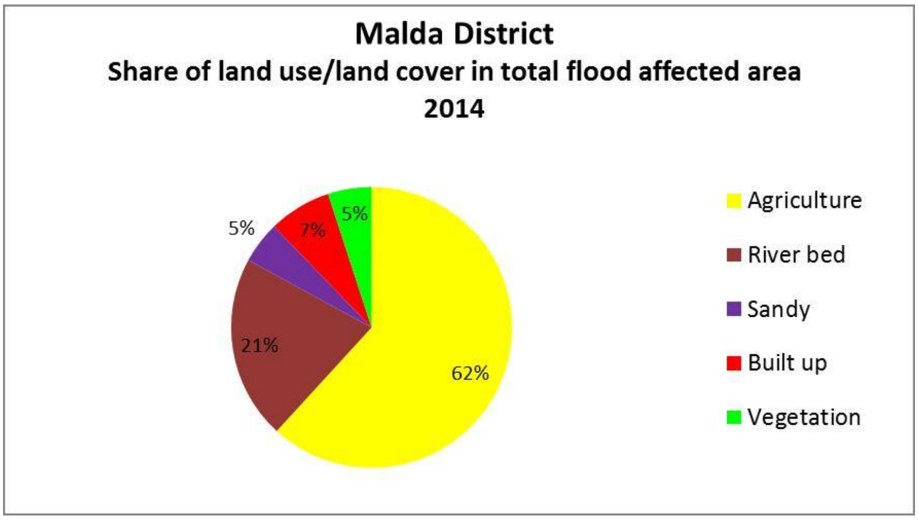

Fig. 9: Land use share in total flood affected area of Malda, August 2014

These three categories were severely affected by the flood in terms of size and percentage of the total flooded area in Malda district. It should be noted that most of the relatively higher elevated areas were not flooded on 3 August 2014. Of the total flood affected area (74,357 hectares), agriculture shared the largest proportion (62%) followed by river bed (21%), built up (7%), vegetation (5%) and sandy bed (5%). It is clearly evident that the agriculture is severely affected by the flood every year in the study area (Fig. 9).

Conclusion

Remote sensing and GIS tools have proved useful for preparing flood inundation, flood risk and flood vulnerability maps. Flood extent was measured by analyzing water versus non-water targets on Landsat 8 images (one acquired before and the other during the flood event). Flood risk zonation map was prepared using equal interval of separation based on elevation and inundated flooded area. Flood inundation map and pre monsoon land use land cover map was compared to assess impact of flood on various land use and land cover classes. Of the total area of the district, 19% area was affected by flood during 2014. Flood vulnerability map based on height shows that areas along the Ganga river namely Kaliachak I, Kaliachak II, Kaliachak III, Manikchak, Ratua I, and Harischandrapur-II and Habibpur were inundated areas and therefore were categorized as highly vulnerable blocks in the study area. Chanchal I, II, English Bazar, and part of Gazol came under medium vulnerability category. These blocks located at relatively higher location were less affected by flood. Low vulnerability blocks comprised of southern parts of Kaliachak I, Kaliachak II, English Bazar and parts of Habibpur. Flood inundation map revealed that area under paddy was largely affected by the flood (62%) followed by river bed (21%), built up (7%), Sands (5%) and vegetation (5%). Of the total area of individual land use classes, agriculture (14%) was highly affected followed by vegetation (30%), and built up (15%). Field investigation revealed that declining depth of the river Ganga and shifting of its course near Kaliachak I, Kaliachak II, Kaliachak III, Manikchak and Ratua blocks are the prime reasons for frequent flood in the study area. The study suggests that efforts should be made to remove the sediments for increasing the depth of river near the affected area of Malda district. Earlier levees were constructed along Farakka covering the parts of Kaliachak, Manikchak and Ratua blocks but these have been eroded. Therefore, the measures such as construction of short spurs and bed bars for diverting flow should be adopted to save agricultural land, property and human lives.

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Territorial patterns of socio-economic development in the Romanian Danube valley

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Abstract

The territorial patterns of socio-economic development in the Romanian Danube Valley (micro-scale, LAU2) are identified in this paper by using the complex index of development (INDEV). The paper presents the computation of secondary indexes reflecting the main aspects of socio-economic development (dwellings, public utilities infrastructure, health, employment, demography, education and local economy). The territorial distribution of the secondary indexes and the complex index of development values emphasized a difference between the rural and urban administrative units, the rural areas shaping the low and very low pattern of socio-economic development and the towns and municipals representing the average pattern of socio-economic development. The complex index of territorial disparities, computed by the variant of the relative distances ranking method (using as baseline the national average value of each statistical indicator selected), shows the overwhelming predominance of socio-economic development pattern below the Romanian average.

Keywords: *territorial pattern, socio-economic development, territorial disparities, Romanian Danube Valley*

Rezumat. Modele teritoriale de dezvoltare socio-economică în sectorul românesc al Văii Dunării

În acest studiu sunt analizate modelele teritoriale de dezvoltare socio-economică în sectorul românesc al Văii Dunării, la nivel de micro-scară (unităţi administrative locale – LAU2) prin intermediul indicelui complex de dezvoltare (INDEV). Lucrarea prezintă calcularea indicilor secundari, care reflectă principalele aspecte ale dezvoltării socio-economice (locuinţe, infrastructura de utilităţi publice, sănătate, ocupare, demografie, educaţie şi economie locală), precum şi distribuţia teritorială a acestora şi a indicelui complex de dezvoltare. Sunt evidenţiate diferenţe între unităţile administrative urbane şi rurale, arealul rural fiind caracterizat de o dezvoltare socio-economică slabă şi foarte slabă, în fapt fiind subdezvoltat, iar spaţiilor urbane fiindu-le specifică dezvoltarea de nivel mediu. Indicele complex de dezvoltare (calculat prin metoda rangurilor reale (sau distanţelor relative) în aplicarea căreia valoarea medie naţională a fiecărui indicator statistic utilizat a fost considerată ca reper) arată că în sectorul românesc al Văii Dunării, comparativ cu nivelul mediu naţional, predomină modelele teritoriale de dezvoltare socio-economică slabă şi foarte slabă.

Cuvinte-cheie: *model teritorial, dezvoltare socio-economică, disparităţi teritoriale, Valea Dunării Româneşti*

Introduction

Socio-economic development refers to the ability of producing an adequate and growing supply of goods and services in a productive and efficient ways of accumulating capital and distributing "the fruits" of production in a relatively equitable manner (Jaffee, 1998). Vast territorial differences in the socio-economic statistical indicators, such as income levels, living conditions etc., are broken down into leading areas and lagging areas. This situation is not beneficial to the process of socio-economic development of the European Union and, indeed, it becomes one of its major barriers (Churski, 2014). The Danube Basin is now largely a European (EU) space (Fig. 1) and socio-economic development, competitiveness, environmental management and efficient growth of resources should be improved, security and transport corridors modernized. These development directions are reflected in the four main objectives of the EU Strategy for the Danube Region (EUSRD), a political initiative of Romania and Austria promoted in June 2008 in order to: 1. connect the Danube region; 2. protect the environment; 3. build prosperity and 4. strengthen the Danube region.

In view of the above, the present study has been focused on the Romanian Danube Valley, aiming to identify the territorial patterns of the socio-economic development at micro-scale (local administrative units–LAU2) and assess the territorial disparities in this sector. Thus, the authors can apply the relative distances ranking method, compute and represent on maps a series of secondary indexes and the complex index of development.

In Romania, four development regions and twelve counties (with 238 rural local-administrative units and 28 urban local-administrative units - LAU2) are situated along the Danube (1,075 km long). The Romanian Danube Valley, spatially delimited by eight terraces (*Geography of Romania,* 2005), is an area with numerous rural settlements, but also towns of appreciable age, human and economic potential (Fig. 2).

Theoretical background

Romanian geographers deal with the "geographical complex of the Romanian Danube Valley" (*Geografia Văii Dunării Româneşti*, 1969, p. 9), as a territorial sub-system, with focus on the geographical problems of population, settlements and labour (employment, employment structures, commutation etc.). Before the historical events at the end of the `80s, scientific geographical research focused on the Danube towns (Ştefănescu, Alexandrescu, 1978), rural settlements and functional types of settlements from various Danube Valley geographical sub-regions (Baranovsky, 1969, Herbst, Băcănaru, Caranfil, 1969), landscape changes (Iordan, Iacob, Ianoş, 1984), geo-demograhic landmarks (Ianoş, Popescu, Tălângă, 1989), etc.

Fig.1: The Danube Basin and the Romanian Danube Valley
(Source: www.danube-region.eu)

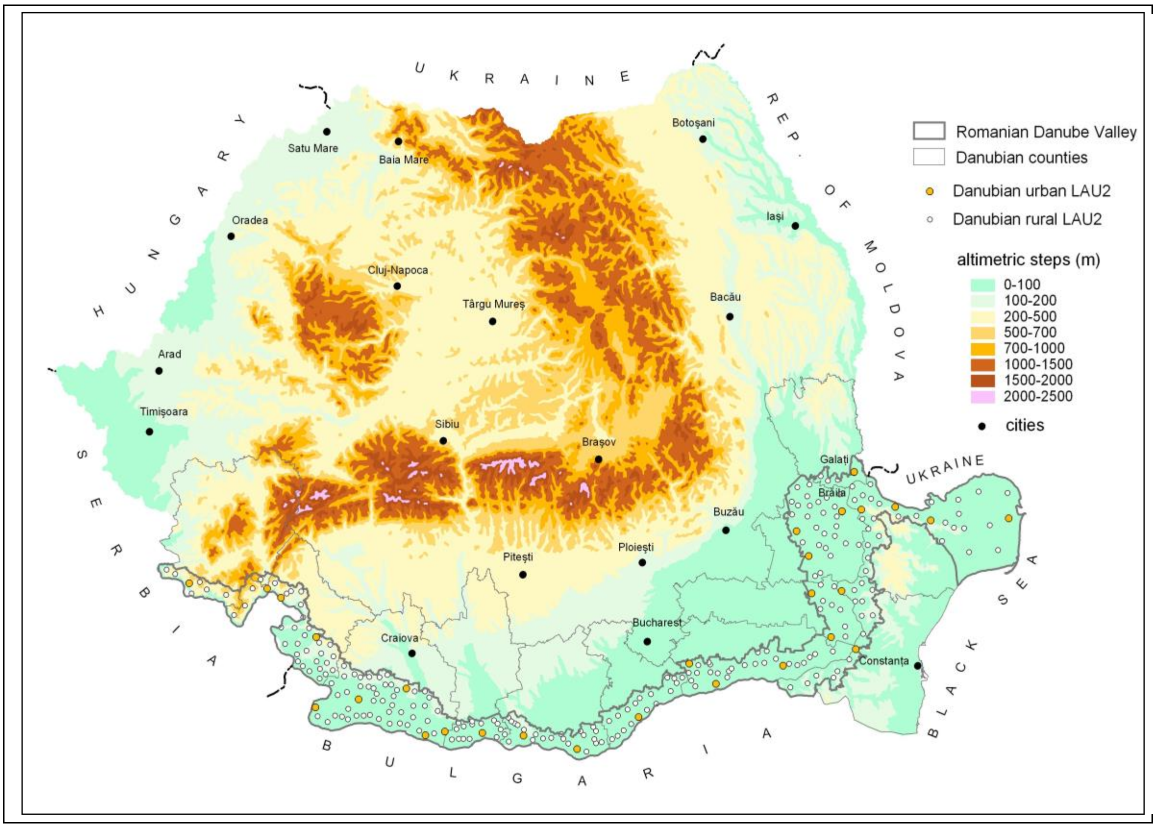

Fig.2: Study area
(Source: Bălteanu, et al., 2006, up-dated and modified)

After December 1989, the transition from socialist centralized economy system to the free economy of capitalism captures the research interest of Romanian geographers. Ever more scientific works on the Danube Valley areas and also a wider range of problems tackled were being published, e.g. urban geography (Ianoş, Tălângă, 1993, 1994, Vîrdol, 2009), rural geography (Ianoş, Popescu, 1990), transport geography (Tălângă, 1994), geography of industry (Popescu, 1991, 1994, 2000, Tălângă, 1995). A comprehensive analysis of the Romanian Danube Valley (Ianoş, 2000) revealed the intra-regional development disparities in terms of economic, demographic, infrastructure and living standard indicators. The study concluded that the Romanian sector of the Danube Valley had a low development level compared to the average national values of the indicators used. In 2005, the Romanian Danube Valley was the subject of a general geographical analysis in the *Geography of Romania*, volume V, edited by the Romanian Academy. Given the complexity of our analysis, the research hypotheses taken into account in order to identify the favourable and less favourable areas for socio-economic development are numerous and inter-related. The indicators of housing and public utilities infrastructure are included in consumption indicators, which show the level of development in a specified space. Access to drinking water, bathroom, sewerage network, etc. is relevant for the level of the population's incomes because payment for drinking water and the construction of a bathroom and service-pipe implies having financial resources. On the other

The labour force reflects the complex linkage between general employment, employment in agriculture, unemployment and social consequences of insecure jobs, finally giving information on the quality of employment. Unemployment is detrimental to the quality of life (Winkelmann, 2014), the social consequences of unemployment and of insecure jobs having negative impact on the employment situation in households and communities. Infant mortality is dependent on a number of factors accepted worldwide, which are: the socio-economic background, the educational and cultural level, behavior, medical factors, geographical and environmental factors and incidental factors (epidemics, disasters, etc.) (UNFPA, 2003). So, infant mortality is a key indicator of a specific area's development level. School enrolment measures the access of a population to the educational system and it is simply a count of the number of children who have registered with school (Baker, Halabi, 2014). There are many territorial differences of school enrolment, because of inter-group disparities regarding the opportunities for academic achievement (educational inequalities). Historically, educational inequality affects some particular social groups, some minority groups being especially concerned (Husen,

hand, these indicators underline how deep-going are the socio-economic problems of the poor population, which have no access to some elementary conditions of life (UNFPA, 2003). Deprivation in housing conditions is measured by the absence of facilities that are deemed necessary for maintaining a minimum standard of quality of life (Weick, 2014, Domanski et.al. 2006). The indicator living floor (sqm/inhabitant) is a key indicator of housing quality, which measures the adequacy of living space in dwellings (a low value of this indicator being a sign of overcrowding) (Millennium Development Goals Dashboard, 2014). Drinking water (freshwater intended for human consumption through activities such as drinking, cooking, or bathing) is critical to assuring human health and well-being. Water is considered to be safe for consumption when using it represents a low risk of immediate or long-term harm, which means having the water supplied through a network system.

A safe supply of drinking water is a cornerstone of public health and community well-being (Kot, Castleden, Gagnon, 2014). Green urban areas (oxygen generating surfaces) fulfill multiple functions and give a certain quality to urban environment and housing (Cucu, Ciocănea, Onose, 2011), also relating to environmental urban and rural health. The physical and built environment (residential structures, infrastructure, and different functional areas) may affect health, especially if there are issues of water quality, sewerage, or air pollution. The urban and rural environment also presents benefits to health through open, green, and recreational spaces (Wuerzer, 2014).

1972, Crahay, Dutrévis, 2014). The economy and urban development of riparian regions have been partly determined by some economic factors (e.g., limited endowments for water transportation) and the geopolitical context, due to the historical events of the late '80s and the early '90s (e.g. the blockade of traffic due to the ex-Yugoslavia crisis) (Hardi 2013).

Data sources and methodological aspects

The study valorizes the data-base on LAU 2 (NUTS V) level, such as TEMPO Online time series published by the National Institute of Statistics, the results of the Population and Housing Census (October, 2011) and other publications edited by the National Institute of Statistics (e.g. The goods transported on inland waterways in 2012). The selection of indicators for an index is still the result of subjective/personal choice, taking into account the aim of the study and the availability and accuracy of the statistical data specified for the process/phenomenon analyzed (Niemeijer, 2002, Niemeijer, de Groot, 2008). In this case, the indicators selected are inspired by the following research paper, reports and studies: Regional

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disparities in Romania 1990 - 1994 (1996), Green Paper. Regional Development Policies in Romania (1997), Preda, 2003, Romania's Millennium Development Goals. Progress Report, 2010, Sandu, 2003, 2011, Kaufmann et al., 2007, Michalek, Zarnekow, 2012, Ianoş, 1997, 1998, 2000.

The identification of areas that are favourable and less favourable to socio-economic development is made based on a series of 21 statistical indicators. The following statistical indicators might have consequences for the socio-economic development level: 1) the share of dwellings with kitchen out of the total number of dwellings (KITCH); 2) the share of dwellings with bathroom out of the total number of dwellings (BATH); 3) living area (sqm/inhabitant) (LIVING); 4) the length of the water supply network (km) (WATER); 5) the length of the sewerage network (km) (SEWER); 6) the green space area (sqm)/inhabitant (GREENSP); 7) hospital beds/1,000 inhabitants (HBED); 8) physicians/1,000 inhabitants (PHYS); 9) variation rate in the number of employees between 2007 and 2012 (%) (EMPLOYEES); 10) unemployment rate (%) (UNEMPLOY); 11) employment rate (%) (EMPLOY); 12) rate of employment in agriculture (%) (EMPLOYAGR); 13) rate of economic dependency (%) (DEPENDEC); 14) infant mortality rate (‰) (INFANT); 15) vitality index (%) (VITALIT); 16) number of pupils enrolled in the primary and secondary education system (PUPILS); 17) number of high school graduates out of the total population over 20 years of age (%) (GRAD); 18) goods transported on inland waterways (thousands tones/km) (TRANSP); 19) number of economic agents (ECAG); 20) physiological density (inhabitants/farm-land area in ha) (PHYSDENS); 21) number of tourist accommodation units (TOUR).

These statistical indicators might influence the general level of socio-economic development and the territorial distribution of the patterns of socio-economic development. A graph matrix was made to establish the degree of determination or subordination of each indicator on a dichotomous query. The value of the determination score (D) reflects the level of dependence or independence on a scale ranging theoretically between +1 (fully determinant) and -1 (totally determined) (Stângă, Grozavu, 2012). In our study, determination score values are very low (positive ones between 0.050 and 0.250 and negative ones between (-0.100) and (-0. 050) (Table 1).

In these conditions, the authors of this paper have considered all the 21 statistical indicators to identify the territorial patterns of each of the seven secondary indexes, the selected indicators being analyzed in terms of their spatial distribution and effects on the secondary index they belong to.

The statistical indicators selected are measured in different units and this comparative analysis of a series of statistical variables with so many characteristics requires standardization. The standardized value of the statistical indicator "X "for the "i" LAU is Xsi = (Xi – Xmin)/(Xmax – Xmin), where Xi is the absolute value of the statistical indicator "X" for the LAU "i", Xmax is the maximum value of X indicator and Xmin is the minimum value of the Xi indicator. The statistical indicators are grouped by seven categories, reflecting the main aspects of socio-economic development: dwellings (DWELL), public utilities infrastructure and green area (INFRGREEN), health (HEALTH), employment/unemployment (LABOUR), demography (DEMO), education (EDU) and local economy (ECONOMY). The seven categories mentioned above represent the secondary index assessed as Hull Score and they are the main components for the complex index of development (INDEV) computation. The Hull Score, with a mean of 50 and a standard deviation of 14, varies between 1 and 100 and it is calculated as the sum of the direct or reverse relation of each statistical indicator or index in relation with the development process: "the indicators with a direct influence have been considered in the determination process as positive and those with a reverse influence were assumed to be negative" (Ianoş, 1997, p. 105, Regional disparities in Romania 1990 - 1994, 1996). Taking into account these remarks, the formula for calculating each secondary index as a Hull Score and the complex index of development are shown in Fig. 3.

Table 1 Categories, initial indicators and selected statistical indicators for identifying the territorial patterns of socio-economic development

Category	Indicators	D=(IS-DS)/n-1 (n is the number of indicators in the matrix)	Indicator selected
DWELL	KITCH	-0.100	
	BATH	-0.150	
	LIVING	0.050	LIVING
INFRAGREEN	WATER	0.150	WATER
	SEWER	-0.050	
	GREENSP	0.000	
HEALTH	HBED	0.100	HBED
	PHYS	0.050	
LABOUR	EMPLOYEES	0.000	
	UNEMPLOY	0.000	
	EMPLOY	0.000	
	EMPLOYAGR	0.100	EMPLOYAGR
	DEPENDED	-0.300	
DEMO	INFANT	0.100	
	VITALIT	0.150	VITALIT
EDU	PUPILS	-0.100	
	GRAD	0.100	
ECONOMY	TRANSP	0.2500	TRANSP
	ECAG	0.2000	
	PHYSDENS	0.0000	
	TOUR	0.1500	

Source: authors' compilation

All indicators are equally weighted in the final index and three territorial patterns of socio-economic development are worked out: very low, low and average.

Aiming to integrate the patterns of socio-economic development of the Romanian Danube Valley into general picture, that of the whole of Romania, the paper uses herein the relative distances ranking method (Goschin, 2008, Iordan, Chilian, 2004, Voineagu et al., 2007, Avrămescu, 2012, Anghelache et al., 2013). The method involves the transformation of the initial values of variables referred to the relative values of the best performance (value) of each criterion (variable). In this study, the variant of the relative distances ranking method used, the best performance for a variable was replaced by the national average value of that variable (Goschin et al., 2008): each statiscal indicator (KITCH, BATH, etc.) is divided by the national average values of the mentioned indicators.

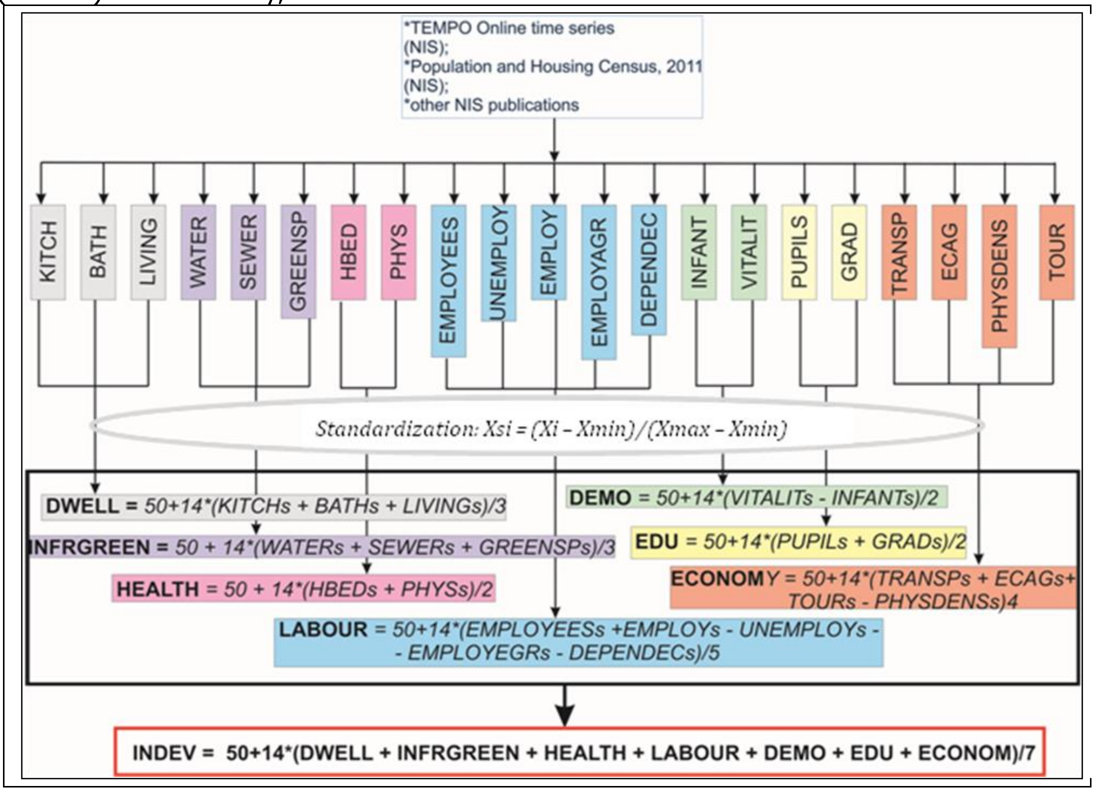

Fig.3: Index design (Source: authors' compilation)

Regarding the indicators with a negative influence on the process of development (e.g. UNEMPLOY, INFANT, DEPENDEC, etc.), the relative distance to the national average for the territorial unit "i" is adapted to this particularity by inverting the fractions (the national average value of these variables being divided by the value specific for territorial unit "i"). According to the methodology of relative distances ranking, the next step is to calculate the average relative distance of each local territorial unit to the national average as a simple geometric mean of the previous ratios for all variables. The local territorial units can be ranked according to the decreasing value of the average relative distance (assimilated to the complex index of territorial disparities (CID).

Results

Identifying and analysing the territorial differences of the secondary index

The secondary index of dwellings comfort (DWELL) shows that the lowest values are clustered over relatively wide areas in Dolj and Brăila counties, and smaller ones in Teleorman, Giurgiu and Ialomiţa counties. The administrative units with a high level of dwellings comfort represent 63% of all of the Danube Valley territorial administrative units, including county-seats, municipia and towns. Some rural units, situated in the neighbourhood of urban centres (Cazasu close to Brăila, Şendreni near Galaţi) have a score comparable to town, because townspeople have built residential places there; a similar situation is specific to the tourist rural settlements located in the Iron Gate Defile and in the Danube Delta (Fig. 4).

The living floor/person (LIVING) is the statistical indicator selected as being determinant for the DWELL category (D = 0.050). The values of this indicator by residential environments show greater scarcity of dwellings in town (18.6 m^2/person) than in the country-side (20 m2/person). In the last ten years, the average living floor/person has been increasing, due especially to increases in the country-side. The largest living floor/person (over 20 m2/person) have the towns of Vânju Mare, Corabia, Sulina, Zimnicea, Moldova Nouă, Orşova, exceeding the average value of the region; similarly, more than 100 communes (in decreasing oder: Carcaliu, Sfântu Gheorghe in Tulcea County, Goicea, Ciuroiaşi in Dolj

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **164-177***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.168.d***

County and Devesel, Pristol, Burila Mare in Mehedinţi County), register over 30 m2/person.

Mapping the secondary index of public utilities infrastructure (INFRAGREEN) shows that the very low development level is widespread (91% of all the Danube Valley territorial administrative units) because of the null values specific to many rural administrative units in the case of indicators such as "length of the water supply network" (30% of all the Danube rural and urban settlements) and "length of the sewerage network" (in the Valley sectors of the Dolj, Olt, Teleorman and Giurgiu counties the majority of the rural settlements are not connected to the sewerage system). The low level of development in terms of the public utilities infrastructure and green space is characteristic of some Danube towns (e.g. Dăbuleni, Bechet, Vânju Mare, Ţăndărei, Sulina), even municipia (Turnu Măgurele) and is caused by the low values of the length of the water supply and sewerage networks. As regards the "green space area/inhabitant" indicator, small towns meet the EU standard (e.g. Băileşti Municipality has the highest green area/inhabitant (86 m2/inh.), due to the position of the "Balta Cilieni-Băileşti" Protected Area of National Interest inside its administrative boundaries). The average development level registered by the public utilities infrastructure and green space is characteristic of the Danube county-seats and of some other small towns (due to the highest values of the green space area/inhabitant indicator – e.g. Băileşti and Bechet Dolj County, Ianca, Brăila County) (Fig. 5).

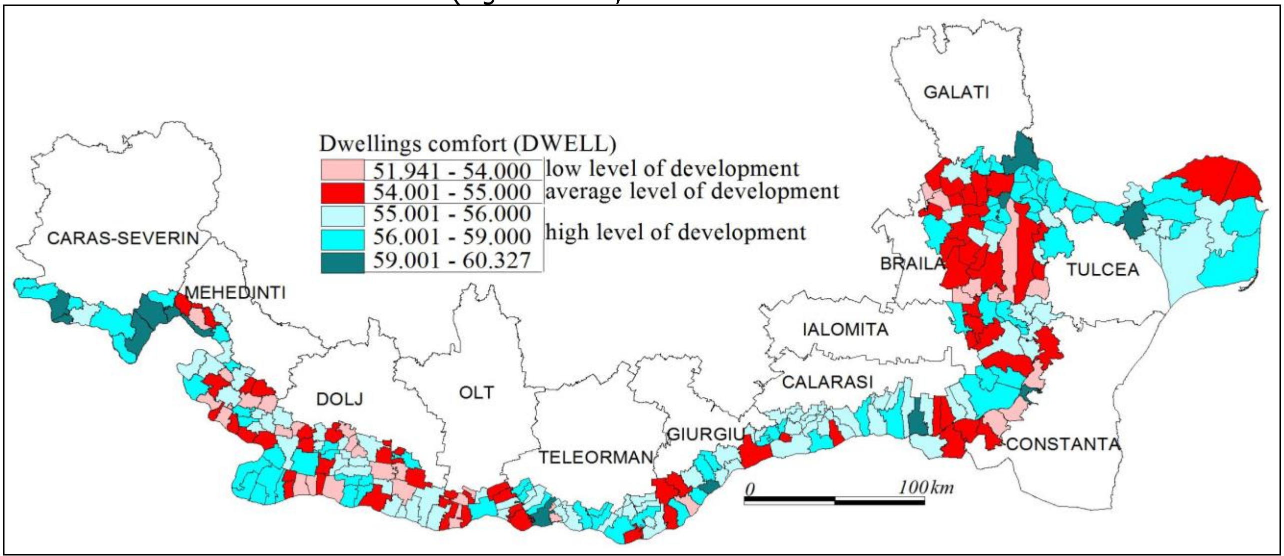

Fig.4: The territorial patterns of dwelling comfort
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

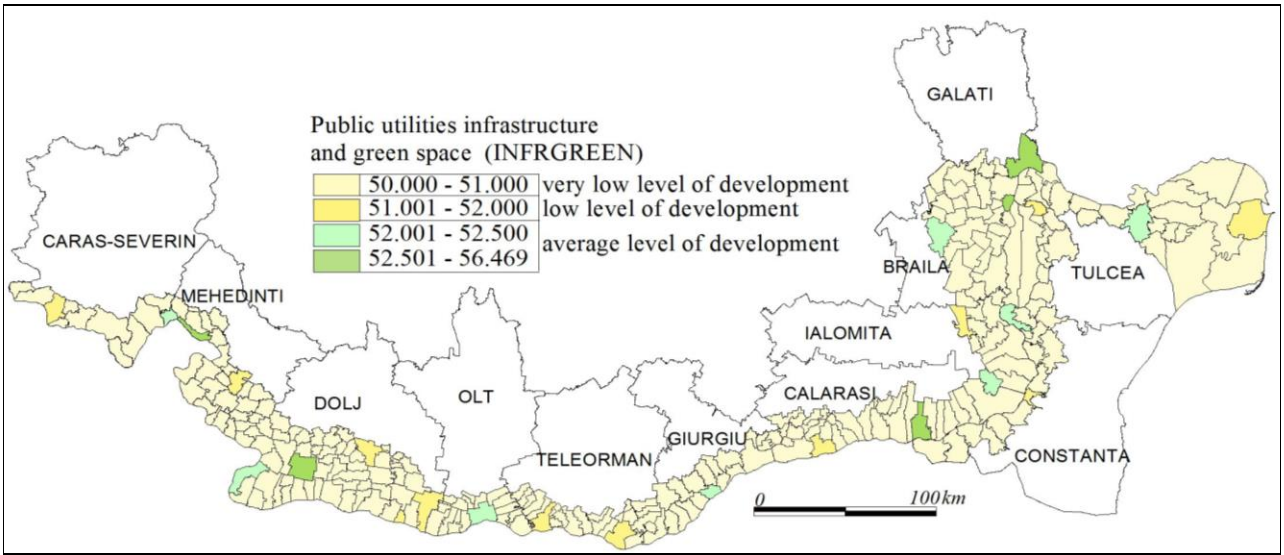

Fig.5: The territorial patterns of public utilities infrastructure and green space development
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

The length of the water supply network (km) (WATER) is the statistical indicator selected as being determinant for the INFRAGREEN category (D = 0.150). In theory, a central-based water supply system, which treats, surveys and permanently controls the water pumped into the network, warrants quality and safety (Chiriac et al., 2001). In practice, the micro-biological and chemical tests performed by some Danube county environmental protection agencies, which monitor the quality of water, have revealed that 99.3% in town and only 68% in the villages of supplied water meets drinking water standards (Dolj County Environmental Protection Agency, 2010). In 30.4% of all Romanian Danube Valley LAU2 (founded inside the Dolj, Giurgiu, Teleorman and Olt counties) are not connected to the drinking water supply system. Another 27 localities (10% of all) hold less than 10 km. In the Danube countryside 33% of the population live in settlements unconnected to the water supply system. Water is taken from people's own fountains and wells and water catchments which usually are improper to drinking. These are the only alternative supply sources. The low quality is the consequence of the absence of a sewerage system, insufficient waste water treatment, improper building of wells, household waste dumps, etc.

The secondary index of infrastructure and human resources in the health system (HEALTH) registers very low and low levels of development in 91% of all the Danube Valley territorial administrative units (half of them have a very low level) because of the null values of "hospital beds/1,000 inhabitants" indicator and the sub-unity values of "physicians /1,000 inhabitants" indicator. Average and high levels of development have 23 territorial administrative units, the majority being urban localities and only 3 rural settlements. The health care index (Dumitrache, 2004) indicates the geographical distribution of health-care resources in Romania, the most disadvantaged counties being located along the Danube Valley: Ialomiţa County is the poorest in terms of health-care resources, limited resources being in the area of Giurgiu, Teleorman, Olt, Mehedinţi, Brăila and Tulcea counties (Fig. 6).

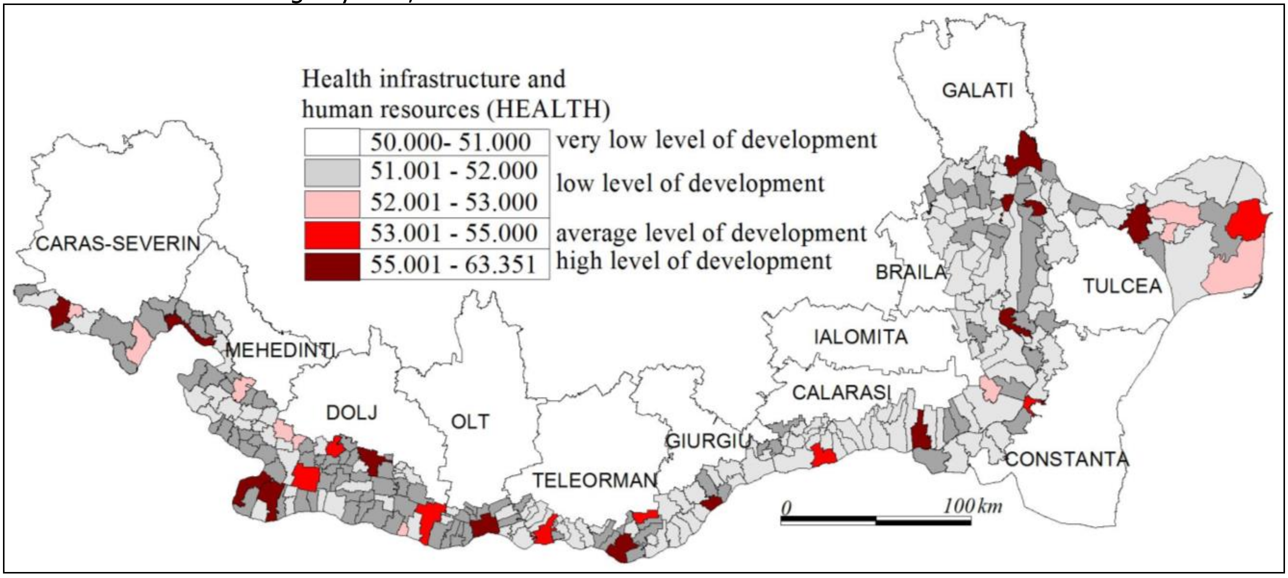

Fig.6: The territorial patterns of the health infrastructure and human resources
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

The number of hospital beds/1,000 inhabitants (HBED) represents the statistical indicator determinant for the HEALTH category (D = 0.100). In Romania, the value of this indicator was of 5.7 in 2013, but according to the National Health Strategy, European values of 4.8 should be attained by 2014-2020. Out of all 266 Danube LAU2, no more than 20 have one or several hospitals (health-centres included) with 9,819 beds in all. The average value of this indicator (5.7 in 2011) results from a value range between a minimum of 5 beds/1,000 inhabitants (Feteşti, Ialomiţa County) and a maximum of 50 beds/1,000 inhabitants (Poiana Mare rural administrative units in Dolj County, population of 10,740 where they have a psychiatry hospital with 540 beds).

The secondary index of employment and unemployment (LABOUR) has the lowest values (44.391) in 97.3% of all of the Danube Valley LAU2, highest ones (51.897) being recorded only in six rural settlements. In fact, the great majority of Danube settlements have alarming labour market problems, as a result of the cumulative effects of restructuring the town industries (top specialisation in the metallurgy in Galaţi, Călăraşi, Ziminicea and Tulcea sector and in the chemical industry in Turnu Măgurele (Ianoş, 2000). The effects of restructuring the town industry was primarily in the downscaling of specific activities and even in stopping them altogether, reducing jobs and closing down units, hence growing unemployment. Along the Romanian Danube Valley, urban economies were severely affected by the restructuring process, the rural

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 164-177
http://dx.doi.org/10.5775/fg.2067-4635.2015.168.d

economy being dominated by subsistence. The economic-financial crisis that started in 2008 had immediate and generalised consequences in the territory by increasing the number of the unemployed population (Fig. 7).

The rate of employment in agriculture (%) (EMPLOYAGR) represents the statistical indicator selected for the LABOUR category (D = 0.100). The Danube Valley rural settlements are largely engaged in agriculture. As expected, the structure of the occupied urban population is diversified, with services dominating (Drobeta-Turnu Severin, Bechet, Corabia, Calafat, Giurgiu, Turnu Măgurele, Călăraşi and Sulina), however, industrial activities hold a good share in the occupational profile of the local workforce (Galaţi, Tulcea and Brăila). The territorial distribution of the rate of employment in agriculture shows that the elevated values of this indicator correlate very well with the highest values of the general employment rate (easily observable in the settlements of Balta Brăilei and in some valley sectors of Giurgiu, Olt and Mehedinţi counties).

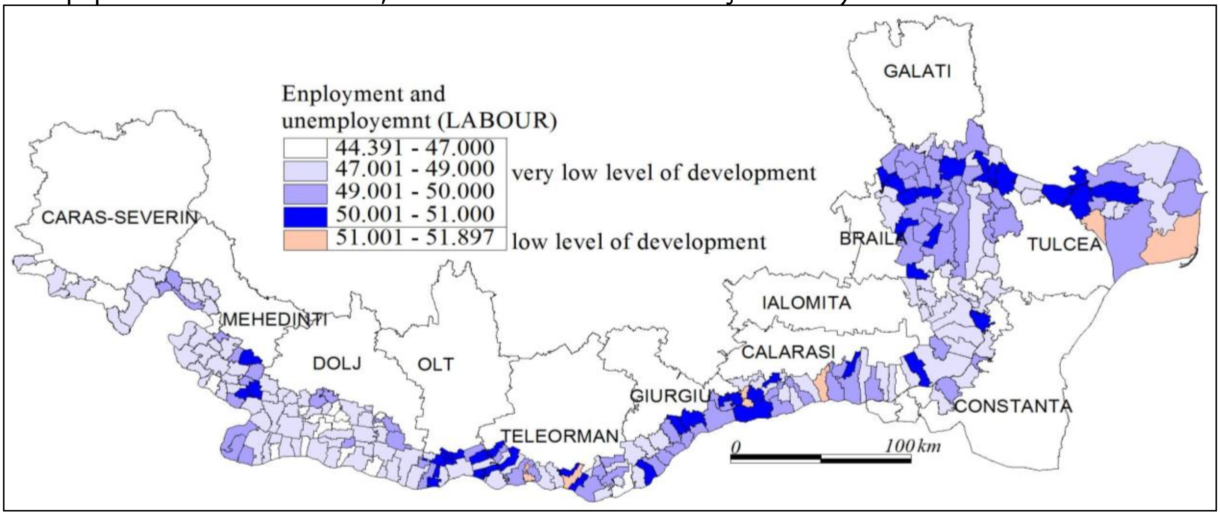

Fig.7: The territorial patterns of labour market development
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

The majority of the Danube urban and rural localities (68.1% total territorial units) register a very low development level in terms of the secondary index of demographic characteristics (DEMO): the cause lies in a mix between the lowest values of the vitality index, which has a positive impact on the development process, and the highest values specific to the infant mortality indicator, that have a negative impact. This class is formed especially by rural administrative units, but there are some urban settlements, too (Orşova, Caraş Severin County and Turnu Măgurele and Zimnicea, Teleorman County). The low level of development is characteristic of one third of all the Danube territorial administrative units spread along the Valley, with some territorial concentrations around the county-seat muncipia (e.g. the cases of Galaţi and Brăila and their surrounding territorial administrative units). The average level is specific only to three territorial administrative units where the vitality index has the highest values (Ţăndărei Town – 307.3% and Stelnica – 170% in Ialomiţa County and Roseti – 150% in Călăraşi County) (Fig. 8).

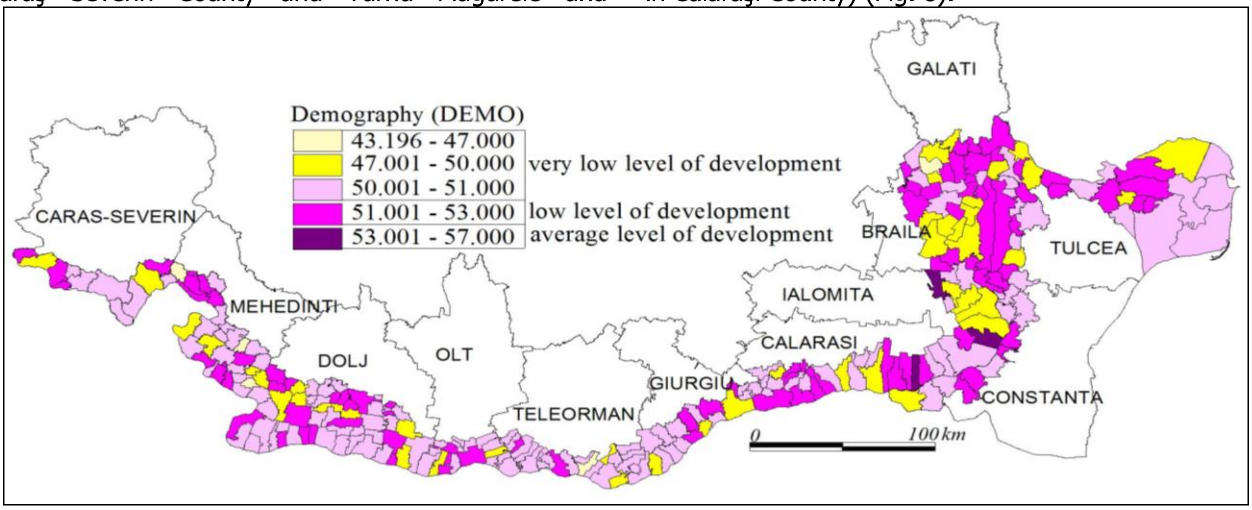

Fig.8: The territorial patterns of demography aspects
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

The vitality index (VITALIT), the statistical indicator selected for the DEMO category (D = 0.150), represents the percentage ratio between the number of live newborns and of deceased people over a certain period of time. Depending on the number of newborns (higher, lower, or equal to the deceased), the vitality index is lower, higher or equal to 100 (when index values near 100, or equal it, the population tends to become stationary, in the absence of migration its number remaining unchanged; when the index tops 100, there are more newborns than dead people and the population tends to increase).

In 2011, the vitality index value of 52.87 indicated a numerical fall in the Danube Valley population, because simple reproduction had not been attained. A detailed analysis of this index by Danube counties shows values above 100 in Călăraşi (6 settlements), Constanţa and Mehedinţi (each with 4 settlements), Brăila and Ialomiţa (3 settlements each), Dolj (2 settlements), Galaţi, Tulcea and Caraş-Severin (one settlement each). Settlements in Olt, Teleorman and Giurgiu counties failed to reach the 100 index value, suggesting that the deceased were in excess of newborns. The low vitality index score in the majority of settlements means the numerical decrease of inhabitants through a negative natural balance and migration of population.

The secondary index of education (EDU) shows that very low and low levels cover most of the Romanian Danube Valley: 93.6% of all territorial administrative units. Very few units (4.5% of total) fall into the class of average education development level: these are urban settlements and some rural localities (with a large number of pupils enrolled in primary and secondary schools, as well as in high schools). The three large Danube county-seats (Galaţi, Brăila and Drobeta Turnu-Sevrin) represent the class of high education development level (Fig. 9).

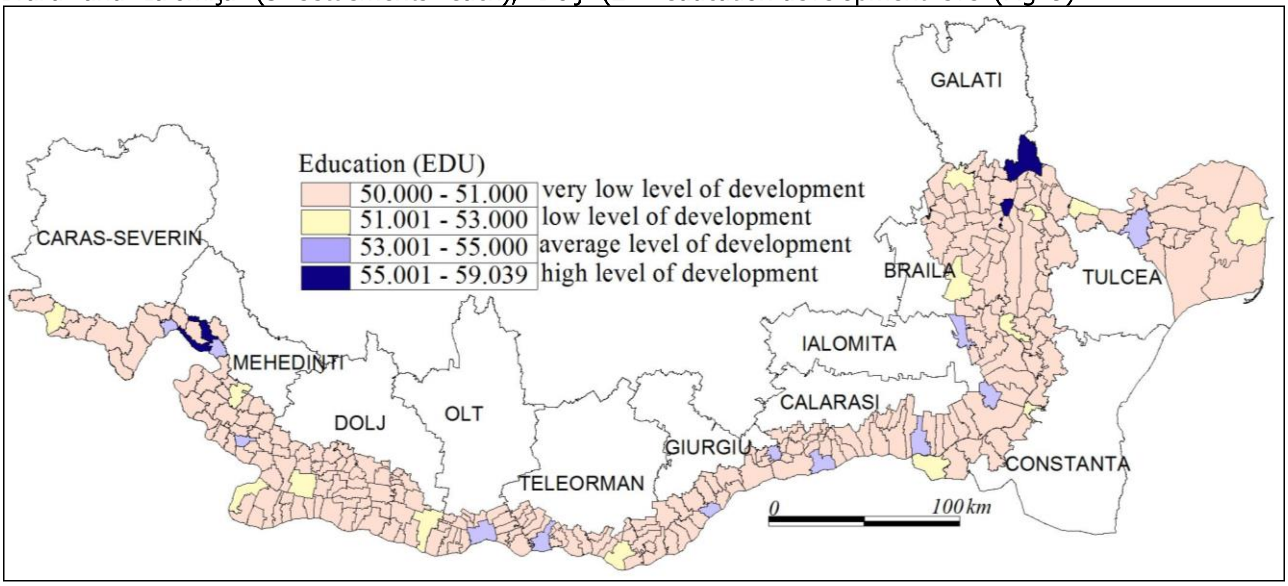

Fig.9: The territorial patterns of the education development
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

The statistical indicator selected for the EDU category (D = 0.100) is the percentage of high school graduates from the total population aged over 20 years (GRAD). In the majority of all Danube territorial units (86.8%), the values of the indicator concerning the percentage of high school graduates from the total population aged over 20 years are null because the high schools are present only in the towns/municipia and in six rural settlements (Izvoru Bârzii, Cujmir, Şimian - Mehedinţi County, Hotarele - Giurgiu County, Poiana Mare, Cetate - Dolj County). Almost half (48.2%) of all high school graduates (16,918 persons) is concentrated in the 55 high schools located in Galaţi, Brăila and Drobeta Turnu-Severin county-seat municipia.

The percentage of high school graduates from the total population aged over 20 years registers the highest values (still only 3% - 6.6%) in some rural administrative units in which high schools operate (Izvoru Bârzii, Cujmir and Hotarele). This is the effect of the shrinking population aged over 20 years in these settlements, compared with the situation specific in the urban settlements, especially in the county-seats muncipia, where the population aged over 20 years is larger and the percentage values are much smaller (Galaţi – 1.9% and Brăila – 1.6%).

The secondary index of the economy (ECONOMY) shows the overwhelming predominance of the very low level of development (96.6% out of the total Danube territorial administrative units). This class includes some of the small Danube towns (e.g. Dăbuleni, Segarcea and Băileşti – Dolj County, Însurăţei – Brăila County, Ţăndărei – Ialomiţa County) and the majority of small port-towns (Moldova Nouă and Orşova – Mehedinţi County, Bechet, Calafat and Corabia - Dolj County, Turnu Măgurele and Zimnicea –

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume XIV, Issue 2 (December 2015), pp. 164-177
http://dx.doi.org/10.5775/fg.2067-4635.2015.168.d

Teleorman County, Giurgiu – Giurgiu County, Olteniţa – Călăraşi County, Hârşova and Cernavodă – Constanţa County, Sulina – Tulcea County) (Fig. 10).

Many of the port-towns lost their economic basis and population, becoming peripheral towns (Hardi, 2013).

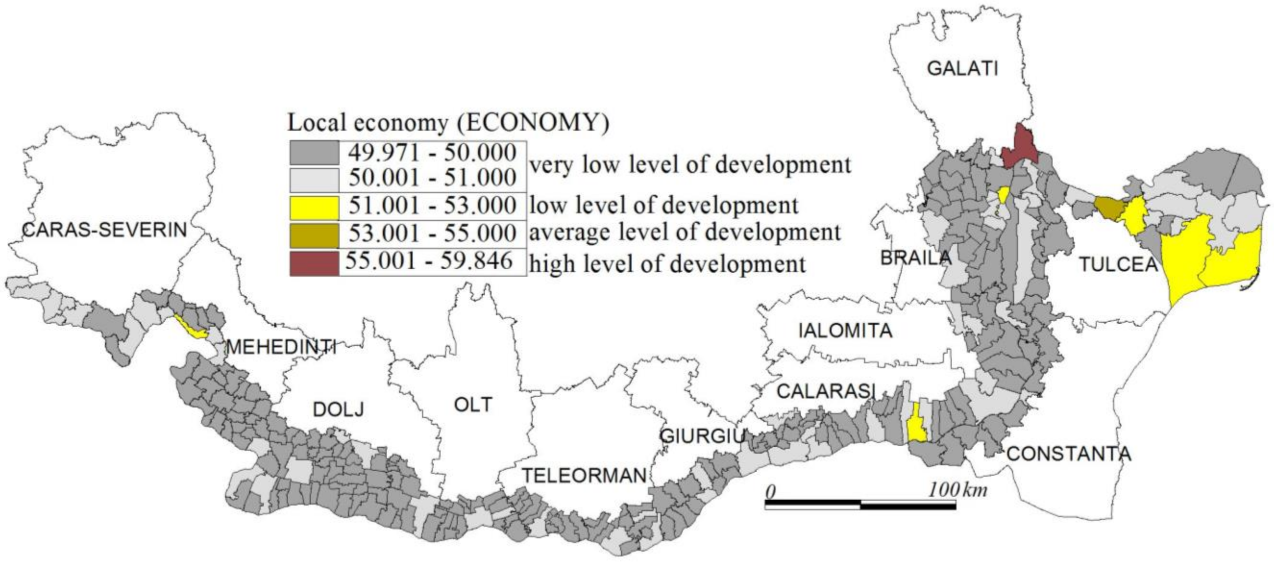

Fig.10: The territorial patterns of local economic development
(Source: 2011 Population and Housing Census and TempOnline statistical data processed and mapped by the authors)

Only six Danube LAU2 have a low developed economy. It is the case of four municipia discharging complex urban economic activities, especially port-related ones (Tulcea, Drobeta Turnu Severin, Brăila and Călăraşi, which cummulate 22% of all the goods transported on the Danube River), second ranking two rural settlements (Murighiol and Sfântu Gheorghe) located along the Sfântu Gheorghe Arm, in the Danube Delta tourist area. Tourism is the main activity at Somova, is the only territorial unit representative for an average development level. The high development level class includes one LAU2 alone: Galaţi Municipality, which is the most important urban and economic centre of the Lower Danube; it is the largest river-maritime port, located on the left bank of the Danube, which benefits from easy access to the Black Sea (The goods transported on inland waterways in 2012, INS, 2013), also having the largest iron-and-steel plant in Romania (ArcelorMittal Galați), which was state-owned until 2001 (former Sidex) (Popescu, 1991, 2000, Săgeată et al., 2004).

The goods transported on the Danube (thousands tones/km) (TRANSP) is the statistical indicator determinant for the ECONOMY category (D = 0.250). The Danube River in Romanian is the backbone of the Lower Danube and of the entire Danube Region and its economy (Fairway Rehabilitation and Maintenance Master Plan–Danube and Its Navigable Tributaries, 2014), connecting Rotterdam harbour (North Sea) to Constanţa harbour (Black Sea). The 20 Danube harbours facilitate the transport of goods (e.g. agriculture products, coal and lignite, crude oil, metal ores and other mining and quarrying products, wood and wood products, chemicals, chemical products, machinery and equipment, secondary raw materials and municipal waste dumps), the main harbours being Galaţi, Drobeta Turnu Severin and Tulcea, which cumulate 75.5% (3,860,385 thousand tones/km) of the total goods transported on the Danube.

Territorial patterns of socio-economic development

A synthetic profile of socio-economic development attributes in the Romanian Danube Valley was obtained by computing and mapping the complex index of development. In the light of this index, the Romanian Danube Valley settlements fell into three territorial patterns: very low, low and average (Table 2).

Table 2 Synthetic situation of the Romanian Danube Valley local administrative units in terms (LAU2) of patterns of development

INDEV values/ Patterns of socio-economic development	Number of LAU2	Population (inh.)
49,697 – 51,000 = very low level	162	489,673 (28.5%)
51,001 – 52,000 = low level	82	274,239 (15.9%)
52,001 – 56.119 = average level	22	960,016 (55.6%)
Romanian Danube Valley	268	1,723,928 (100%)

Source: authors' compilation

The very low pattern of socio-economic development is characteristic of the majority of Danube LAU2 which cumulate almost 29% of the total Romanian Danube Valley population. This type of socio-economic development is wide-spread along the Valley, being specific especially to the rural settlements (only one small town is included in this pattern, Însurăţei, Brăila County). The very low pattern of socio-economic development is the result of the structural imbalance at the demographic and economic levels and implicitly in the labour market. Also, this pattern of socio-economic development mirrors major deficiencies in the systems of health, education and public utilities, as well as in the low quality of dwellings (Fig. 11).

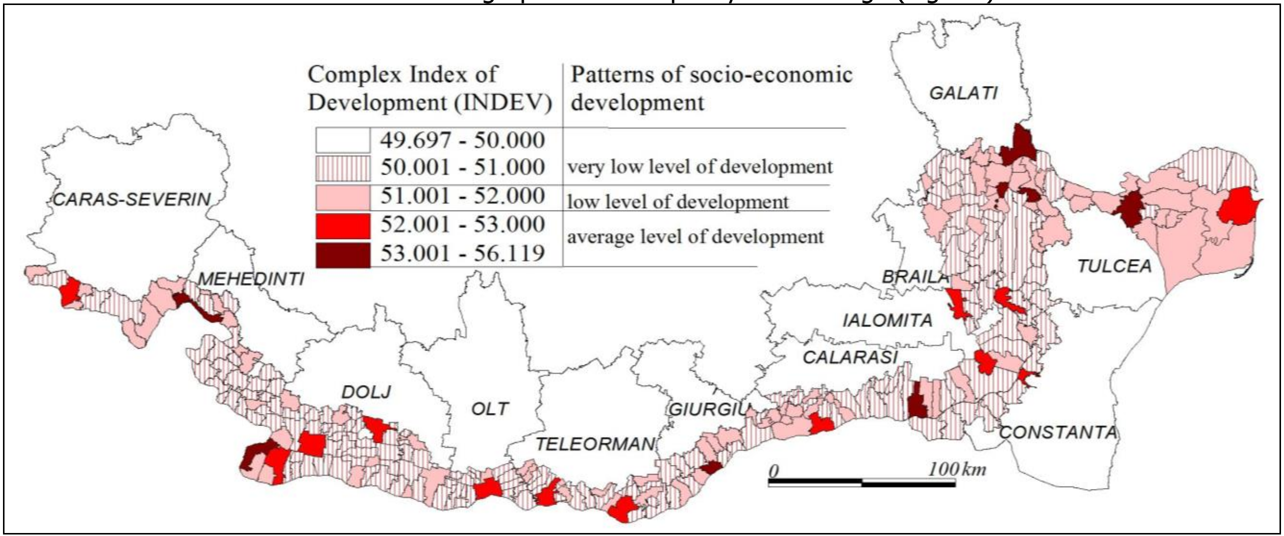

Fig.11: Territorial patterns of socio-economic development in the Romanian Danube Valley
(Source: authors' compilation)

The low pattern of socio-economic development is specific to 80 rural settlements and only 4 towns (Ianca, Brăila County, Isaccea, Tulcea County and Dăbuleni and Bechet, Dolj County). Their socio-economic situation is not much better than that of the very low development ones. The quality of dwellings level and in some cases of economic level (e.g. the rural administrative units located close to large cities, or discharging tourist activities in Danube Delta and the Iron Gate Defile) are the indicators promoting them in the Romanian Danube Valley hierarchy .

More than 20% of the Romanian Danube Valley population live in the 22 towns which fall into the class of average socio-economic development pattern. Their highest secondary index values have a positive impact on the general socio-economic development level mainly through the high quality of dwellings, general public utilities and more dynamic economies, moreover in Galaţi, Brăila and Drobeta-Turnu Severin where population is better-educated and the medical services are the best at regional level.

Comparing the national average values of each statistical indicator selected with the value specific for each territorial unit "i" and with the secondary indexes values analysed above, the Romanian Danube Valley, it falls into a general context of socio-economic development. In terms of territorial disparities in socio-economic development at micro-scale, it is important to underline that the values of the complex index of territorial disparities (CID) above unity (baseline = the national average) indicates the developed (leading) areas versus the national average, while values below unity designate the territorial units which need economic assistance (lagging areas).

In the Romanian Danube Valley, mapping the complex index of territorial disparities ranks between 0.21 and 2.53, revealing the existence of three disparity pattern degrees (Fig. 12).

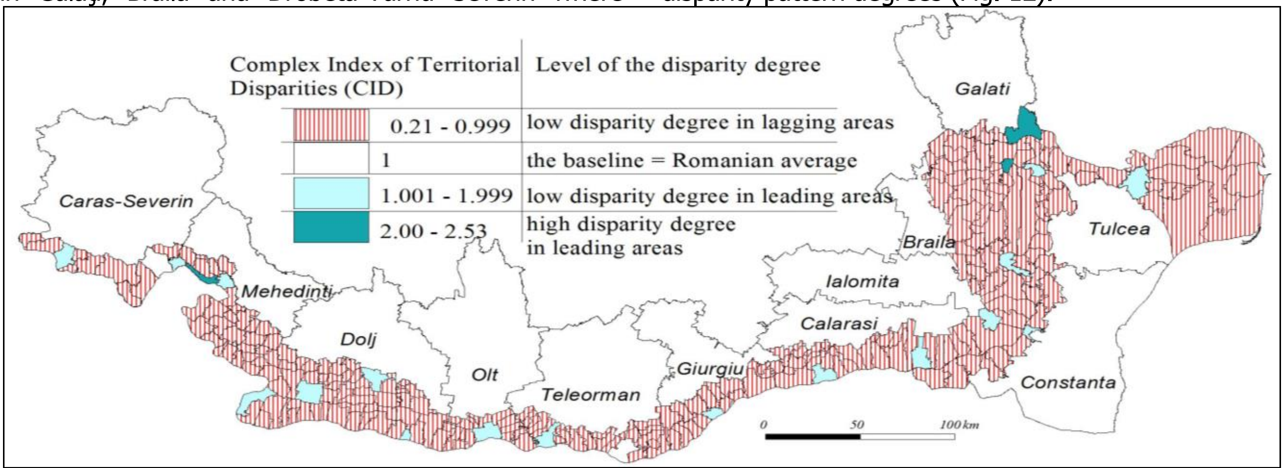

Fig.12: Territorial disparities in the Romanian Danube Valley

The spread of values below unity (92.4% of all of the Danube Valley territorial administrative units) shows the overwhelming predominance of lagging areas, forming the low disparity pattern degree.

This reality shows that 246 of the total of 263 Danube LAU2 units have a socio-economic development level below the national average.

Compared with the national average, the disparity patterns degrees in 7.6% of all Danube settlements are low and average. The majority Danube towns represent the leading urban segmented areas with low disparity degree, the difference between them and the national average being reduced.

Conclusion

The present study shows the Romanian Danube Valley to be a wide lagging area, with leading urban centres. The less-favoured areas, socio-economically developed are spread all along the Valley (rural lagging being in the Dolj, Teleorman, Ialomişa, Brăila and Tulcea counties). There are also urban centres with a good socio-economic potential for development (Galaţi, Brăila, Drobeta Turnu-Severin, Tulcea etc.), and small towns (Moldova Nouă, Băileşti, Corabia, Cernavodă, etc.). The influence of towns (especially of Galaţi, Brăila, Drobeta Turnu-Severin and Tulcea municipalities) on their neighbouring areas confirms the spillover effect.

Looking at the socio-economic life, the Romanian Danube Valley was and still is experiencing an uneven development. The basic solution for the less developed areas is to connect the local/regional communities to the opportunities offered by developing cities. The convergence of living standards will occur as benefits from leading urban areas spill over to surrounding communities and people who had left the rural and small urban lagging areas bring capital, jobs and modern ideas. The outflow of town population to the surrounding country-side, relatively recently experienced by Romania (Ianoş, 1998, WB, 2013), has resulted in suburbanization in metropolitan area Galaţi-Brăila within the Romanian Danube Valley. The development policy should focus on measures to create conditions for the rural to absorb the positive effects of development from urban areas and reinforce their functional links.

Key investment priorities should be different in the Romanian Danube Valley between leading and lagging areas. Driving forces in lagging areas might consist in basic public utilities, education, health, and the implementation of measures targeting the marginalised groups or communities. The importance of public utilities is reflected by the statistical coefficient of correlation between the ranking values of secondary indexes of the public utilities infrastructure and services and the INDEV values. This coefficient is more than representative: R2 = 0.897. Also, the values of this statistical coefficient of correlation and human resources in health and education systems and the INDEV values are statistically representative (R2 = 0.885 and R2 = 0.780, respectively) suggesting that an increase in these domains might ensure a higher socio-economic development for lagging areas.

Improving the connective infrastructure between cities and surrounding areas and promoting quality-life investments represents a key driving-force for turning lagging areas into leading areas. At mezo-scale, improving the connection between developed areas and less-favoured areas at macro-scale (country) level would enable efficient concentration of resources and spillover effects.

The existing geographic distribution of socio-economic development patterns in the Romanian Danube Valley is the result of driving forces which have actioned in a distinctively and with variable intensity during the last 25 years as well as before 1989. In this respect, the future research agenda includes assessement of the main changes in the territorial patterns of socio-economic features, the outcome outlining the future spatial trends of less-favoured and of developed areas. The future research agenda will be in line with the EUSRD priority areas, especially with PA9 - "*Investing in People and Skills*", which referes to this topic of great importance not only for the Danube Region, but also for Europe 2020.

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The Human Pressure on the Environment Quality Through Land Use in Northern Side of the Someșan Plateau – Romania

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Abstract

The analysed rural area has encountered, over the years, a series of economic, demographic and especially ecological changes, driven by the development of the society. Most of these changes had negative effects upon the environment. Human activities have also determined positive and negative topographic changes on the environment. The economic activities taking place in this rural area suffer from a lack of diversity and focus only on the usage of local resources, mainly agricultural and forestry. This is the main reason that caused the increase of the human impact upon the landscape and its components.
The current state of the quality of the environment and the changes it has suffered should have a significant importance for the rural community, so that one may issue some measures for protecting the ecosystems, for a sustainable development process to take place. The present study analyses the main human activities from the northern part of the Someșean Plateau in order to draw attention to the impact of human pressure on the quality of the environment.

Keywords: *human pressure indices, environmental indices, land use, Someșan Plateau, Romania*

Rezumat. Presiunea umană asupra calității mediului prin modul de utilizare a terenurilor în partea nordică a Podișului Someșan – Romania

De-a lungul timpului, spaţiul rural analizat s-a confruntat cu o serie de modificări de natură economică, demografică, dar mai ales ecologică impuse de dezvoltarea societăţii, modificări care în cea mai mare parte au avut efecte negative asupra mediului. Activităţile antropice asupra mediului au provocat schimbări topografice, unele positive, altele însă negative, practicile economice din acest spaţiu rural necunoscând o diversificare accentuată, bazându-se doar pe valorificarea resurselor locale, în special agricole şi forestiere, aspect ce a cauzat o accelerare a impactului antropic asupra peisajului şi componentelor sale.
Inventarierea situaţiei actuale a calităţii mediului şi a modificărilor apărute ar trebui să deţină un rol foarte important pentru comunitatea rurală, în vederea identificării unor măsuri de protecţie a ecosistemelor în scopul asigurării procesului de dezvoltare durabilă. Studiul de față își propune spre analiză situaţia actuală a principalelor activități antropice din zona nordică a Podișului Someșean, pentru a evidenția impactul presiunii umane asupra calităţii mediului.

Cuvinte-cheie: *indici de presiune umană, indici de mediu, mod de utilizare a terenurilor, Podişul Someşean, Romania*

Introduction

The rural space, seen as the space that started to function in the same time with the establishment of population and the first permanent settlements, represents the direct result of people transforming the natural environment in order to meet their necessities. Keeping the quality of the environment high for a long period of time provides to those communities the resources necessary for living. Exceeding the environmental tolerance limits because of an excessive usage determines a non-natural, artificial aspect of the environment with negative effects upon the rural sustainable development capacity. Ionescu (1989) and Dumitraşcu (2006) expressed their opinions that the artificial is not beneficial for the human society unless it becomes a part of nature, aiming to enhance the comfort and well-being of humanity, helping to preserve and revitalize the natural.

The human pressure on the environment represents a synthetic indicator of its quality and of its degree of transformation following the human intervention (Goudie and Viles, 2003; Goudie, 2006). Anthropogenic activities exert pressure upon the environment, pressure that differs according to the type of space and society. For instance, the agricultural, forestry and industrial exploitation, as

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **178-189***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.198.d***

well as transportation, accelerate the impact upon the environment (Dumitraşcu, 2006). Mander and Jongman (1998) asserted that the analyses of the different aspects of the anthropogenic impact upon the rural space offer important information used in planning and sustainable development of the future.

In Romania, after 1990, the rural spaces where most of the land was used for agriculture have suffered important changes under the influence of factors such as the decollectivization of the former collectivized farms under the communist regime and the growth of private owners of the land (Bălteanu and Grigorescu, 2006). These two factors influenced the usage of the land in the analysed rural area as well.

In consequence, an analysis of the interaction between the agricultural activities and the components of natural environment is necessary in order to determine the environmental degree of equilibrium in favour of a sustainable development of the area.

Human pressure exerted on the environment is a synthetic indicator of the quality of the environment and the degree of artificial change of landscape (Dumitraşcu, 2006); it appears in different stages of evolution for all the 14 administrative territorial units (ATUs) that belong to the analysed rural space.

As a result, human pressure was evaluated analysing the spatial and temporal dynamics of the human pressure exerted through the different ways of agricultural land-use (Pătroescu, 1996; Pătroescu and Niculae, 2010), that one may draw attention to pressure factors and their effects on every commune.

Study area

The analysed rural space includes all the northern part of the Someşan Plateau, covering 852.64 sqkm (18.9%) of the total surface of the Someşan Plateau (4,500 sqkm), which is located in the north-western part of Romania, overlapping on the western part of the Transylvanian Plateau (Fig. 1). This geographical unit acts as a connection between the Eastern and Western Carpathians, sharing the same geological characteristics (Geografia României, 1987); it is, at the same time, a transition geographical unit between the Tisza Plain and the Transylvanian Plateau (Mihăilescu, 1969).

The geographical location of the analysed rural area has been very favourable for the development of human settlements, over the centuries, because of the existence of the following natural conditions: low altitude of the plateau (approximately 64.0% of its surface spreads between 200 m and 400 m altitude, Fig. 2), a wide opening to the western part of the country, which allowed the development of a mild temperate continental climate, the existence of a rich hydrographic basin (tributary to the Someş river) and the prevalence of forests and luvisols.

The analysed region is divided into 14 administrative territorial units (Băbeni, Benesat, Cristolţ, Gâlgău, Gârbou, Ileanda, Letca, Lozna, Năpradea, Poiana Blenchii, Rus, Şimişna, Surduc, Zalha), which are located in Sălaj county. Each one of these units usually comprises between 2 and 13 villages, having a total population of 25,818 inhabitants.

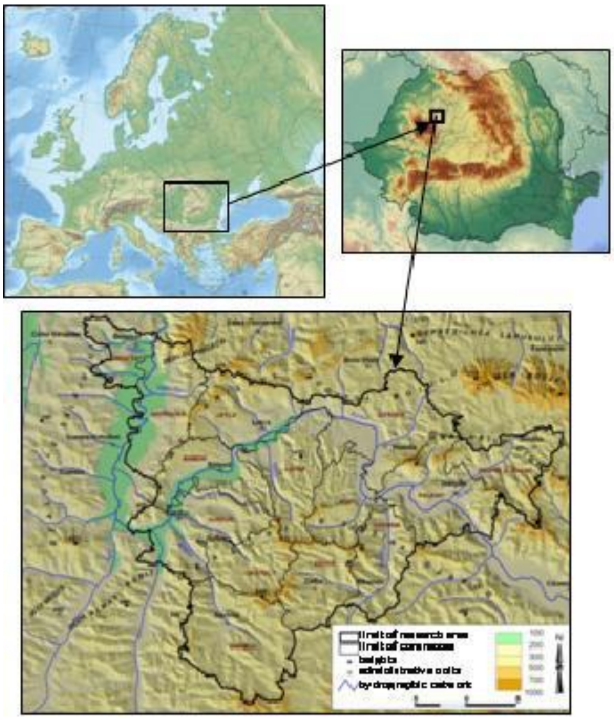

Fig. 1: Geographical location of the study area (Source: *accomplished by the authors*)

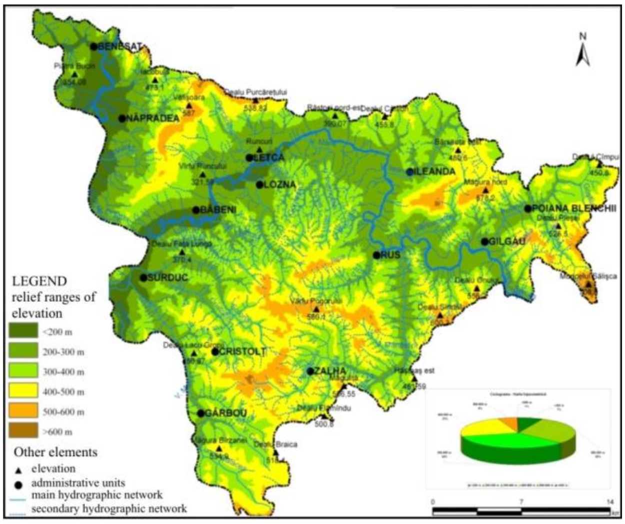

Fig. 2: Hypsometric map of the study area (Source: *accomplished by the authors*)

Methodology

In order to highlight the degree of human intervention upon the quality of the environment, a series of synthetic indices is used; their quantitative value is given by different quotients calculated based on statistical data (Pătroescu *et al.*, 2000; Bastian, 2002).

For the present case study the following indices were employed: human pressure upon the environment exerted through the different ways of agricultural land-use, naturality index, environmental transformation index. These indices are the result of the surface of the area (for a certain class of land use) divided by the total number of inhabitants of the administrative territorial unit. The results shall be analysed taking into consideration certain limits, which, once surpassed, endanger the quality of the environment.

The analysed period extends over a period of twenty-three years (1990 – 2014) and applying the formula above for each ATU, for the years 1990, 2002 and 2014, six human pressure indices have been calculated, using statistical data (regarding to population and land use) supplied by the National Institute of Statistics Sălaj. In addition, topographic maps (scale 1:25,000) and forest arrangement maps were used in order to emphasize the spatial and temporal variation of land use and indices; also, the database regarding land-use, provided by the European Environment Agency within CORINE (Coordination of Information on the Environment) Land Cover Programme, for the years 1990, 2000 and 2006, was re-projected in Stereo 70 - the national projection system and processed in a GIS environment.

In consideration of the changes regarding land use in the studied area, data for the years 1990 and 2006, which mark a transition period, was used. Land use classes within CLC (CORINE Land Cover) have been converted in accordance with the research methods.

Field observations have also taken place in order to display the interrelation between the existing cartographic materials, obtained statistical data and the facts on the ground, as well as understanding the studied phenomena thoroughly.

Results and discussions

Human pressure exerted upon the environment through different types of agricultural land use

Physical, chemical and biological processes can have either positive or negative effects on the structure and quality of the soil.

The natural qualities that a land possesses lead to a specific arable land use, which, in the past decade has been marked by certain dynamics, due to the fact that the soils in Sălaj county require a prior treatment because of their low fertility rate, so many private landowners have given up crop cultivation. Approximately 15% of the agricultural land in Sălaj county is affected by both natural and anthropogenic soil degradation processes and it requires the implementation of numerous measures for the ecological balance to be restored.

The effects of these processes have led to several forms of soil degradation: erosion (topsoil and depth), landslides, excavations and deposits, geological erosion, pollution, shore erosion, moisture in excess, salted lands, vegetation without value (Fig. 3).

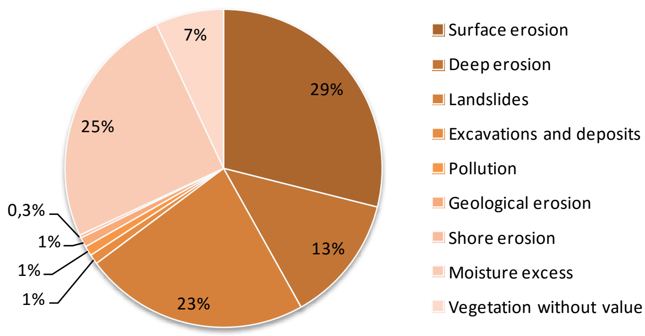

Fig. 3: Forms of land degradation

The human pressure index through the use of the agricultural land. The analysed area is characterized by a high rural aspect; in consequence, the agricultural landscape suffers the most important and rapid transformations. In this case, the human pressure index is the most appropriate one to employ for the present study.

The above mentioned index is measured in hectares per number of inhabitants; in 1990, it ranged between 0.77 and 2.15, the highest ones being recorded in ATUs such as Rus, Poiana Blenchii and Ileanda. In 2014, the rate of agricultural land use has grown and the human pressure index has recorded values between 0.85 (Surduc) and 3.13 (Gârbou).

According to the data in table 1, the number of ATUs where the human pressure index value is higher than 2 greatly increased from 1, in 1990 to 6 (Gărbou, Letca, Lozna, Poiana Blenchii, Rus, Şimişna and Zalha) (Fig. 4), in 2014. On the other hand, the number of ATUs where minimum values of the human pressure index through agricultural land use were recorded has decreased from 2, in 1990 (Surduc şi Benesat) to 1, in 2014 (Surduc).

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume XIV, Issue 2 (December 2015), pp. 178-189
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Table 1: Dynamics of human pressure index through agricultural land use (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	1.06	1.47	1.48	0.42
Benesat	0.98	1.24	1.29	0.32
Cristolţ	1.39	1.65	1.91	0.52
Gâlgău	1.17	1.35	1.43	0.26
Gârbou	2.14	2.70	3.13	0.99
Ileanda	1.67	1.79	1.95	0.28
Letca	1.48	1.89	2.11	0.63
Lozna	1.55	1.66	2.04	0.49
Năpradea	1.13	1.24	1.21	0.08
Poiana Blenchii	1.67	2.21	2.33	0.66
Rus	1.75	2.19	2.24	0.49
Şimişna	-	-	2.05	2.05
Surduc	0.76	0.82	0.84	0.08
Zalha	1.61	2.39	2.75	1.14
Average	**1.06**	**1.65**	**1.76**	**0.38**

Source: values calculated using statistical data provided by the National Institute of Statistics

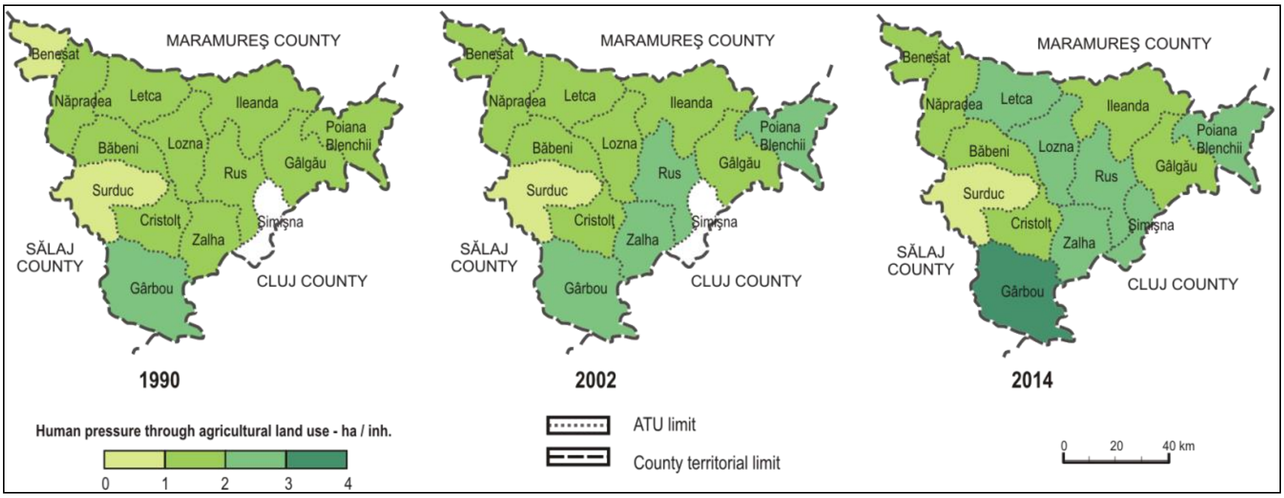

Fig. 4: Human pressure index exerted through agricultural land use (1990 – 2014) (Source: Processed after data provided by the *National Institute of Statistics*)

Between 1990 and 2014, the human pressure index through agricultural land use has recorded high values for all the ATUs - 7 (Năpradea), 10.3 (Surduc) and 45.5 (Gârbou), 69.7 (Zalha).

For a better understanding of the way the environment changes under the influence of human pressure exerted through agricultural land use, we compared the dynamics of the agricultural areas with the dynamics of population and reached the conclusion that with the increase of the agricultural land use and decrease of population size, the human pressure index exerted through agricultural land use has increased with approximately 27.3%.

The human pressure index through arable land use has recorded values between 0.42 and 0.89 in 1990; in 2014, the minimum value has increased with 12% and reached 0.47, while the maximum value has increased with 47%, reaching 1.31 (table 2). According to figure 5, in 2014, in comparison with 1990, only one ATU has recorded a value lower than 0.5 (Surduc), while 31% of all communes (Gârbou, Letca, Rus - Şimişna, Zalha) have recorded values higher than 0.91 in 2014, as in 1990 only 2 communes recorded values higher than 0.8 (Cristolţ, Gârbou).

Table 2: Dynamics of human pressure index through arable land use (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	0.59	0.75	0.77	0.18
Benesat	0.65	0.83	0.88	0.23
Cristolţ	0.81	0.94	0.83	0.02
Gâlgău	0.55	0.57	0.65	0.10
Gârbou	0.89	1.09	1.30	0.41
Ileanda	0.70	0.57	0.60	-0.10
Letca	0.68	0.85	0.96	0.27
Lozna	0.68	0.80	0.87	0.19
Năpradea	0.72	0.74	0.85	0.13
Poiana Blenchii	0.48	0.48	0.54	0.07
Rus	0.60	0.69	0.67	0.07
Şimişna	-	-	0.64	0.64
Surduc	0.42	0.42	0.46	0.04
Zalha	0.75	0.91	0.92	0.17
Average	**0.64**	**0.75**	**0.76**	**0.12**

Source: values calculated using statistical data provided by the National Institute of Statistics

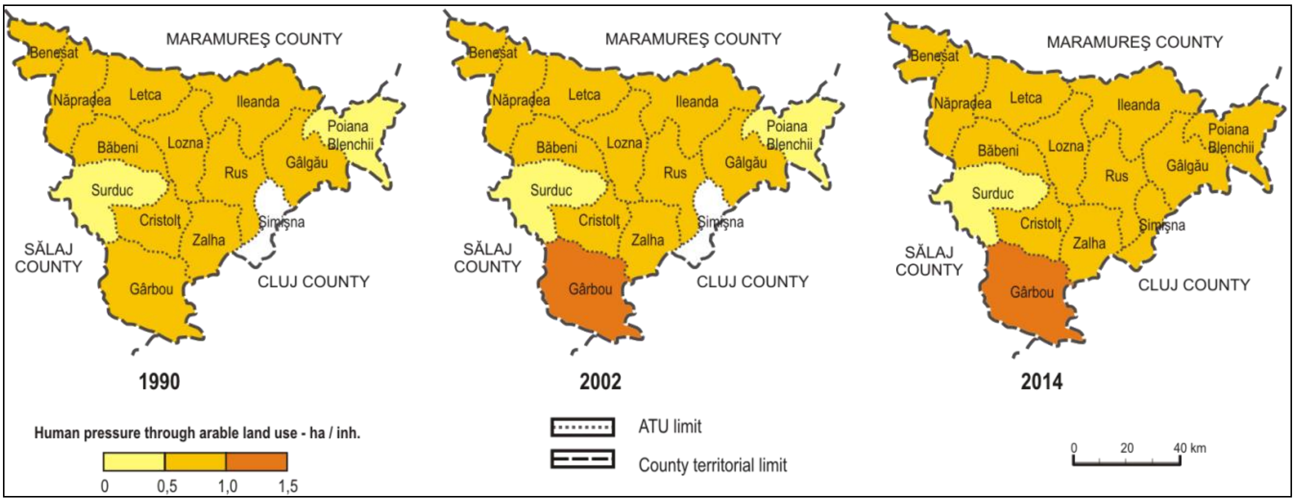

Fig. 5: Human pressure index exerted through arable land use (1990 – 2014) (Source: Processed after data provided by the *National Institute of Statistics*)

Generally, in the period between 1990 and 2014, the value of the human pressure index exerted upon the environment through arable land use has increased with 18.4%; however, significant differences between ATUs have been noted. Thus, the communes Letca, Rus-Şimişna and Gârbou have recorded an increase with over 40% of this index, 6 communes have recorded increases between 15%-40%, whilst in Cristolţ the value of the human pressure index remained constant – approximately 0.83 and only in Ileanda has decreased from 0.7 to 0.6.

Therefore, we can say that the arable usage of the land exerts a high pressure upon the components of the environment, fact which affects the structure and functionality of rural landscapes. The main reasons for the occurrence of this situation are: the main activity of the population is agriculture – especially subsidence crops and, in the same time, the surface of land used for arable purposes has decreased with 7.4% and the population with almost 22%.

The index of *human pressure exerted upon the environment through pastures* has recorded a specific spatial and temporal dynamics expressed by high values for all the years of observation (Table 3, Fig. 6). The values are situated between 0.29 (Benesat, Surduc) and 0.8 (Rus) in 1990, while in 2014 have decreased to 0.06 for Surduc and increased to 1.15 for Gârbou.

Table 3: Dynamics of human pressure index exerted upon the environment through pastures (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	0.43	0.66	0.60	0.17
Benesat	0.28	0.31	0.31	0.03
Cristolţ	0.45	0.57	0.75	0.30
Gâlgău	0.38	0.51	0.48	0.09
Gârbou	0.77	1.03	1.15	0.38
Ileanda	0.63	0.82	0.90	0.27
Letca	0.57	0.75	0.82	0.25
Lozna	0.72	0.65	0.95	0.23
Năpradea	0.36	0.45	0.25	-0.11
Poiana Blenchii	0.77	0.83	0.79	0.02
Rus	0.80	1.07	1.22	0.42
Şimişna	-	-	0.81	0.81
Surduc	0.29	0.35	0.22	-0.07
Zalha	0.59	1.09	1.03	0.44
Average	**0.53**	**0.67**	**0.65**	**0.12**

Source: values calculated using statistical data provided by the National Institute of Statistics

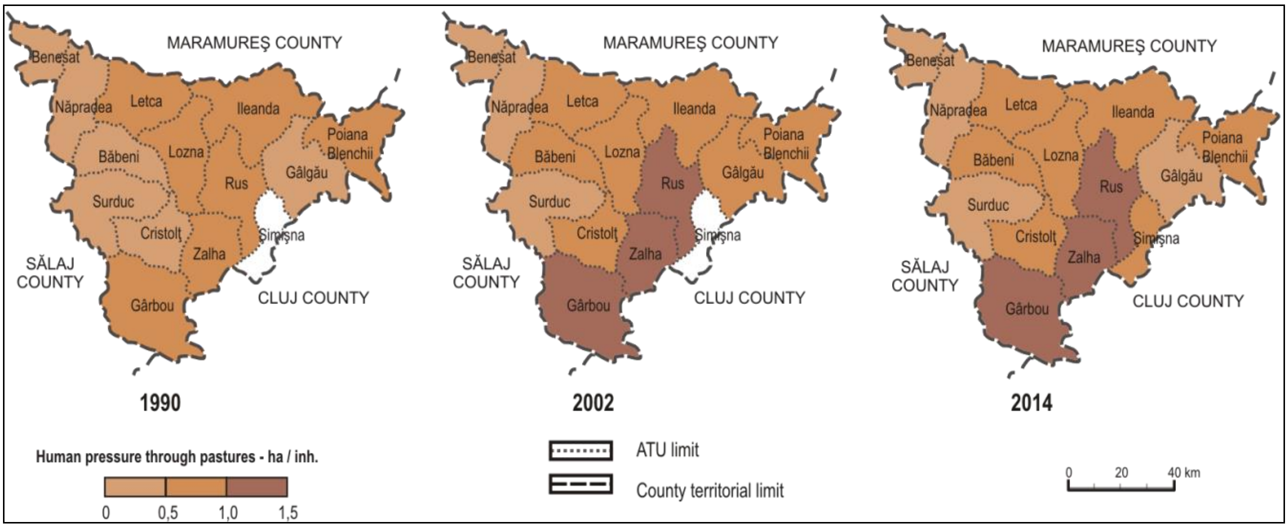

Fig. 6: Human pressure index exerted through pastures (1990 – 2014) (Source: Processed after data provided by the *National Institute of Statistics*)

The number of ATUs which recorded values of the human pressure index through hayfields lower than 0.3 has remained constant throughout the research. The ATUs which recorded values higher than 0.7 have encountered a major increase and their number doubled in 2014, reaching 8 communes. On the other hand, the number of ATUs with values between 0.31 - 0.5 and 0.51 - 0.7 have encountered a major decrease in 2014. The value of human pressure index exerted upon the environment through hayfields has encountered a high dynamics throughout the research period. Thus, the communes that recorded the highest increase are Rus – Şimişna (155%) and Zalha (76.2%), while Surduc is the only one to note a major decrease. For the year 1990, the values of the above mentioned index were situated between 0.03 and 0.37, in comparison with the year 2014, when the values were situated between 0.08 and 0.99 (Table 4, Fig. 7).

Table 4: Dynamics of human pressure index exerted upon the environment through hayfields (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	0.03	0.05	0.10	0.07
Benesat	0.02	0.08	0.08	0.06
Cristolţ	0.10	0.14	0.31	0.21
Gâlgău	0.21	0.26	0.30	0.09
Gârbou	0.36	0.49	0.66	0.30
Ileanda	0.32	0.39	0.44	0.12
Letca	0.20	0.29	0.32	0.12
Lozna	0.14	0.20	0.22	0.08
Năpradea	0.04	0.04	0.10	0.06
Poiana Blenchii	0.30	0.89	0.99	0.69
Rus	0.34	0.42	0.34	0.00
Şimişna	-	-	0.59	0.59
Surduc	0.04	0.05	0.14	0.10
Zalha	0.22	0.39	0.77	0.55
Average	**0.18**	**0.26**	**0.33**	**0.15**

Source: values calculated using statistical data provided by the National Institute of Statistics

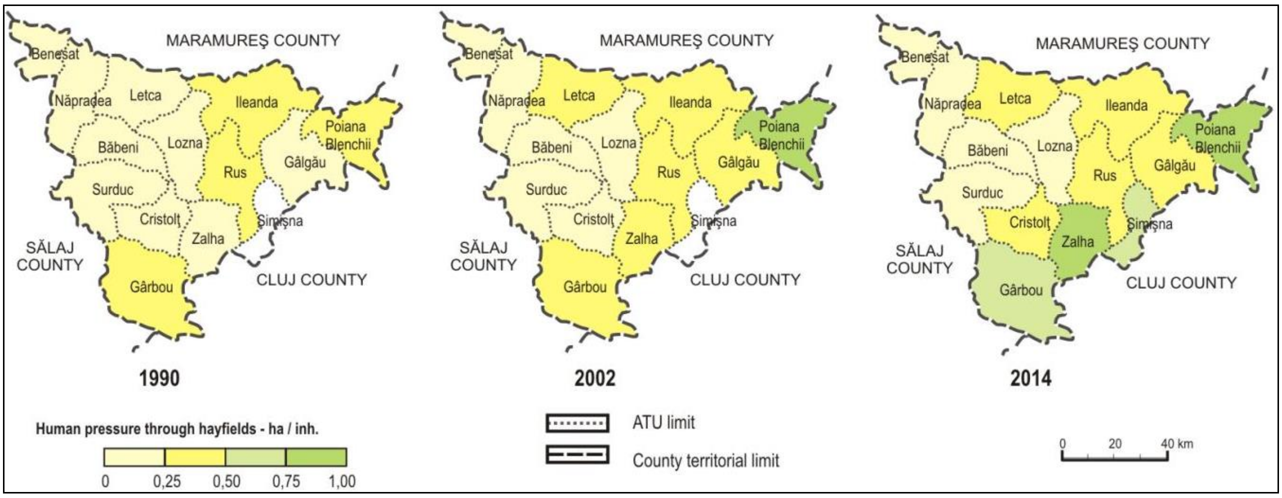

Fig. 7: Human pressure index exerted through hayfields (1990 – 2014) (Source: Processed after data provided by the *National Institute of Statistics*)

The lowest values – under 0.1 - were recorded in Benesat, Băbeni, Năpradea and Surduc, in 1990, while in 2014 only one recorded a value lower than 0.1 – Benesat. The highest values – over 0.31, were recorded in Ileanda, Rus and Gârbou, in 1990, while in 2014 their number doubled; the maximum value reached in Poiana Blenchii was 2.6 times higher in 2014 in comparison with 1990. The index of human pressure exerted upon the environment through hayfields has recorded a high dynamics during the research period, similar with the other indices analysed earlier. Increases between 43% (Gâlgău) and over 200% (Surduc, Poiana Blenchii and Zalha) were registered.

Orchards and vineyards exert a low amount of pressure upon the environmental and rural space components. Human pressure upon the environment exerted through orchards was registered in 69% of the total ATUs, whilst in Băbeni, Lozna, Năpradea, Rus and Şimişna there were no orchards. Therefore, the index of human pressure through orchards has recorded values between 0.0029 (Benesat) and 0.1172 (Poiana Blenchii) for the year 1990 and between 0.0004 (Ileanda) and 0.0210 (Zalha), in 2014 (Table 5). Overall, the index has decreased with 0.0228 and the number of ATUs where the index has grown is 2, in comparison with 7 communes which registered a decrease. The highest dynamics of the human pressure index through orchards were registered in Băbeni, Lozna, Năpradea, Rus and Şimişna, where decreases of 0.0260, 0.0271 and 0.1036 were noted and Năpradea, where the index has grown with 0.0014, while in Gâlgău the orchards have reduced with 100%.

Table 5: Dynamics of human pressure index exerted upon the environment through orchards (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	0	0	0	0
Benesat	0.002972	0.002404	0.003762	0.00079
Cristolţ	0.010064	0.004935	0.00581	-0.004254
Gâlgău	0.026049	0	0	-0.026049
Gârbou	0.11536	0.071146	0.011759	-0.103601
Ileanda	0.020789	0	0.000423	-0.020366
Letca	0.017932	0	0.005013	-0.01292
Lozna	0	0	0	0
Năpradea	0	0.000675	0.001407	0.00141
Poiana Blenchii	0.117233	0.003652	0.004075	-0.113158
Rus	0	0	0	0
Şimişna	-	-	0	0
Surduc	0.006385	0	0.005411	-0.000974
Zalha	0.048178	0	0.02103	-0.027147
Average	**0.026608**	**0**	**0.003835**	**-0.022772**

Source: values calculated using statistical data provided by the National Institute of Statistics

Table 6: Dynamics of human pressure index exerted upon the environment through vineyards (1990 – 2014)

Administrative Unit	1990	2002	2014	Difference 1990 - 2014
Băbeni	0.00489	0	0	-0.00489
Benesat	0	0.010216	0.016928	0.01693
Cristolţ	0.004767	0.000617	0.000726	-0.004041
Gâlgău	0	0	0	0
Gârbou	0.001275	0.001581	0	-0.001275
Ileanda	0	0	0	0
Letca	0	0	0	0
Lozna	0	0	0	0
Năpradea	0	0	0.000352	0.00035
Poiana Blenchii	0	0	0	0
Rus	0	0	0	0
Şimişna	-	-	0	0
Surduc	0.001228	0.000979	0.002435	0.00121
Zalha	0	0	0	0
Average	**0.000909**	**0.000909**	**0.001472**	**0.00056**

Source: values calculated using statistical data provided by the National Institute of Statistics

The index of *human pressure exerted through vineyards* (Table 6) registers lower values than the index of human pressure exerted through orchards. The natural climate and relief conditions in the studied area are not favourable for vineyards, so only 4 ATUs register this type of land use within their territorial limits. In addition, only in 2 (Cristolţ and Surduc) out of these 4 the vineyards were maintained throughout the research period. In Băbeni and Gârbou the land cultivated with vineyards was reduced to zero, whilst in Năpradea and Benesat people started using the land for vineyards. In 1990, the values of the above mentioned index oscillated between 0.0012 and 0.0048, in comparison with the year 2014, when the values fluctuated between 0.0003 and 0.0169 (maximum value).

The dynamics of the agricultural land use during the 1990-2014 period shows visible modifications in their structure, as well as a decrease of 392 hectares of all the land used for agriculture. In consequence, the pastures have decreased with 3.4%, arable lands with 7.4%, vineyards with 26.6%, while orchards have encountered a major decrease - 88.7%. Only hayfields have registered a significant growth of approximately 42%.

The analysed rural area has suffered transformations of the natural environment, as well as the rural landscape under the influence of human pressure exerted through different ways of using the land: agricultural, arable, pastures, hayfields, orchards, vineyards (Table 7, Fig. 8). The temporal dynamics of the indices of human pressure through the different agricultural land-use were compared with the limits imposed by FAO for maintaining the equilibrium between the components of the environment.

FAO imposes `as superior limit for maintaining the equilibrium between the components of the environment` the value of 0.4 ha/inhabitant (Dumitraşcu, 2006). Comparing the values of the human pressure indices with this value imposed by FAO, it results that the largest extent corresponds to the arable lands – 43% of the total area. Odum and Odum (1972), quoted by Dumitraşcu (2006) considered that for an adult person to have a high life standard, in the temperate area, he would need 2 hectares of land, which should be divided as follows: unspoiled natural area (0.8 ha), land used for agricultural purposes (0.6 ha), forests (0.4 ha) and 0.2 ha of land used for constructions, industrial platforms and transportation infrastructure.

Table 7: Dynamics of the indices of human pressure through different agricultural land-use

Human pressure indices	Year			Dynamics 1990 - 2014	
	1990	2002	2014	ha/inhab.	%
Agricultural (ha/inhab.)	**1.39**	**1.65**	**1.77**	**+0.38**	**+27.3**
Arable (ha/inhab.)	0.65	0.71	0.77	+0.12	+18.4
Pastures (ha/inhab.)	0.53	0.67	0.66	+0.13	+24.5
Hayfields (ha/inhab.)	0.19	0.26	0.34	+0.15	+78.9
Orchards (ha/inhab.)	0.0266	0.0069	0.0038	-0.0228	-85.7
Vineyards (ha/inhab.)	0.0009	0.0009	0.0014	+0.0005	+22

Source: values calculated using statistical data provided by the National Institute of Statistics

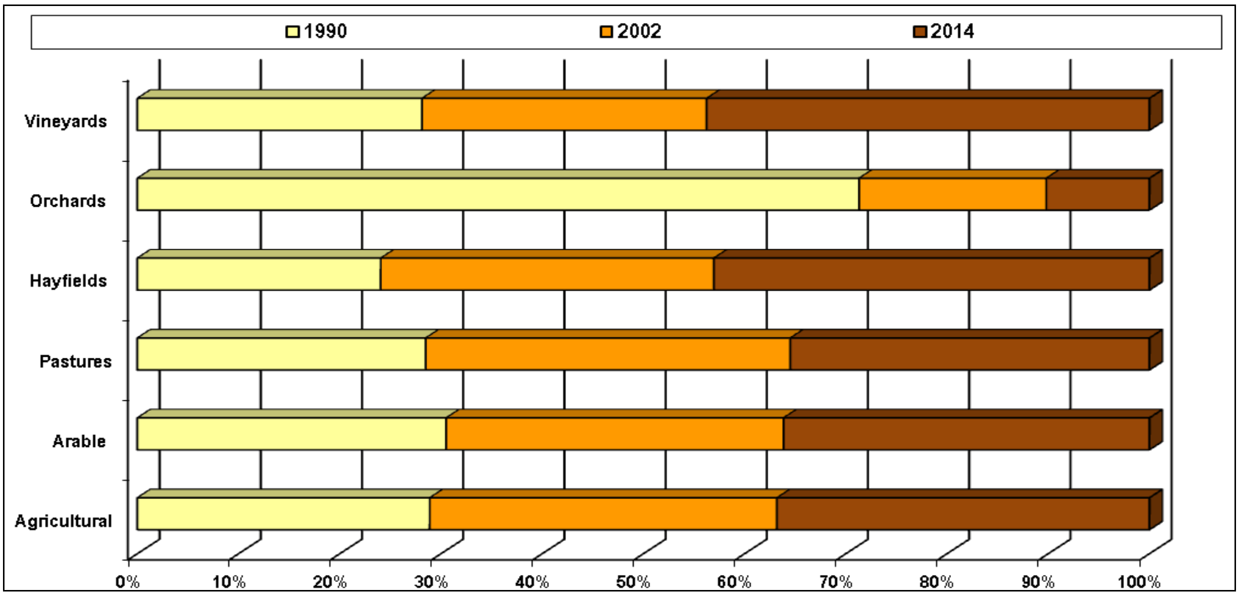

Fig. 8: Dynamics of the indices of human pressure through different agricultural land-use

For 2014, the total analysed area – 85,264 ha, would have the following structure: 45,624 ha agricultural lands, 33,500 ha forest, other lands – 5,500 ha, with a total population of 25,818 inhabitants. Each inhabitant receives 3.3 ha of land, from which 1.76 ha is agricultural and 1.3 ha is represented by forests.

Naturality index

The naturality index is defined as the ratio between the area occupied by forest and the total area (Dumitraşcu, 2006) (Fig. 9).

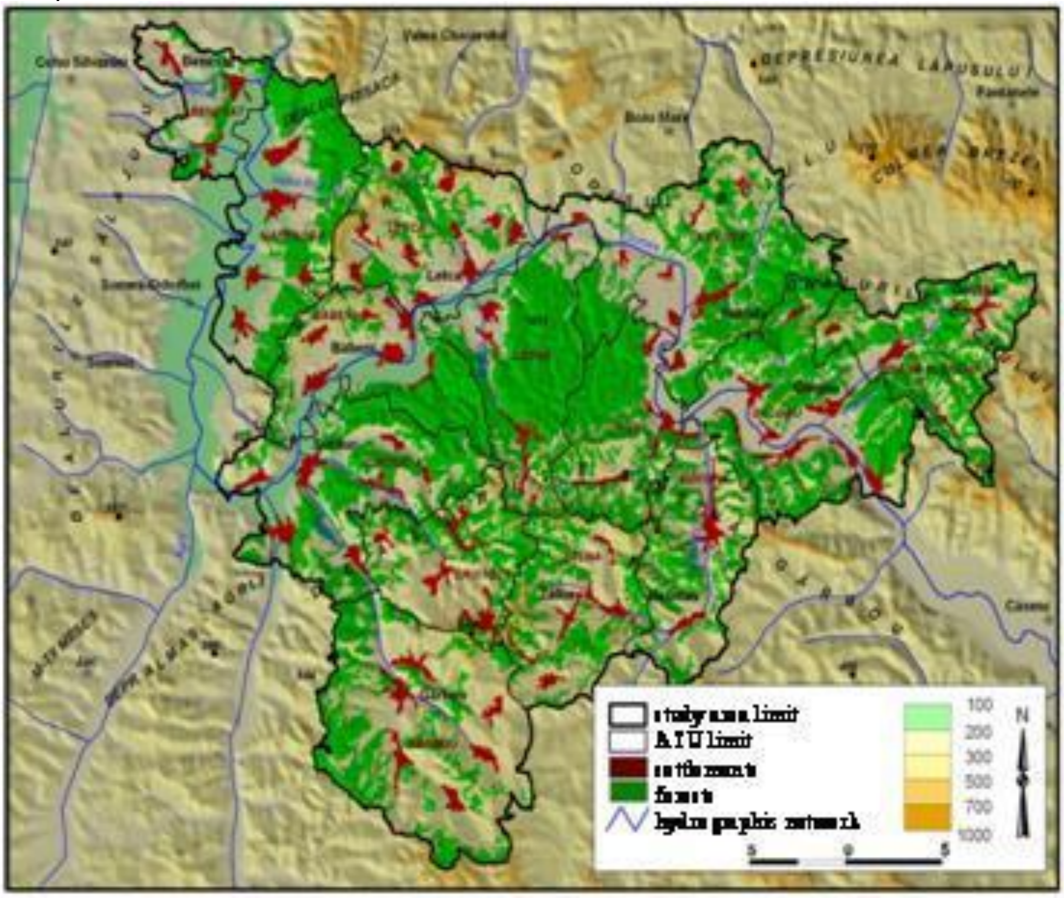

Fig. 9: Distribution of land covered with forests

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*http://dx.doi.org/**10.5775/fg.2067-4635.2015.198.d***

The action of clearance of forests and initial vegetation has influenced soil's evolution over the years. This anthropogenic action has taken place for various reasons, such as the enlargement of the human settlements, agricultural areas or emplacement of industrial platforms, but neither one was a result of specialized analysis.

The values of the naturality index have been divided into five categories which reflect the degree of disturbance of the ecological balance (Fig. 10):

Totally affected ecological balance (values between 0 - 10%), in Băbeni;

Strongly affected ecological balance (10.1% - 30%), in Benesat and Letca;

Moderately affected ecological balance (30.1% - 50%) in over 50% of the administrative units;

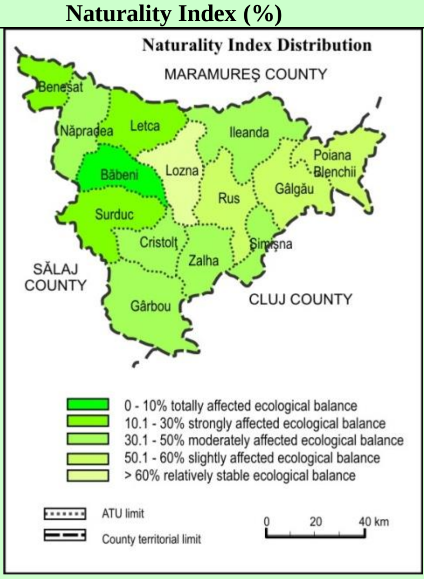
Slightly affected ecological balance (50.1% - 60%) in Rus, Poiana Blenchii and Gâlgău;

Relatively stable ecological balance (over 60%), in Lozna.

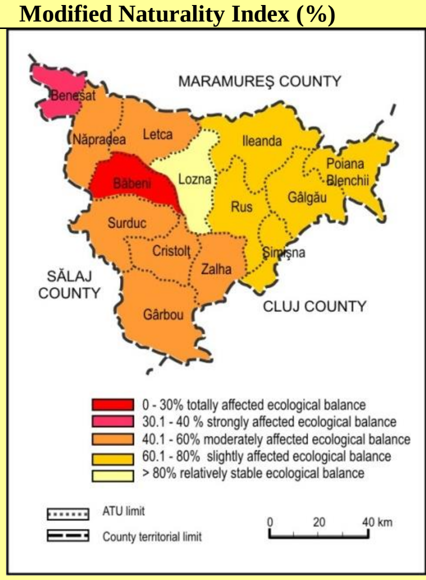
This index is important if aspects such as forest being a natural area, slightly affected by human activities and, on the other hand, it represents the initial vegetation, are taken into consideration. For this reason, a modified naturality index was used in the research process. In addition to the forests, this index includes the pastures.

The results obtained applying the formula show a high value for the ATUs where the ecological balance is moderately affected (42.8%); here, the naturality index has values situated between 40.1% and 60%.

Administrative Unit	Naturality Index (%)	Modified Naturality Index (%)
Băbeni	3.88	24.2
Benesat	18.47	35.76
Cristolţ	33.45	56.85
Gâlgău	52.75	68.42
Gârbou	30.24	54.6
Ileanda	45.05	69.57
Letca	25.4	52.63
Lozna	64.81	81.07
Năpradea	39.61	50.29
Poiana Blenchii	53.38	71.74
Rus	53.51	79.84
Şimişna	37.89	60.35
Surduc	44.12	55.81
Zalha	33.38	52.7
Average	**39.33**	**59.2**



Naturality Index Distribution



Modified Naturality Index Distribution

Fig. 10: Naturality index and modified naturality index in 2014

From all the analysed ATUs, Băbeni and Benesat register values close to the upper limits of the ecological carrying capacity. Only Lozna maintains a relatively stable ecological balance.

Environmental Transformation Index

The environmental transformation index was introduced and used for the first time by Maruszczak (1988), to assess the human impact on the Sub-Carpathian landscape from Poland and then used by many Romanian authors (Armaş *et al.*, 2003; Manea, 2003; Pătru-Stupariu, 2011; Ionuş *et al.*, 2011; Zarea and Ionuş, 2012; etc.); this index is the ratio between the area covered with forests and pastures and the built area.

According to figure 11, the value of the index has exceeded 11 and the maximum one was registered in the commune Ileanda – 17.5. Overall, the majority of the ATUs have a relatively stable ecological balance.

Administrative Unit	Environmental transformation index (ha)
Băbeni	2.98
Benesat	4.25
Cristolţ	6.73
Gâlgău	9.11
Gârbou	10.53
Ileanda	17.51
Letca	6.03
Lozna	15.46
Năpradea	7.16
Poiana Blenchii	16.84
Rus	16.43
Şimişna	11.72
Surduc	7.15
Zalha	8.27
Average	**15.45**

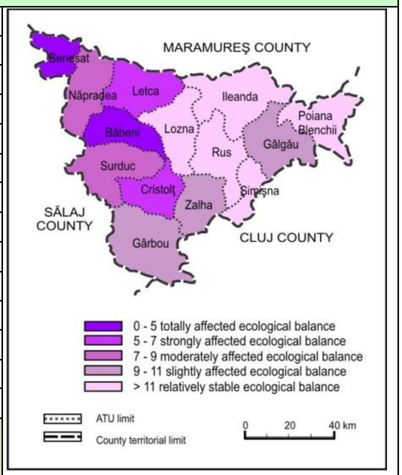


Fig. 11: Environmental transformation index (ha) in 2014

The result of this research indicates that the current state of the environment is influenced by the different types of human pressure, as well as the intensity of the event, transforming the environment under the influence of anthropogenic activities, emphasizing the necessity of adaptation of human society to the new environmental conditions. The analysis performed on the dynamics of spatial and temporal patterns of these transformations led to the revelation of locally disparities determined by their occurrence (Fig. 12).

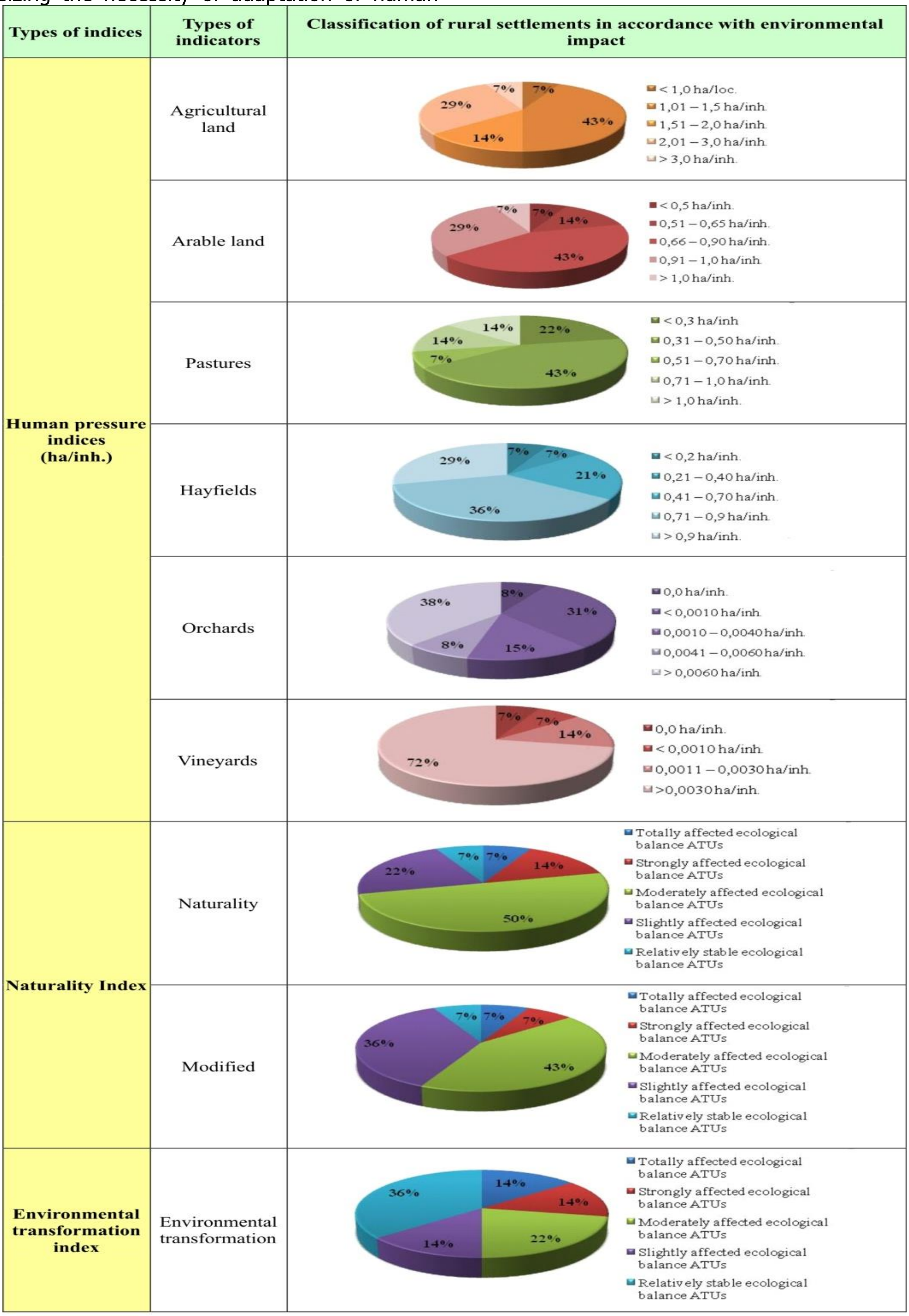


Fig. 12: Environmental impact indices

Conclusions

The spatial and temporal evolution of the rural landscape in Someșean Plateau is induced primarily by the diversification of human pressure forms through the use of agricultural land, the main activity carried out by the rural communities.

Spatial differences in the values of pressure and weighting factor of the various categories of land use in relation to agricultural areas depend largely on the number of inhabitants of each administrative-territorial unit, as well as morphological and morphometric characteristics of the relief of the analysed area, identified as favourable or restrictive factors in regards to the agricultural use of land.

For a harmonious development of the area, it is necessary to start the practice of ecological agriculture, based on modern principles, in order to bring as few environmental damage as possible and also pay attention to the protection of all its natural components.

One can also practice intensive farming, but modern, that combines various methods, related to meeting the expected objectives. These methods include: the use of mechanization of irrigation systems, pest control, increase soil fertility, plant protection, agrotechnical and agrophytotechnical works.

The beneficial effects are reflected in all environmental factors as well as the health of population.

Even though the region is situated at the starting point of this process and there are difficulties in the implementation of these principles, on one hand because of the lack of interest of population maintained by lack of information, on the other hand due to the lack of financial resources, local authorities have begun to promote and join these methods, knowing their long term beneficial effects.

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Romanian citizens in Hungary according to 2011 Population Census data

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Abstract

Over the past decades the migration role of Europe has been revalued. Nowadays, the majority of Western and Southern European states have a foreign born population of several million. The subject of international migration increasingly comes into the front in the context of the sustainability of the ageing Western societies and the climate change (environmental migration). Since the regime changes of the 90s, the Central European countries, as a result of economic convergence and integration, have become host areas. In the life of Hungary and the neighbouring countries, this phenomenon resulted in a very new situation. Most of the migrants are from neighbouring countries. So, there are obvious border effects and the territorial ethnic redistribution.

Keywords: *International migration, network analysis, Hungary*

Rezumat. Cetățenii români din Ungaria conform Recensământului din 2011

În ultimele decenii, rolul Europei în cadrul fluxurilor migratorii s-a schimbat. În prezent, în majoritatea statelor din vestul și sudul Europei, numărul populației străine se ridică la câteva milioane. Subiectul migrației internaționale este din ce în ce mai actual în contextul durabilității societăților vest-europene îmbătrânite și al schimbărilor climatice (migrație environmentală). O dată cu schimbarea regimului politic din anii 90, statele din centrul Europei, ca urmare a convergenței și integrării economice, au devenit areale receptoare. În cazul Ungariei și a statelor învecinate, acest fenomen a dus la apariția unor situații noi. Majoritatea migranților provin din statele învecinate. Prin urmare, există certe efecte de graniță și o redistribuire teritorială a etniilor.

Cuvinte-cheie: *migrație internatională, analiza rețelelor, Ungaria.*

Introduction

From the second half of the '90s, Hungary - like many other Central European countries - has become a host country of migrants thanks to its economic catching-up and the European integration. Resident population of Hungary has been steadily decreasing since the early ‘80s. Part of the declining domestic population has been replaced by foreign citizens, bringing with them their customs and different demographic composition. Thus, in addition to its direct population replacement role, migration has economic, social, demographic effects for Hungary. Since the regional distribution of foreign citizens is significantly different from that of Hungarian population, the impacts of national scope are significantly outweighed by their influence that is perceptible in the areas preferred by them. Most migrants come from Romania, so the aim of this article is – using the data the 2011 census – to demonstrate what Romanian migration groups can be observed in Hungary. The paper addresses in detail the exploration of source areas of Romanian citizens at regional and settlement levels, as well as the analysis of the connections between the present dwellings and those of emigration.

Framework of analysis, data sources

Migration is an interdisciplinary phenomenon that mainly affects the field of demography, statistics, geography, law, economics, history, labour science, psychology, and political science. Consequently, interpretation and definition thereof emphasize various aspects. According to the Demographic Yearbook of the Hungarian Central Statistical Office (KSH, 2008), international migration means the permanent abandonment of the country of original (usual) residence with the intent of establishing a residence in another country with the aim of establishment, stay, or performing gainful activity. As the motivation of migration is constantly changing, the definitions for the establishment or merely gainful activity have been expanded with the concepts of migration for learning purposes (Rédei, 2007), as well as the elderly migration (motivation may include the better use of pensions' purchasing power, the recreational opportunities, or search for more favourable climate) (Illés, 2008). Motivations concerning family reunifications are also emphasized, they mean one of the main reception channels of international migration.

Former core of migration interpretations has presumed migration as a once occurring event. Thus, wandering happens relatively rarely in an individual's career, so it is a kind of extraordinary

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*Volume **XIV**, Issue **2** (**December 2015**), pp. **190-198***
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case. Migration determines the migrants' life, being a single, one-way event which is tied to the symbolic moment of crossing the "border" (Kovács&Melegh, 2000). Migration characteristics, however, are not independent from the era, the socio-economic environment in which they take place. In the era of globalisation, income gaps between countries are increasing at an accelerating rate, the development is uneven (Kofman&Youngs, 2003). Widening differences in quality of life encourages the growth of human movements between poor and rich countries. In parallel, the financial possibilities of the migrants are constantly improving, the transport is developing rapidly, so the different parts of the world are getting closer and closer to each other, in the sense that the price of long-distance moves – in proportion of household incomes – are now so low that a growing part of people living in peripheral countries is able to involve in the migration processes (Hatton & Williamson, 2005). Circular migration and the phenomenon of transnational migration have also appeared on the international scene by the explosive development of the information and transport technology, as well as the decline of the separating function of country borders and the expansion of porosity of borders. Cross-border migration is becoming less and less a final intention to settle, but rather stations of a career (Hatton & Williamson, 2005).

Therefore, it is important to have accurate statistical data. Advantage of the data gained in population census is – in comparison with administrative ones – the fact that everybody can be connected to the settlement of the habitual residence together with all variables of the questionnaire. This provides the opportunity that living conditions, economic, educational, social background of all inhabitants of Hungary can be known for statistical purposes in territorial breakdown. Hungarian census is a regular (repeated generally every 10 years) full-scope survey that covers the population as a whole of a given area (country) and refers to a predetermined date. The census is of full scope and bound to a reference date. Enumeration is conducted simultaneously throughout the country with the same content and on a uniform methodological basis, covering all dwellings and persons. Specific survey was carried out concerning those who are Hungarian citizens and were living habitually in the country, or if they were abroad, they stayed there only temporarily (for less than 12 months); as well as those foreign citizens or stateless persons, there were enumerated those who have lived in the country for a specified time. The reference date of the 2011 census - it was the 15th census in Hungary – which was specified by the Act of the Hungarian Parliament (Act CXXXIX of 2009 on the Census 2011) as 0'clock on the 1st of October, 2011.

In 2011, those foreign citizens who had habitually lived in Hungary at least for 12 months, or intended to live here at least one year at the reference date of the census belonged to the target population of the census. Out of foreign citizens, the members of the diplomatic corps and their families; the members of the foreign armed forces stationing in our country on the basis of the decree of the Parliament or Government; as well as those staying in Hungary with the purpose of tourism (recreation, hiking, hunting etc.), visit, medical treatment, business meetings, etc. were not enumerated.

Results

Number of migrants and composition thereof by citizenship in Hungary

Census found less foreign citizens in comparison with the earlier updated migrant population data of HCSO: exceeding 200 thousand persons. The probable reason is that the above number contained the only foreign and Hungarian and foreign citizens as well at the same time. At the reference date of 0'clock on the 1st of October 2011, 143,197 foreign (without those dual citizens having also Hungarian citizenship) and 383,236 foreign-born citizens stayed in Hungary. It is true for both groups that most of them came from Hungary's neighbouring countries and from Germany. Europe's role is significant, in particular in the case of foreign-born group, 90% of migrants came from this continent. Particular importance of neighbouring countries is related to the cross-border language and cultural ties. Thus, the consequences of peace treaties ending World War I and II are still dominant in migration processes of the Carpathian Basin (Tóth, 2005). Political changes in the 90s have been accompanied by the Hungarian nationals' massive migration to Hungary.

Hungary is the primary destination for Europeans, the short-haul international migrations are rather typical. Romania's role is also prominent among them, as from here comes the most, mainly ethnic Hungarian migrants to Hungary. It is interesting that the number of Romanian-born people living in Hungary is higher than the total population in Szeged (Hungary's third largest city after Budapest and Debrecen). However, the number of Asian, African, American migrants is not insignificant any more, as the foreigners living in Hungary dispose of a total of 161 different citizenships and were born in 195 different countries (together with associated countries and territories), so there is hardly any part of the world, from which foreigners had not arrived in Hungary with the intention of settlement.

Table 1 Participant groups in migration, living in Hungary by countries, 2011

Country of citizenship/place of birth/country of residence before return	Dual citizens (Hungarian and other)	Foreign citizens	Foreign-born people
Romania	39 270	38 574	176 550
Germany	6 412	16 987	22 605
Slovakia	1 679	8 246	33 155
Austria	1 467	3 936	6 160
United Kingdom	1 627	2 602	3 597
France	1 298	2 201	3 233
Netherlands	762	2 058	2 438
EU28	**59 644**	**85 414**	**266 701**
Ukraine	2 383	11 820	35 354
Serbia	9 394	7 752	29 144
Europe other	3 434	7 536	13 608
Europe total	**74 855**	**112 522**	**344 807**
China	952	8 852	8 767
Viet-Nam	783	2 358	2 668
Iran	146	1 523	1 713
Asia other	2 240	9 571	12 358
Asia total	**4 121**	**22 304**	**25 506**
USA	4 978	3 022	4 684
Canada	2 149	484	1 198
America other	741	1 237	2 416
America total	**7 868**	**4 743**	**8 298**
Nigeria	128	1 015	1 101
Egypt	168	472	632
Africa other	679	1 366	2 256
Africa total	**975**	**2 853**	**3 989**
Other and unknown	1 087	775	636
Total	**88 906**	**143 197**	**383 236**

Migration source areas of Romania, in terms of migrants to Hungary

From the geographical point of view, the mapping of Hungarian host areas is focused on the research of migration concerning Hungary. This is basically due to two reasons. On the one hand, the examination of the domestic effects requires this approach, on the other hand, the emigration areas are mostly unidentifiable. Its main reason is the lack of data availability, which makes the region-specific researches definitely more difficult. So, the goal of the paper is to explore the migration source areas of Romania and a more detailed understanding of the regional impacts according to the latest census information.

Census data represent a detailed demographic, labour market, sociological data set on the population of migrant origin living in Hungary, but concerning the emigration and birth places, only country-level information is available. Relevant Hungarian migration databases (database of Office of Immigration and Nationality and the HCSO data files based on thereof), however, contain less information on the characteristics of migrants, but also extend to their places of birth. Establishment of the link between the two databases enables to connect the examination of the emigration areas with the detailed census information material. The method is based on the use of a complex conversion key between databases which assigns the data files according to the common variables (nationality, residence in Hungary, date of birth, gender, marital status) the municipalities in foreign places of birth to the census files. Thus, data on foreign settlements underlying the specific analyses were available but a separate classification became necessary as they contained often the denominations of settlements or parts thereof in different languages.

Hereinafter, the migration processes according to the original (Romanian, Ukrainian, Serbian, etc.) place of residence at the date of birth and the demographic, sociological and labour market variables of the migrants will be examined. The studied area level is municipal or county level (NUTS 3).

Later, those Romanian citizens who live in Hungary and were born in Romania will be analysed, thus linking them to the foreign area of their birth place. On the 1st of October 2011, 627 Romanian citizens were living in Hungary who are not born in Romania, but elsewhere, in most cases already in Hungary. So they were omitted from the following area studies.

The largest population of Hungarian ethnicity outside Hungary lives in Romania. In 1992, 7.1% of Romania’s population identified themselves as Hungarian, this figure was 6.7% in 2002, while 6.1% in 2011. The proportion of Hungarians living in Transylvania, Banat and Partium is 18%. More than half of the Hungarians in Romania live in Székely Land. Beside Transylvania, a significant number of Hungarians in Romania live in Csángó Land and

Forum geografic. Studii și cercetări de geografie și protecția mediului
Volume XIV, Issue 2 (December 2015), pp. 190-198
http://dx.doi.org/10.5775/fg.2067-4635.2015.225.d

Bucharest (Kapitány&Rohr, 2013). Belonging to the ethnicity has long played an important role in international migration characteristics between the two countries. Hungarian characteristic of the international migration is that most of the foreign citizens are of Hungarian nationality or mother tongue. The intensity of cross-border linguistic and cultural links is the consequence mainly of the peace treaties ending World War I and II. This determinism is continuously decreasing, but still dominant: in 2001, 65% of foreign citizens were of Hungarian mother tongue, while in 2011 this figure was 47%. The decrease is essentially due to three reasons: first, the weight of the neighbouring countries declines within the migrant population, secondly, in the neighbouring countries the weight of areas without Hungarian inhabitants (in 2001, 86% of those arriving from neighbouring countries were of Hungarian mother tongue, while in 2011 it was 79%) increases, thirdly, non-Hungarian speakers arrive to Hungary in a higher proportion from the areas with Hungarian inhabitants. Eighty-six percent of the Romanian citizens living in Hungary identified themselves as belonging to the Hungarian ethnic group.

Majority Orthodox Romanians were under-represented in the migration processes of the past regime (Brubaker, 1998). Based on the findings of the Romanian migration sociology and demography, at least 90% of the Romanian migrant population come now out of the majority Romanians (Sandu, 2000). While those of Hungarian nationality prefer more and more Hungary as the main destination, for the Romanians the job opportunities in Italy and Spain are significant. So the shift in the migration towards Western Europe is characteristic for Romania as a source country of migration as a whole. The ethnicity plays a significant role in the development of migration networks, but migration is supposed to be organized not only on the basis of ethnicity, but also of acquaintances (Gödri, 2007).

Romanian-Hungarian migration relations are traditionally strong. According to census data, 38.6 thousand Romanian citizens live in Hungary (as of October 1, 2011), and 176.6 thousand people settled into our country if those becoming Hungarian citizens since 1993 are listed here. International migration between the two countries affects all Romanian and Hungarian counties. This means that migrants come to Hungary from each Romanian county while Romanian migrants can be found in all Hungarian counties. According to the 1st of October 2011 census, this process covers 25% of Romanian towns, while 56% of Hungarian settlements, respectively. Thus strong regional effects can be observed.

The most affected Romanian settlements in the migration to Hungary (observing only the Romanian citizens, except for Romanian-born Hungarian citizens) are: Târgu Mureș (according to 2011 census, 3,184 Romanian citizens who were born in Romania, Târgu Mureș were living in Hungary), Odorheiu Secuiesc (2334 people), Miercurea Ciuc (1980 people), Satu Mare (2334 people), Sfântu Gheorghe (1876 people), Oradea (1689 people), Târgu Secuiesc (1,398 people), Gheorgheni (1,101 people) and Cluj-Napoca (919 people). The counties most affected by migration are Harghita (7,658 people), Mureș (6,458 people), Covasna (4,678 people). Bihor (3,733 people), Satu Mare (3382 people) Sălaj (1,986 people) and Cluj (1,867 people). A significant number of Hungarian minorities live in these areas. About 77% of the foreigners coming to Hungary come from these seven counties. In addition to Covasna (230%), Sălaj (152%) and Mureș (141%) counties having major migration potential, the most dynamic increase of the issuer role had Bacău (354%), Suceava (299%) and Hunedoara (146%) since 2001.

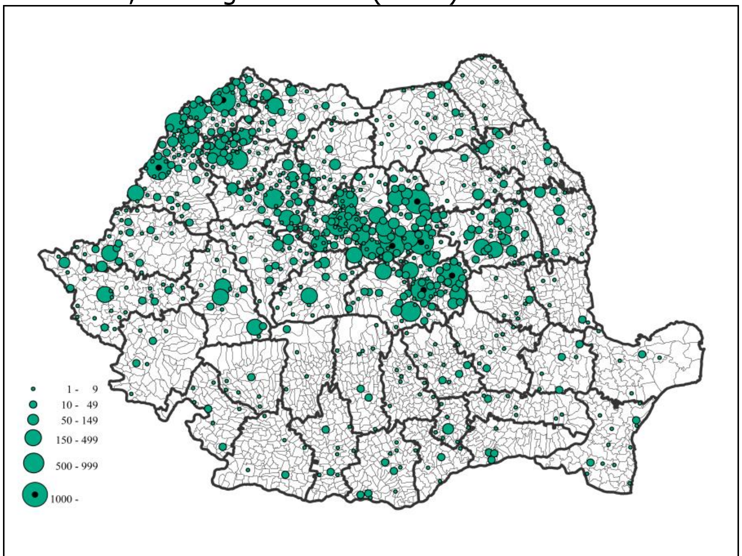

Fig. 1: Romanian citizens living in Hungary by the settlement of emigration, 2011

Relationship of Romanian citizens' demographic, labour market and sociological characteristics' with the region of birth

The average age of Romanian citizens living in Hungary is the highest in case of those coming from the regions of Romania outside Transylvania, in several cases is well above the average 50 years at county level. The reason for this is not the elderly migration, but the migration of the large number of those of working age and small number of young people. Most of the young people come from the counties near the border. Away from the border, their share is gradually declining.

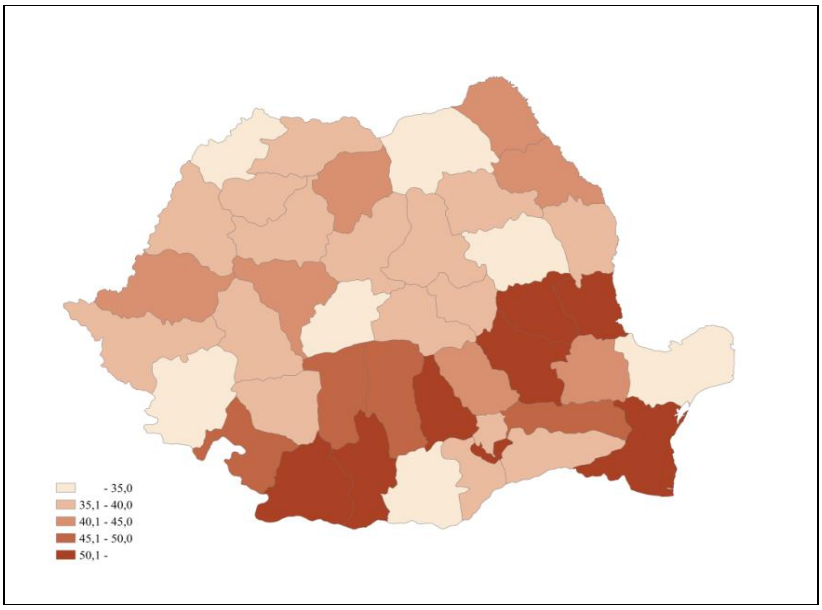

Fig. 2: Romanian citizens living in Hungary by average age and region of birth thereof, 2011

Educational level of the Romanian citizens living in Hungary is slightly lower than that of the Hungarian average resident population: 17% have university degree, compared with 20% of the resident population rate. Greatest deviation from the Hungarian average can be observed in case of the more remote border regions, in these counties the proportion of university graduates may exceed 30%. That is, lower-skilled people participate in the smaller distance migration in higher proportion than in the case of longer distances where those with higher education become dominant. It can be concluded that the potential impact area of migration increases with the educational attainments.

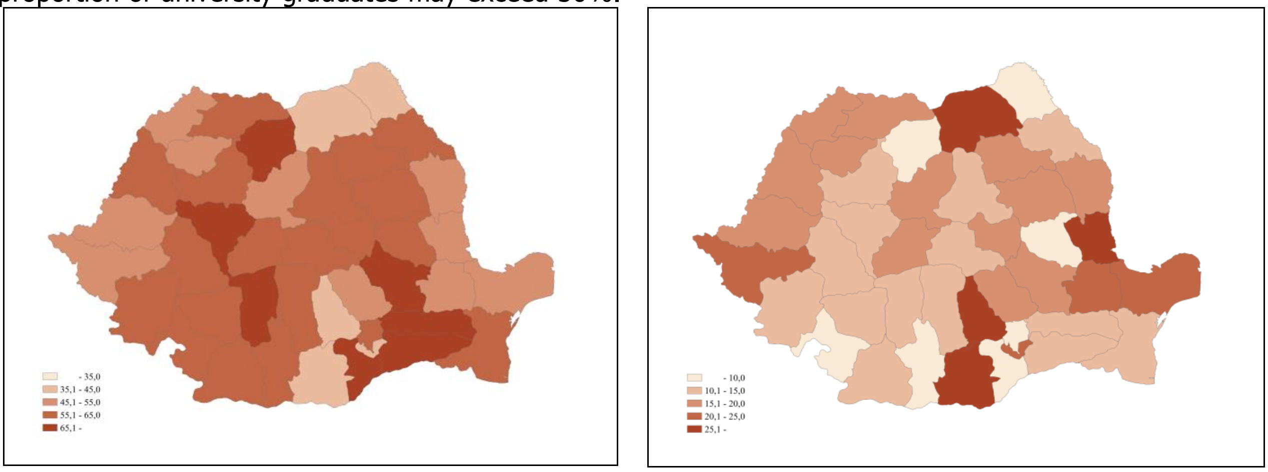

Fig. 3: Romanian citizens living in Hungary above 25 years by educational attainment and region of birth thereof, 2011 (a - primary school, b - higher education)

The level of education has a decisive influence on the labour market characteristics as well. The employment rate of 25-64 years old Romanian citizens living in Hungary was 72.5% in 2011.

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **190-198***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.225.d***

Similar data of the Hungarian resident population was 64.4%, while it was 70.2% for all 25-64 years old foreign citizens living in Hungary. That is the Romanian citizens work in higher proportion than the resident population, or other foreign citizens in Hungary.

The rate of those arriving from the areas close to the border is lower than those coming from the inner areas. Still, in the case of employment, the standard deviations are smaller between groups than at the level of education or the mother tongue.

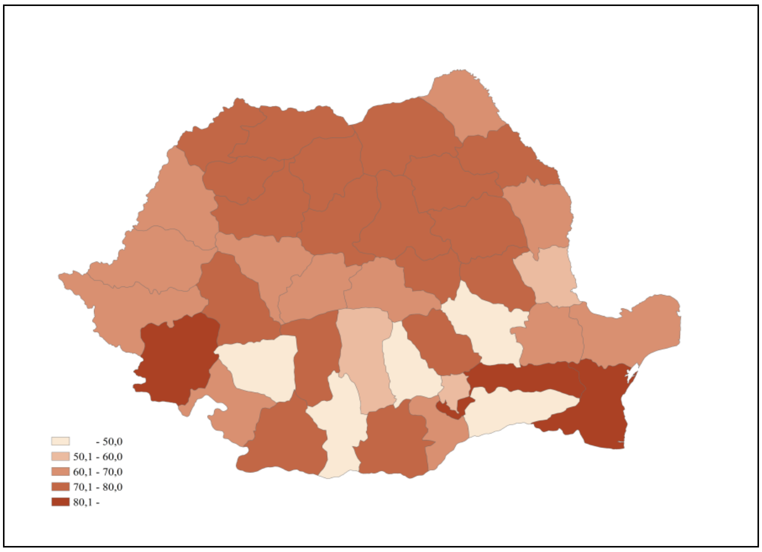

Fig. 4: Employment rate of Romanian citizens living in Hungary above 25 years by region of birth thereof, 2011

Relations of source and destination areas

Hereinafter I will examine the relations between the residence of birth and current dwelling of foreign citizens coming from Romania to Hungary at NUTS 3 level. In the matrix of migrations, significant concentrations can be observed from the 42 Romanian counties established this way to the 19 Hungarian counties and Budapest. Extracting those region pairs which contribute to the total turnover with more than 0.5% of the total migration we get much tighter group than the previous one. Thus, in 4.76% (40 region pairs) of all matrix cells (42x20=840) 70% of migrations in 2011 come together so the spatial distribution of migration shows a strong concentration.

Table 1 Participant groups in migration, living in Hungary by countries, 2011

Romanian/ Hungarian county	**Budapest**	**Pest**	**Fejér**	**Győr-Moson-Sopron**	**Hajdú-Bihar**	**Szabolcs-Szatmár-Bereg**	**Bács-Kiskun**	**Békés**	**Csongrád**
Bacău	**1,2**	**0,9**	**0,5**	0,0	0,0	0,0	0,1	0,1	0,3
Vaslui	0,3	0,0	0,0	0,0	0,0	**0,5**	0,0	0,0	0,0
Arad	0,2	0,1	0,0	0,0	0,0	0,0	0,1	**0,8**	0,1
Hunedoara	**1,6**	0,4	0,0	0,0	0,0	0,0	**0,7**	0,0	0,2
Timiș	**0,6**	0,1	0,0	0,1	0,0	0,0	0,1	0,2	0,3
Bihor	**1,1**	**0,9**	0,2	0,3	**2,8**	**0,7**	0,2	**0,7**	**0,8**
Cluj	**1,6**	**0,8**	0,1	0,0	0,2	0,1	**0,6**	0,0	0,0
Satu-Mare	**3,2**	**1,5**	0,1	0,2	**0,7**	**1,5**	0,3	0,1	0,2
Sălaj	**2,6**	**1,1**	0,1	0,1	**0,7**	0,1	0,1	0,0	0,0
Brașov	0,3	**1,4**	0,0	0,1	0,1	0,3	0,1	0,1	0,0
Covasna	**5,3**	**3,2**	0,3	**0,5**	0,1	0,0	**0,6**	0,1	**0,6**
Harghita	**6,8**	**6,3**	0,4	**1,0**	0,3	0,3	**1,5**	0,2	0,4
Mureș	**8,1**	**2,8**	0,4	**0,5**	0,3	0,1	**1,3**	0,2	**1,3**
Sibiu	**0,6**	0,3	0,0	0,0	0,0	0,0	0,0	0,1	0,1

The region of Central Hungary was the most attractive for those arriving from the Middle-Romanian Development Region in 2011. 8.1% of all migrations from Romania to Hungary took place between Harghita county and Budapest, while the share of movements between Mures county and Budapest was 6.8%. The border areas were of considerable importance as well, which can be explained partly with the phenomenon of circulation migration (Fercsik, 2008), partly with the easier keeping in touch with family members staying at home (Rédei, 2007). Between the border counties intensive flows (Anderson & O'Down, 1999, Baranyi & Balcsók, 2004, Hansen, 1977, Van Geenhuizen & Ratti, 2001) and transnational areas were formed (Melegh, 2011). Among them the most significant movements were between the counties Bihor – Hajdú-Bihar (2.8%), Satu-Mare – Szabolcs-Szatmár-Bereg (1.5%), and the Arad – Békés (0.8%).

Hungary's capital is the Hungarian region which is a significant destination for the Romanian migrants of mainly Hungarian ethnicity, even in the case of major geographic distances (Rédei, 2009, Soltész et al, 2014). This statement is especially valid for working age migrants, those having higher education and/or working in leading positions.

In case of smaller geographic distances and near border movements the occupations and level of education of migrants are more diversified but in their economic activity there are no significant differences from those long-term migrants.

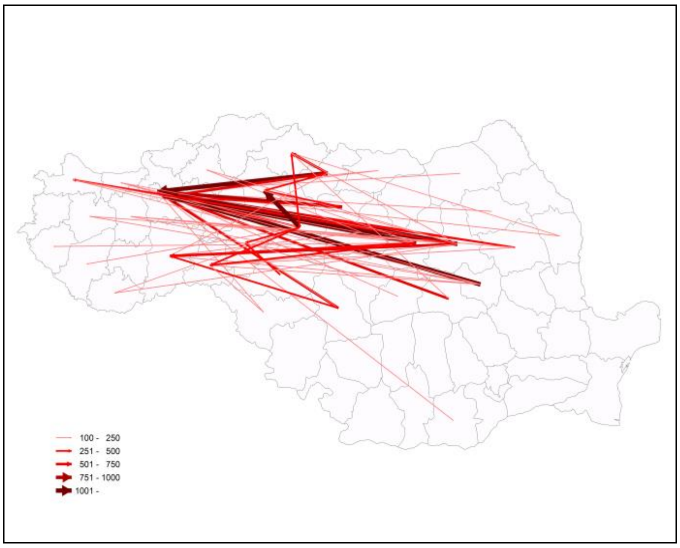

Fig. 5: Area relations between source and destination regions (person), 2011

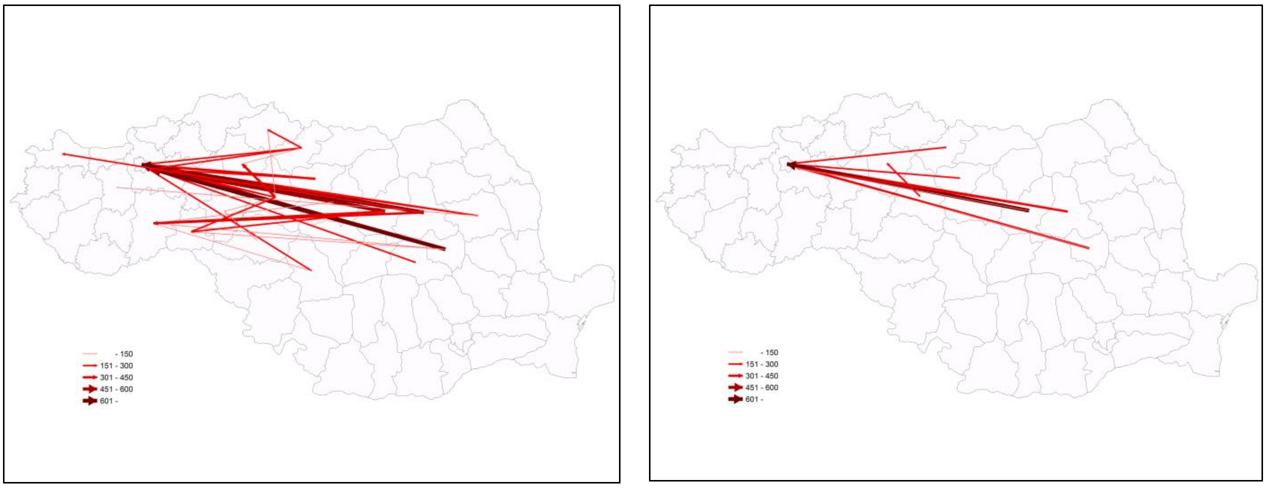

Fig. 6: Relation between regions of the residence of birth and current Hungarian residence of foreign citizens above 24 years, by education attainment, 2011 (person) (a – primary education, b – higher education)

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIV**, Issue **2** (**December 2015**), pp. **190-198***
*http://dx.doi.org/**10.5775/fg.2067-4635.2015.225.d***

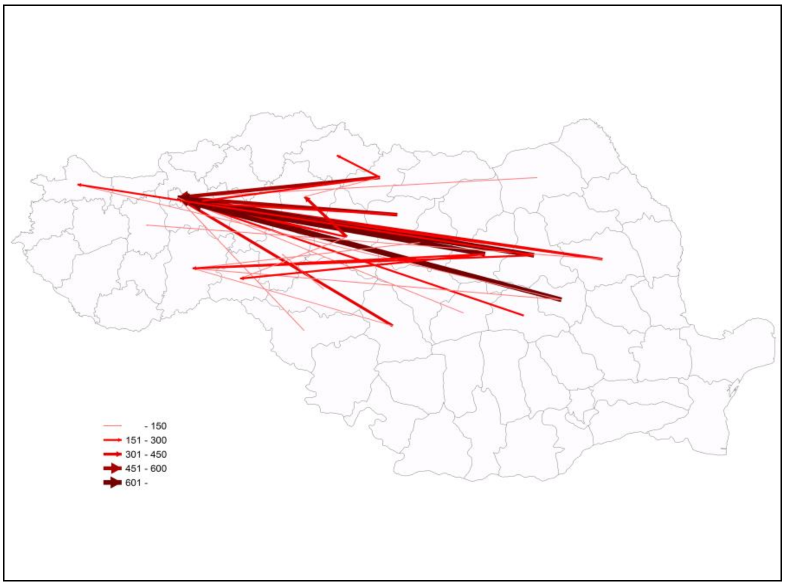

Fig. 7: Relation between regions of the residence of birth and current Hungarian residence of employed foreign citizens of 25-64 years, 2011 (person)

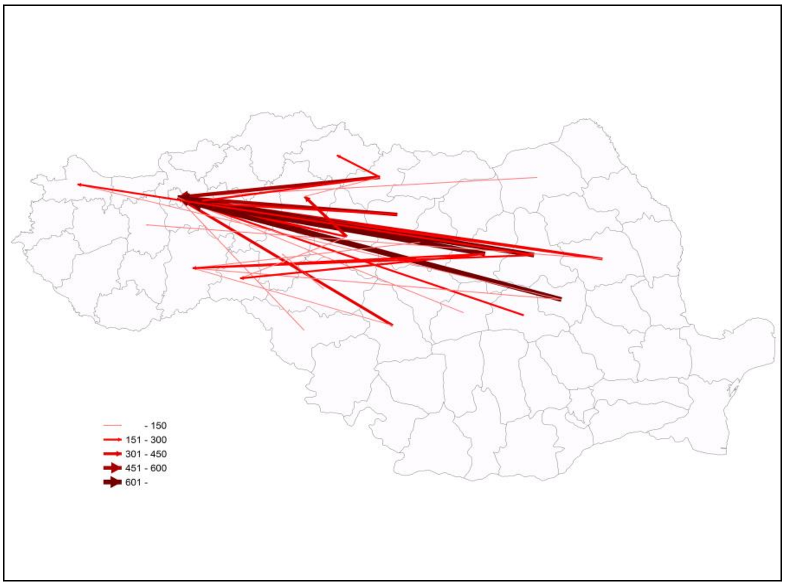

Fig. 8: Relation between regions of the residence of birth and current Hungarian residence of foreign citizens of 25-64 years by occupation, 2011 (person); a - Economic, administrative managers, advocacy leaders, b - Simple occupations (not requiring professional skills)

Conclusion

In Hungary the number of migrants and the proportion thereof in the population continues to grow. There are basically two reasons for this: on one hand the decrease of Hungarian population, on the other hand, the increase in the population of foreign origin. Greater numbers of foreign citizens began to immigrate to our country after the change of regime. In this period mainly ethnicity had a decisive role, as ethnic Hungarians arrived in the vast majority. Later, after the EU-accession the global trends no longer left migration networks in Hungary untouched: Hungary's migration source areas widened, it was able to attract foreign citizens even from larger distances. In 2011 foreigners living in Hungary dispose of a total of 161 different citizenships and were born in 195 different countries (together with associated countries and territories). Proportion of population of migrant origin is near to reach 5% of the resident population. Consequences of peace treaties ending World War I and II, as well as the cross-border language and cultural connections are still dominant in migration processes of Hungary. This is evidenced by the fact that the number of Romanian citizens is the highest, among them primarily those of Hungarian ethnicity settle down in Hungary. In addition to its direct population replacement role, migration has positive economic, social, demographic effects for Hungary. Younger age structure, more employment, lower unemployment is characterized by Romanian migrants in relation to the resident population.

Location of target areas plays a decisive role also in the territorial distribution of Romanian migrants in Hungary. In choice of the new domicile the border areas also play an important role in addition to the economic centers. Budapest is the Hungarian region which is a significant destination for the Romanian migrants of mainly Hungarian ethnicity, even in case of major geographic distances. This statement is especially valid for working age migrants, those having higher education and/or working in leading positions. The border areas are rather local destinations. In case of smaller geographic distances and near border movements the occupations and level of education of migrants are more diversified but in their economic activity there are no significant differences from those long-term migrants.

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Mapping the differences in online public information by local administrative units in Romania

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Abstract

We evaluated the differences existing in the public information presented by local administrative units in Romania by analyzing the websites of 3175 local administrative units based on a standard database which contains 17 indicators (grouped into three categories: identification, content and administrative support). We used descriptive statistics for analyzing results and ArcGis 10 for mapping the geographical patterns of distribution. 2769 local administrative units (87.09%) have a dedicated website, but the information presented on them are scarce, and in a direct connection with its rank in the network of settlements. The unbalance between content indicators and the administrative support indicators reveals a politicization of the websites, detrimental to public information and participation. The lowest values of online public information (<20%) are present in counties with a high proportion of profound rural settlements or a particular ethnical distribution of population.

Keywords: *Geographic distribution, online information, public services, local administrative units*

Rezumat. Reprezentarea cartografică a diferențelor în nivelul de informare publică online al unităților administrativ teritoriale din România

Am analizat diferențele existente în informațiile publice prezentate de unitățile administrativ teritoriale din România prin analiza website-urilor a 175 unități administrative locale folosind o bază de date standard cu 17 indicatori grupați în: indicatorii de identificare, conținut și suport administrativ. Rezultatele au fost analizate folosind elemente de statistică descriptivă și ArcGis 10 pentru reprezentarea cartografică a distribuției geografice. 2769 unități administrativ teritoriale (87,09%) au un website propriu, dar informațiile prezente pe acestea sunt deficitare, și în legătură direct cu rangul localității în rețeaua de așezări. Dezechilibrul existent între frecvența indicatorilor de conținut și a celor administrativi de suport indică o politizare a website-urilor, în detrimentul informării și participării publicului. Cele mai mici valori ale informațiilor publice disponibile online (<20%) se regăsesc în județele cu un nivel ridicat al ruralității sau în cele care au o distribuție etnică a populației distinctă.

Cuvinte-cheie: *distribuție geografică, informații online, servicii publice, unități administrative teritoriale*

Introduction

Public information on data and elements of interest are on the rise in contemporary society (Kassing, Johnson, Kloeber, & Wentzel, 2010) that has identified increased public awareness as a method of achieving its objectives of sustainability (Kendall, 2008) and transparency (Welch, 2012).

The need of authorities to inform the public derives also from the mandatory character of certain information, as foreseen in the provision of several European Directives (Directive 2003/35/CE, Directive 85/337/CE or Directive 96/61/CE). Romania, as a member country of the European Union should enforce the provision of European directives in the national legislation (such as Law no. 544/2001 regarding the free access to information of public interest).

The main purpose of the websites of authorities is to inform and educate the public by ensuring transparency and promoting projects (Karkin & Janssen, 2014) and reducing time consumption, as 80% of the citizens believe that the public services offered on the Internet allow them to save time (Sa, Rocha, & Cota, 2015). Built in an interactive manner, their websites should also have the capacity of collecting information and monitor public opinion (Uzunoğlu & Misci Kip, 2014), increasing the citizen's trust in the authorities (Hong, 2013).

Development of web resources and increased internet access facilitated the flow of information in both public and private institutions. This technological development had a significant impact in the information about data with public character (Chen, Wang, Liu, Wu, & Wang, 2013), national and local authorities developing institutional websites that evolved in the main methods of communication between citizens and public institutions (Karkin & Janssen, 2014), fostering the emergence of the e-government concept (Huang & Benyoucef, 2014).

E-government comes with many definitions (Verdegem & Verleye, 2009), all of them underlying the relation between information technology (Basu, 2004) and increased access and delivery of information or services to the public (Huang & Benyoucef, 2014) with the purpose of increasing the citizen's confidences in the authorities (Morgeson, VanAmburg, & Mithas, 2010) and the communication between actors (Sousa, Agante, & Gouveia, 2014). Although e-government has both information and transaction components, the current e-government applications remain mainly as a one-way communication (Hong, 2013).

In developed countries authorities have developed their websites and even associated social networks account to them for better reaching the citizens and increasing the transfer of information (Marlin-Bennett & Thornton, 2012) based on changes in the internet through social, economic and technologic tendencies that promote a large involvement of users and greater opening towards the access to information (Georgescu & Popescu, 2014) or promote multimedia tools such as video, audio, or online presentations (Sandoval-Almazan & Gil-Garcia, 2012), although disparities between developed and developing countries in their e-government are still observed by surveys (United Nations, 2014)

Governments worldwide face a permanent challenge of transformation and reinvention, in order to deliver services in an efficient, efficacious and cost effective way (Zhao, Shen, & Collier, 2015), therefore the need to monitor the success of their politics and programs. The E-Government Development Index (EGDI) is an aggregated indicator of three important dimensions of e-government: provision of online services, telecommunication connectivity and human capacity (United Nations, 2014), with a world average of 0.4721.

Previous studies on authorities' websites have focused on the perspectives of users and websites (Wang, 2014), with an emphasis on the accessibility of websites (Youngblood, 2014) in wide range of approaches (Kuzma, 2010). Other studies have analysed the model of communication existing on the websites (Endres, 2009) or the use of websites in academic research, because they contain valuable information for teaching, research and the provision of consulting services (Chen et al., 2013). Only a few studies analysed the geographical distribution of information presented on the websites of authorities (Youngblood, 2014).

Public information is realized in Romania both through traditional methods (panels and notice boards at the headquarters of local authorities – city halls, local councils, environmental protection agencies, etc.) and modern methods (the use of online resources – websites, social media or mass media). The process is confronted with a series of obstacles in the enforcement of an efficient e-government for local authorities in Romania: lack of interest, reduced awareness of the citizens, impossibility of using state-of-the-art technologies, limits in the creativity of employees, deficiencies in using experts in the field (Georgescu & Popescu, 2014). These deficiencies are causes in the emergence of various conflicts (Tudor, Iojă, Pătru-Stupariu, Niță, & Hersperger, 2014) or reduced public support for projects or decisions (Martin, 2007).

The main aim of our study is to evaluate the differences existing in the public information presented by local administrative units in Romania. For achieving this we have established the objectives of (1) assessing the information presented on the websites of local administrative units; (2) mapping the distribution of indicators for identifying geographical patterns of distribution and (3) ranking the local administrative units and counties after the level of public information they present.

Methodology

In our analysis we evaluated the e-government of local authorities from 3175 local administrative units (Figure 1) - LAU2 (municipalities, cities, communes, corresponding to EU NUTS 5) included in all of Romania's counties (LAU1, corresponding to NUTS 4).

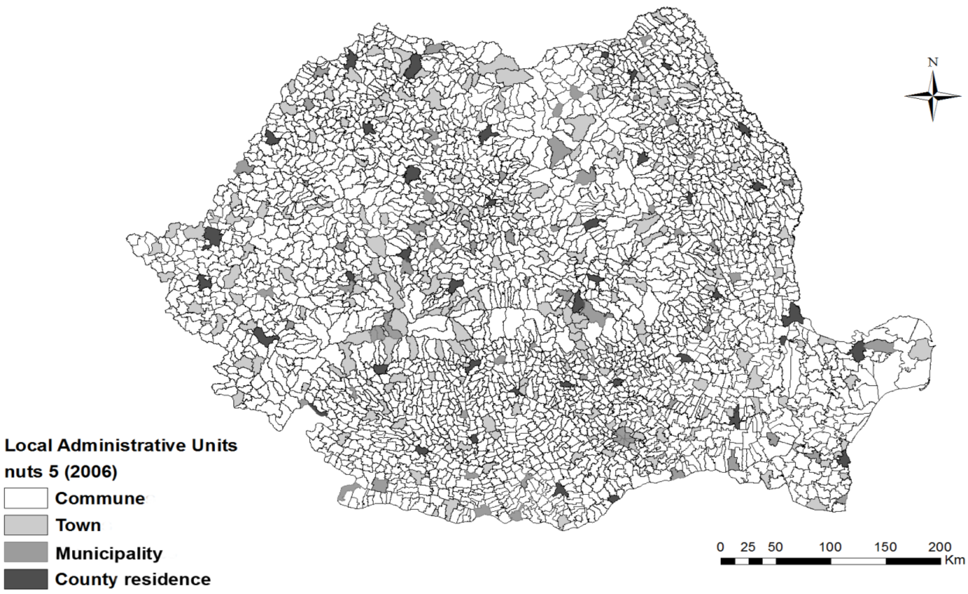

Fig. 1: Local administrative units (LAU2) in Romania

We obtained the limits of LAU2 from the National Authority for Cadastre and Real Estate (www.ancpi.ro, accessed at October 10, 2014) and the list of LAU2 by counties from the public database of the National Institute for Statistics (www.insse.ro, accessed at October 10, 2014).

Researchers have used many methodological approaches in exploring environmental issues and the communication surrounding them (Kassing et al., 2010). For our analysis we evaluated the websites of 3175 local administrative units between March and October 2014. As found in other studies that used coding (Dotson, Jacobson, Kaid, & Carlton, 2012) we shared the total sample of LAU2 between 7 college students, native Romanian speakers, and they had a standard database for filling the information (coded so that it will contain mostly numerical values such as 0-absence, 1-presence).

To avoid large differences of approaches between the coders we shared 11.02% of the websites between at least two random decoders and we found a similarity of 90.50% between them, a percent which we considered reliable for the purpose of our study. The database contained a number of 17 indicators (Table 1) grouped into three main categories:

- Identification indicators: used mainly as metadata and for connecting the recordings in the database with the shapefiles;
- Content indicators: represent the main objective of interest in our study as they represent information we considered to be essential for the website of a LAU2;
- Administrative support indicators: related to the functioning of institution that we used as a control group for assessing if the website was lacking information by design or selectively.

All of the 17 indicators are content indicators – referring to information or services, and not a single one is a design indicator – the way in which the information is presented (Karkin & Janssen, 2014).

Table 1 Selected indicators used in the analysis

Indicator	Explanation	Data range
A. Identification indicators		
A1. Siruta code	Unique number used for identifying each local administrative unit	
A2. Type of unit	According to the classification of Romanian settlements	0-commune, 1-town, 2-municipality, 3-county residence
A3. Website	A dedicated website for the local administrative unit	0-not present, 1-hosted on another domain, 2-personal domain
A4. Frequency of updates	Difference between evaluation date and that of the last update	number of days
B. Content indicators		
B1. General data	A short geographic presentation of the local administrative unit	0-absence, 1-presence
B2. Map	Any form of map presenting the local administrative unit	0-absence, 1-presence
B3. General Urban Plan	Presentation of the General Urban Plan (written and drawn sections)	0-absence, 1-presence
B4. Urbanism certificate	Details about the urbanism certificates	0-absence, 1-presence
B5. Construction permits	Details about construction permits	0-absence, 1-presence
B6. Public services	Sections for the public services of the local administrative units	0-absence, 1-presence
B7. Projects	Presentation of on-going and future projects	0-absence, 1-presence
B8. Environmental section	A dedicated section for the environment	0-absence, 1-presence
C. Administrative support indicators		
C1. Contact data	Post address, telephone, e-mail	0-absence, 1-presence
C2. Mayor	Name of the elected mayor	0-absence, 1-presence
C3. Local Council	Structure of the local council	0-absence, 1-presence
C4. Decisions	Decisions of the local council	0-absence, 1-presence
C5. Declaration of revenues	Declaration of revenues for the main staff members	0-absence, 1-presence

All statistical analyses were performed utilizing Microsoft Office Excel and IBM's SPSS Statistics 19 software (IBM Inc.). We used descriptive statistics for analyzing the distribution of each indicator at county and national level, as well as the Chi square test (χ^2) which determines whether there is a significant association between two indicators (Perkins, Tygert, & Ward, 2014).

In realizing the maps we used ArcGIS 10.X from ESRI, by associating to each polygon in the LAU2 shapefiles the corresponding recording in the Excel database using the A1 indicator – Siruta Code.

Afterwards we were able to realise distribution maps for each category of indicators, but also to aggregate them in a final map. We selected for presentation only maps that revealed a clear geographic distribution or pattern of the analyzed indicator.

Results and discussion

From the total number of 3175 local administrative units that we analyzed we found that 2769 (87.09%) have a dedicated website and only 406 (12.82%) do not have such an online form of e-government (Figure 2). A number of 115 websites (3.62%) were either not working or under construction at the time of our analysis. The largest proportion of local administrative units without websites corresponds to communes and other small settlements, situated mainly in remote areas.

A large majority of the websites (2538 local administrative units – 79.81% of the total number) have their own domain (frequently that being ".ro") while only a small proportion (231 local administrative units – 7.28%) are hosted by a different domain. Websites that are hosted on other domains present little information, mainly about the mayor or contact data.

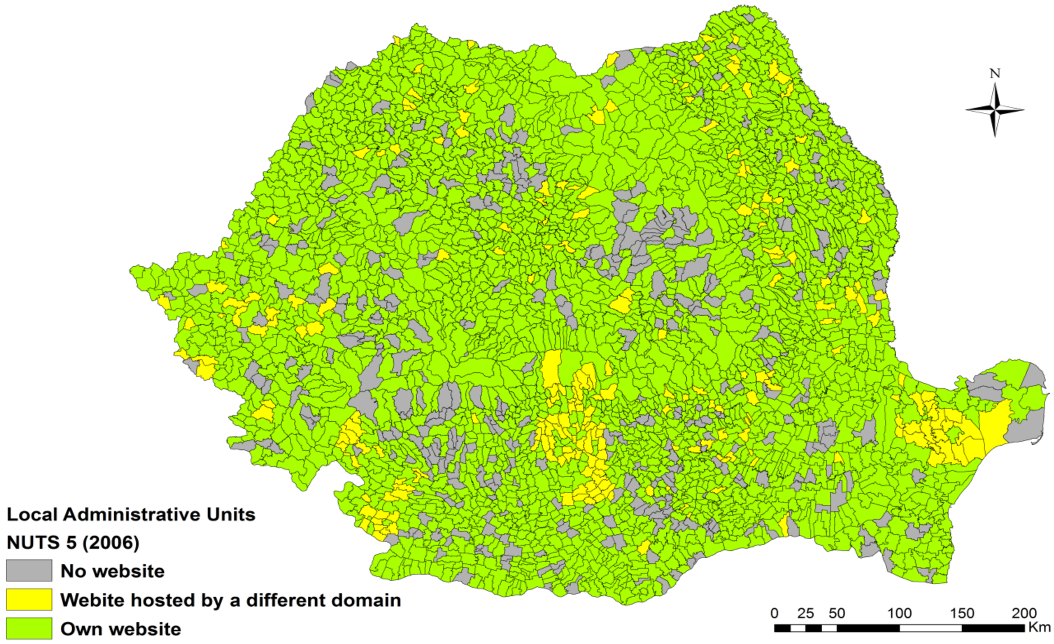

Fig. 2:The existence of a dedicated website for local administrative units in Romania

We observed a connection between the type of settlement and the absence of a corresponding website, as 400 communes (accounting for 13.90% of the total number of communes in Romania) do not have a dedicated website, while only 5 towns (2.63%), 1 municipality (1.47%) and no county residence are in the same situation. The reduced penetration of such services in the rural environment in Romania can be an explanation of the reduced value of the EGDI Telecommunication Infrastructure Component - 0.4385 (United Nations, 2014).

The frequency of updates was a parameter harder to quantify as we were able to count the difference between the date of access and the last post on the website for only 1628 (58.87%) of the local administrative units. We found the difference to be quite impressive, of 281.59 days. We also recorded differences between the frequency of updates for communes (average 292.8 days), towns (235.8 days) and municipalities (69.7 days).

Content indicators

From the total number of 2769 LAU2 that we found websites for, a number of 2037 (73.56%) presented general data (Indicator B1) about the settlement (mainly the geographical characteristics and data about the population) with no significant difference between urban and rural settlements.

Only 754 websites (27.23%) presented a map (Indicator B2) of the LAU2 (we did not assess the quality of the map or the detail levels presented on the map), with great differences between communes (only 24.22% presenting maps) and municipalities (76.12%). From Figure 3 we can observe that the presence of maps is higher in the regions with higher altitudes, but we cannot make the assumption that this connects with the difficulty of realizing the map, as we observed numerous local administrative units that used maps from external sources. We have found a significant relationship between the variables about general data (B1) and map (B2): χ^2 (1) = 238.218, p< 0.001.

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We have found the General Urban Plan of the local administrative unit (Indicator B3) in only 173 websites (6.25%), with a strong relation between the rank of the settlement and the presence of such information (4.12% for communes, 18.92% for towns, 28.36% for municipalities and 40.00% for county residences).

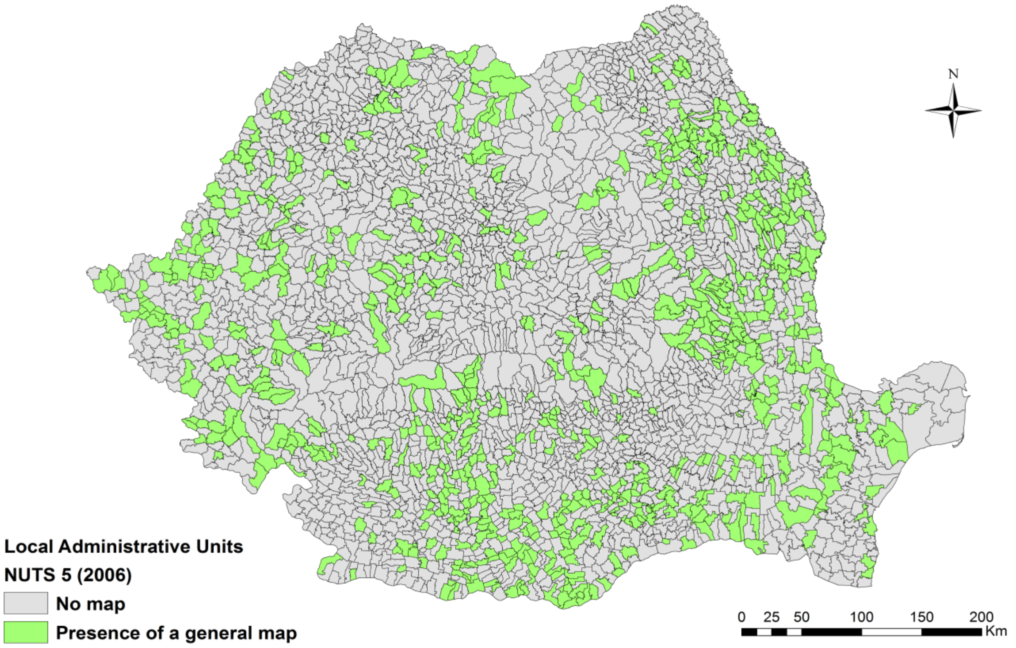

Fig. 3: Presentation of a general map for local administrative units in Romania

The geographic distribution of the General Urban Plan being present on the website (Figure 4) reveals the small number of local administrative units that make it available on the websites. We were not able to identify a geographical pattern of distribution, but generally in Romania, local administrative units tend to consider this type of document as being a confidential one, and accessible only upon request.

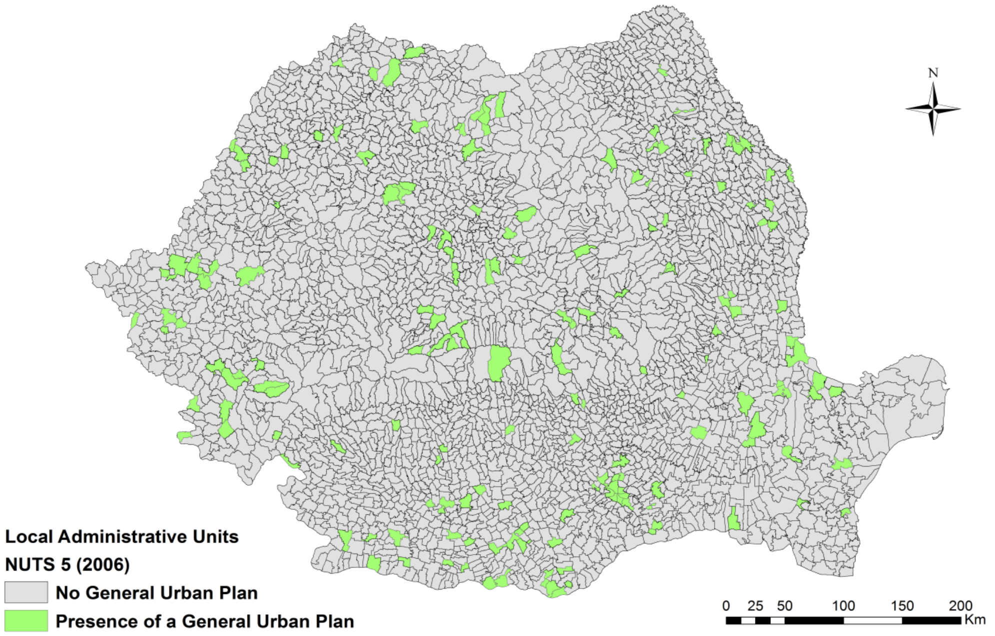

Fig. 4: Presentation of the General Urban Plan for local administrative units in Romania

Only 108 LAU2 (3.90%) have both a map and a General Urban Plan (Indicators B2 and B3), ranging between 2.02% in the case of communes to 26.87% for municipalities. The absence of such documents that spatially represent the local administrative units and its composition is an indicator that authorities are not providing to the general public the opportunities to involve in the decision-making process, and planning according to the perception of the public (Ioja, Rozylowicz, Pătroescu, Niță, &

Vânău, 2011) still remains a theoretical concept in Romania. The number of websites that presented urbanism certificates (Indicator B4) is slightly higher – 454 (16.40%), reaching 52.24% in the case of municipalities. From Figure 5 we can observe an increased distribution of these documents in certain areas of the country and counties (Tulcea, Bihor, Timișoara, etc.).

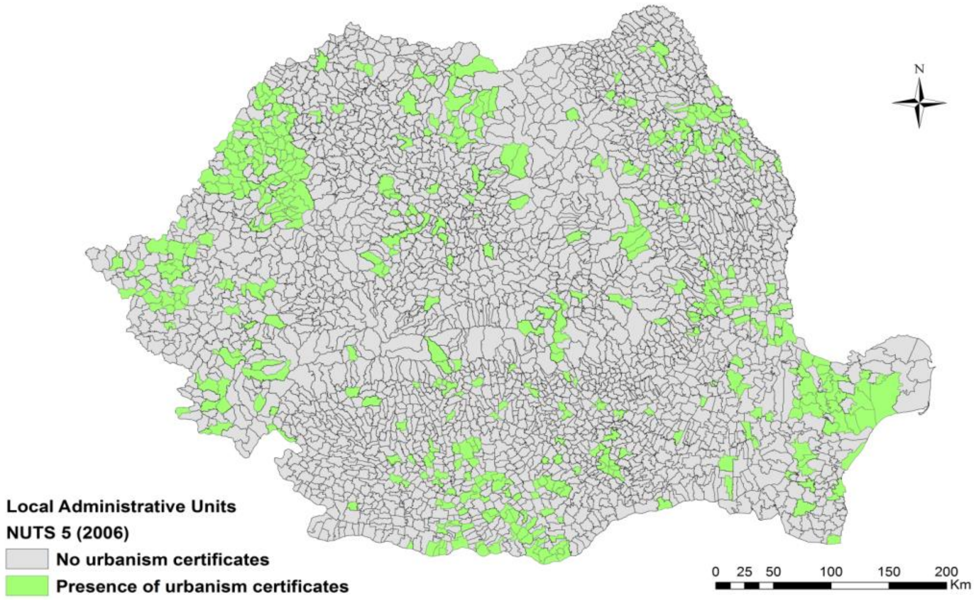

Fig. 5: Presentation of urbanism certificates for local administrative units in Romania

A number of 494 LAU2 (17.84%) presented on their websites information about the construction permits (Indicator B5), with variations between 15.50% for communes and 90.00% for county residences. We have found significant relationships between the variables about the general urban plan (B3) and urbanism certificates (B4): χ^2 (1) = 254.355, p< 0.001; the general urban plan (B3) and the construction permits (B5): χ^2 (1) = 192.250, p< 0.001; urbanism certificates (B4) and construction permits (B5): χ^2 (1) = 1927.705, p< 0.001. The small proportion in which these types of information are presented on the websites can have significant land use consequence (Niță, Ioja, Rozylowicz, Onose, & Tudor, 2014) in the planning process at local and regional level.

From the total websites on 38.17% (1057 LAU2) we can find information about the public services (Indicator B6) offered to the population (Figure 6), the percent increasing in the case of towns (56.76%) or municipalities (70.15%).

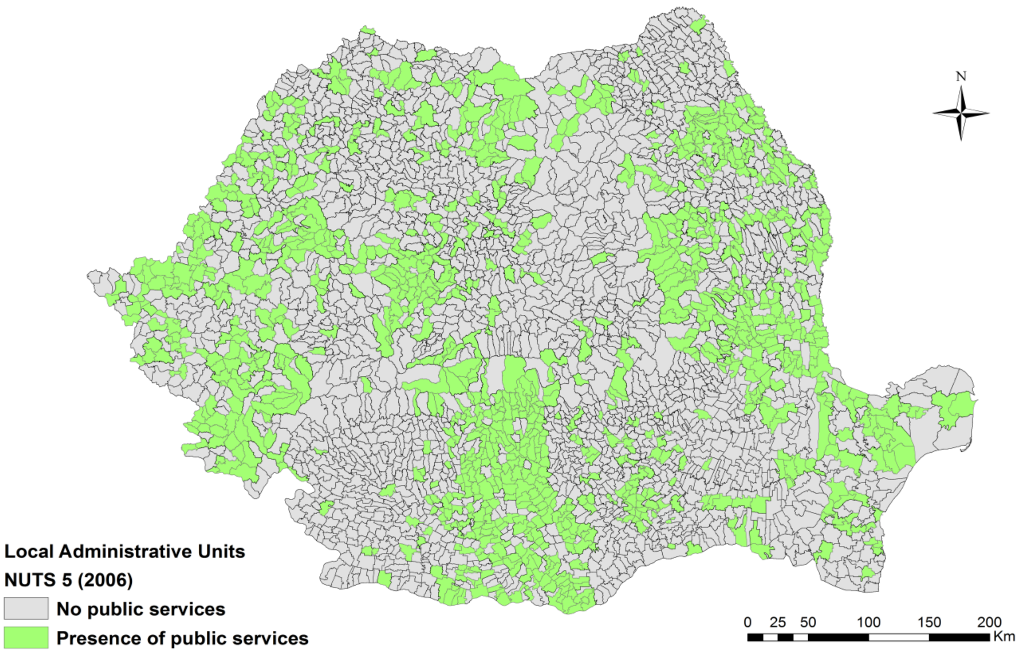

Fig. 6: Presentation of public services for local administrative units in Romania

Projects of the local administrative units (Indicator B7) are presented on 1173 websites (42.36%), and reaches up to 79.10% in the case of municipalities, while communes present this kind of information in only 40.21% of the websites. Indicators B6 and B7 are present simultaneously in the case of 26.04% of the LAU2 (23.38% for communes, 39.46% for towns and 64.18% for municipalities).

There is a significant relationship between the variables about the general urban plan (B3) and projects (B7): χ^2 (1) = 87.819, p< 0.001 and the general urban plan (B3) and public services (B6): χ^2 (1) = 120.666, p< 0.001. Their presence on the websites indicates that authorities are still behind the potential results and expectations generated regarding the use of websites in disseminating information to the general public (Sandoval-Almazan & Gil-Garcia, 2012).

The presence of an environmental dedicated section (Indicator B8) is the indicator with the lowest appearance in the websites of local administrative units from Romania, only 66 LAU2 (2.38%) presenting such an information (with 1.66% in the case of communes and 10.45% in the case of municipalities).

There is no obvious pattern in the distribution of Indicator B8 (Figure 7) due to the small number of LAU2 presenting them. We have found a small relationship between the variables about projects (B7) and the environmental section (B8): χ^2 (1) = 30.038, p< 0.001, underlying the relation between land use and cover changes and environment (Pătroescu, Vânău, Niţă, Iojă, & Iojă, 2011).

The reduced presence of environmental sections is an indicator of the importance given to them by local authorities, which only recently started acknowledging its role in the development of their settlements, and still lack the capability of understanding how to effectively manage the reactions of public (Aladwani, 2013).

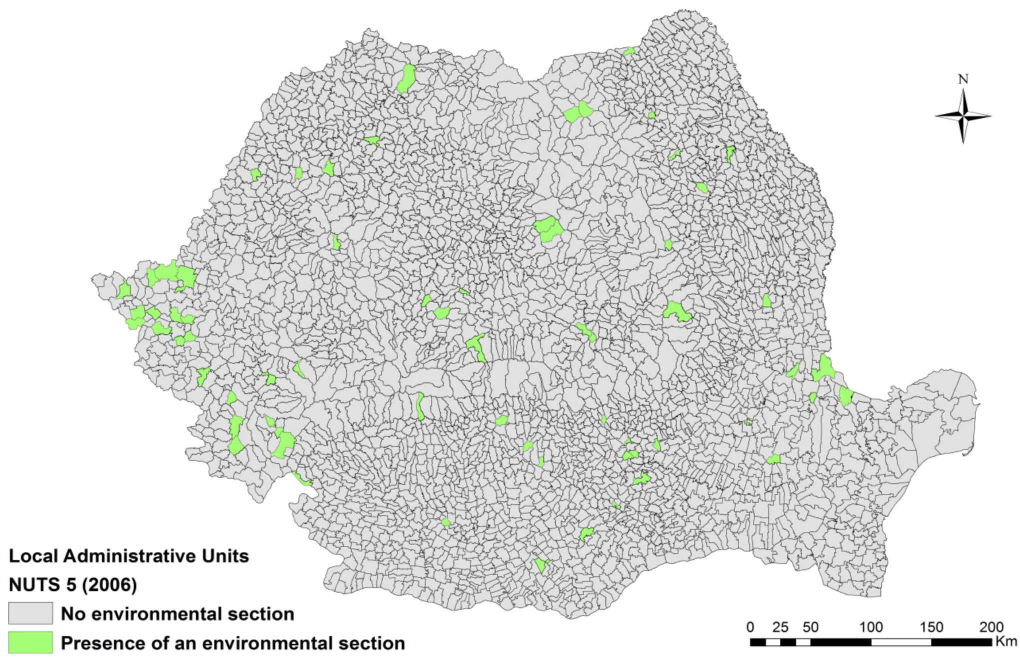

Fig. 7: Presence of a dedicated environmental section for local administrative units in Romania

The distribution of the content indicators by county (Table 2) indicates large variations between the counties for each indicator: existence of website (in Arges, Ilfov, Maramures, Mures and Neamt all local administrative units have websites, while in Harghita over 50% of them don't), general data about the local administrative unit (22.7% in Covasna to over 90% in Arges and Maramures), presence of a map (smallest values in Buzau county and largest of 67.1% in Vrancea), existence of the general urban plan (24.4% in Ilfov), urbanism certificates (77% in Bihor), construction permits (76% in Bihor), public services (85.3% in Arges), projects (66.3% in Teleorman) and an environmental dedicated section (11.7% in Caras-Severin).

With the exception of general data about the local administrative unit, for all the other indicators national average are low, under one third of LAU2 presenting such information. Assuming that the results have not been biased during our methodological approach, we can say that similar to other studies, websites of authorities differ in their characteristics and level of detail (Yavuz & Welch, 2014).

Further insight could be directed on analysis explaining the difference between counties for certain indicators, and finding possible correlation between the values and projects developed by the authorities from respective local administrative units, as they are still a large proportion of the population who know little about the websites of authorities (Wang, 2014), requiring therefore an optimisation for easier access and increasing online public information (Kopackova, Michalek, & Cejna, 2009).

Table 2 Distribution of the content indicators by county

County	No. of analysed LAU2	Without website	General data about LAU2	Map	General Urban Plan	Urbanism certificates	Constructi on permits	Public Services	Projects	Environm ental dedicated menu
			B1	B2	B3	B4	B5	B6	B7	B8
Alba	77	2.6	79.2	29.9	0.0	9.1	10.4	70.1	29.9	2.6
Arad	80	16.3	72.5	28.8	7.5	12.5	12.5	55.0	33.8	3.8
Arges	102	0.0	93.1	9.8	2.0	3.9	5.9	85.3	38.2	2.9
Bacau	93	6.5	77.4	16.1	4.3	9.7	10.8	54.8	41.9	1.1
Bihor	100	6.0	71.0	29.0	6.0	77.0	76.0	53.0	36.0	2.0
Bistrita-Nasaud	62	24.2	62.9	22.6	11.3	25.8	21.0	43.5	45.2	0.0
Botosani	79	2.5	75.9	11.4	1.3	3.8	2.5	5.1	22.8	0.0
Braila	45	17.8	55.6	28.9	11.1	11.1	4.4	24.4	42.2	6.7
Brasov	58	6.9	67.2	12.1	5.2	10.3	8.6	8.6	19.0	3.4
Buzau	88	11.4	53.4	0.0	3.4	1.1	1.1	2.3	12.5	0.0
Calarasi	54	13.0	66.7	38.9	9.3	5.6	5.6	22.2	44.4	0.0
Caras-Severin	77	16.9	80.5	33.8	14.3	23.4	29.9	63.6	57.1	11.7
Cluj	81	18.5	53.1	9.9	4.9	8.6	6.2	12.3	22.2	0.0
Constanta	70	11.4	52.9	17.1	5.7	14.3	14.3	25.7	20.0	0.0
Covasna	44	29.5	22.7	11.4	6.8	4.5	4.5	9.1	9.1	0.0
Dambovita	89	22.5	38.2	15.7	1.1	4.5	4.5	12.4	15.7	0.0
Dolj	113	20.4	29.2	15.0	4.4	4.4	5.3	8.8	12.4	0.0
Galati	64	3.1	87.5	37.5	9.4	28.1	50.0	70.3	67.2	4.7
Giurgiu	53	41.5	43.4	26.4	1.9	3.8	1.9	9.4	26.4	1.9
Gorj	68	44.1	33.8	10.3	2.9	2.9	1.5	0.0	13.2	0.0
Harghita	67	53.7	35.8	7.5	1.5	1.5	1.5	1.5	3.0	1.5
Hunedoara	69	30.4	49.3	10.1	0.0	0.0	0.0	8.7	5.8	0.0
Ialomita	64	14.1	60.9	25.0	0.0	4.7	3.1	10.9	29.7	0.0
Iasi	92	9.8	88.0	48.9	10.9	34.8	52.2	66.3	65.2	1.1
Ilfov	45	0.0	68.9	57.8	24.4	24.4	24.4	55.6	33.3	2.2
Maramures	76	0.0	90.8	22.4	3.9	10.5	6.6	26.3	53.9	1.3
Mehedinti	67	1.5	46.3	20.9	1.5	3.0	3.0	6.0	41.8	1.5
Mures	104	0.0	76.0	10.6	7.7	12.5	12.5	22.1	62.5	1.0
Neamt	81	0.0	84.0	25.9	6.2	8.6	8.6	21.0	46.9	2.5
Olt	113	10.6	87.6	49.6	8.0	32.7	49.6	63.7	61.1	0.9
Prahova	103	13.6	51.5	9.7	2.9	7.8	7.8	22.3	30.1	4.9
Salaj	61	9.8	50.8	4.9	4.9	1.6	1.6	23.0	59.0	3.3
Satu Mare	64	6.3	45.3	1.6	1.6	4.7	4.7	15.6	48.4	0.0
Sibiu	66	9.1	34.8	4.5	10.6	3.0	3.0	22.7	22.7	4.5
Suceava	112	7.1	24.1	5.4	0.0	5.4	6.3	16.1	35.7	3.6
Teleorman	98	10.2	88.8	51.0	16.3	38.8	54.1	68.4	66.3	2.0
Timis	94	4.3	80.9	27.7	4.3	23.4	7.4	38.3	54.3	9.6
Tulcea	51	7.8	70.6	33.3	5.9	51.0	45.1	56.9	21.6	2.0
Valcea	90	23.3	67.8	43.3	2.2	12.2	12.2	37.8	33.3	1.1
Vaslui	87	12.6	81.6	47.1	5.7	2.3	2.3	33.3	35.6	0.0
Vrancea	73	9.6	87.7	67.1	2.7	16.4	16.4	60.3	57.5	1.4
National Average		13.4	63.1	23.9	5.7	13.8	14.6	32.0	36.0	2.1
Minimum		0.0	22.7	0.0	0.0	0.0	0.0	0.0	3.0	0.0
Maximum		53.7	93.1	67.1	24.4	77.0	76.0	85.3	67.2	11.7
Standard Deviation		12.4	20.2	16.6	5.0	15.5	18.3	24.1	18.0	2.6

Administrative support indicators

Contact data (Indicator C1) are presented on the websites of 2122 LAU2 (76.63%), being one of the most encountered information, that reaches 97.01% in the case of municipalities and 86.49% in the case of towns. Similar to other studies, authorities' website content tends to vary in the provision of employee contact information (Yavuz & Welch, 2014). On 1102 websites (39.80%) are present information about the mayor (Indicator C2), the percent being slightly higher in the case of towns (50.27%) and municipalities (67.16%).

There is a significant relationship between the variables about the mayor (C2) and the local council (C3): χ^2 (1) = 351.033, p< 0.001, the mayor (C2) and the declaration of revenues (C5): χ^2 (1) = 287.611, p< 0.001 or the mayor (C2) and the decisions of the local council (C4): χ^2 (1) = 241.617, p< 0.001. The

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composition of the local council (Indicator C3) is presented on 1956 websites (70.64%), with lower values in the case of communes (68.87%) and higher for towns (82.70%) and municipalities (88.06%).

Decisions of the local council (Indicator C4) are shown on 1630 websites (58.87%). There is a significant relationship between the variables about the local council (C3) and the decisions of the local council (C4): χ^2 (1) = 861.691, $p< 0.001$. Declarations of revenues (Indicator C5) are presented on 1484 websites (53.59%), with lower values for communes (51.07%), and higher ones for towns (71.89%), municipalities (77.61%).

Although our construction of the database considered these indicators as "support indicators", more like the metadata in the construction of a geodatabase, we have found that with the exception of information about the mayor, in all other cases the values of these indicators were significantly higher than the ones of content indicators.

These indicate on one hand, the politicization of the websites in the detriment of public information and participation (Cox, 2007). Another explanation could be that this type of information is the only one mandatory to be published by Romanian legislation. Therefore, although transparency of information and participation in government are considered to be linked (Welch, 2012), we see the current approach of local authorities as a "fake transparency", which could reduce their credibility and raise the concerns of population about the use of information and services offered to them (Huang & Benyoucef, 2014).

Table 3 Distribution of administrative support indicators by county

County	No. of analysed LAU2	Without website	Contact data	Mayor	Local Council	Decisions of Local Council	Declaration of revenues
			C1	C2	C3	C4	C5
Alba	77	2.6	89.6	44.2	79.2	59.7	50.6
Arad	80	16.3	77.5	21.3	60.0	51.3	35.0
Arges	102	0.0	95.1	16.7	66.7	26.5	45.1
Bacau	93	6.5	81.7	15.1	76.3	53.8	53.8
Bihor	100	6.0	78.0	24.0	62.0	51.0	48.0
Bistrita-Nasaud	62	24.2	62.9	61.3	62.9	48.4	41.9
Botosani	79	2.5	72.2	45.6	68.4	60.8	50.6
Braila	45	17.8	71.1	17.8	66.7	57.8	66.7
Brasov	58	6.9	84.5	19.0	53.4	53.4	32.8
Buzau	88	11.4	73.9	14.8	73.9	62.5	39.8
Calarasi	54	13.0	75.9	13.0	59.3	50.0	38.9
Caras-Severin	77	16.9	76.6	71.4	68.8	51.9	53.2
Cluj	81	18.5	44.4	13.6	59.3	56.8	49.4
Constanta	70	11.4	52.9	28.6	68.6	64.3	64.3
Covasna	44	29.5	29.5	15.9	54.5	50.0	52.3
County	**No. of analysed LAU2**	**Without website**	**Contact data**	**Mayor**	**Local Council**	**Decisions of Local Council**	**Declaration of revenues**
			C1	C2	C3	C4	C5
Galati	64	3.1	82.8	84.4	65.6	65.6	62.5
Giurgiu	53	41.5	49.1	43.4	28.3	30.2	22.6
Gorj	68	44.1	33.8	26.5	33.8	27.9	33.8
Harghita	67	53.7	35.8	25.4	22.4	17.9	16.4
Hunedoara	69	30.4	50.7	37.7	34.8	34.8	29.0
Ialomita	64	14.1	79.7	34.4	42.2	46.9	37.5
Iasi	92	9.8	82.6	82.6	65.2	59.8	63.0
Ilfov	45	0.0	80.0	44.4	80.0	60.0	51.1
Maramures	76	0.0	93.4	40.8	75.0	57.9	48.7
Mehedinti	67	1.5	91.0	32.8	50.7	10.4	19.4
Mures	104	0.0	97.1	38.5	64.4	48.1	38.5
Neamt	81	0.0	96.3	49.4	87.7	72.8	58.0
Olt	113	10.6	83.2	84.1	61.9	55.8	61.1
Prahova	103	13.6	55.3	30.1	54.4	59.2	53.4
Salaj	61	9.8	54.1	23.0	67.2	57.4	54.1
Satu Mare	64	6.3	71.9	28.1	65.6	65.6	42.2
Sibiu	66	9.1	68.2	15.2	71.2	53.0	39.4
Suceava	112	7.1	60.7	19.6	60.7	31.3	39.3
Teleorman	98	10.2	83.7	84.7	67.3	60.2	65.3
Timis	94	4.3	38.3	24.5	68.1	59.6	47.9
Tulcea	51	7.8	80.4	17.6	76.5	76.5	35.3
Valcea	90	23.3	45.6	18.9	56.7	47.8	55.6
Vaslui	87	12.6	24.1	12.6	52.9	55.2	43.7
Vrancea	73	9.6	68.5	28.8	65.8	65.8	63.0
National Average		13.4	66.7	34.0	61.2	51.5	46.1
Minimum		0.0	24.1	12.4	22.4	10.4	16.4
Maximum		53.7	97.1	84.7	87.7	76.5	66.7
Standard Deviation		12.4	21.0	21.4	13.8	14.0	12.4

The distribution of the administrative support indicators by county (Table 3) indicates mainly their higher values confronted with the content indicators, national averages being above 50% for three of the indicators (C1, C3 and C4). There are differences between the counties for all the indicators: contact data (from 24.1% in Vaslui to 97.1% in Mures), mayor (12.4% Dambovita, 84.7% Teleorman), local council (22.4% Harghita, 84.7% Teleorman), decisions of the local council (10.4% Mehedinti, 76.5% Tulcea) and declarations of revenues (16.4% Harghita, 66.7% Braila).

Total score of indicators

We considered each indicator as having equal value for the information presented on the website and added them, ranking the local administrative units based on the number of indicators they provide, similar to other studies (Hirwade, 2010). We mapped the results (Figure 8) and found that only 15 local administrative units (0.54%) have on their website all content (B1-B8) and administrative support (C1-C5) indicators.

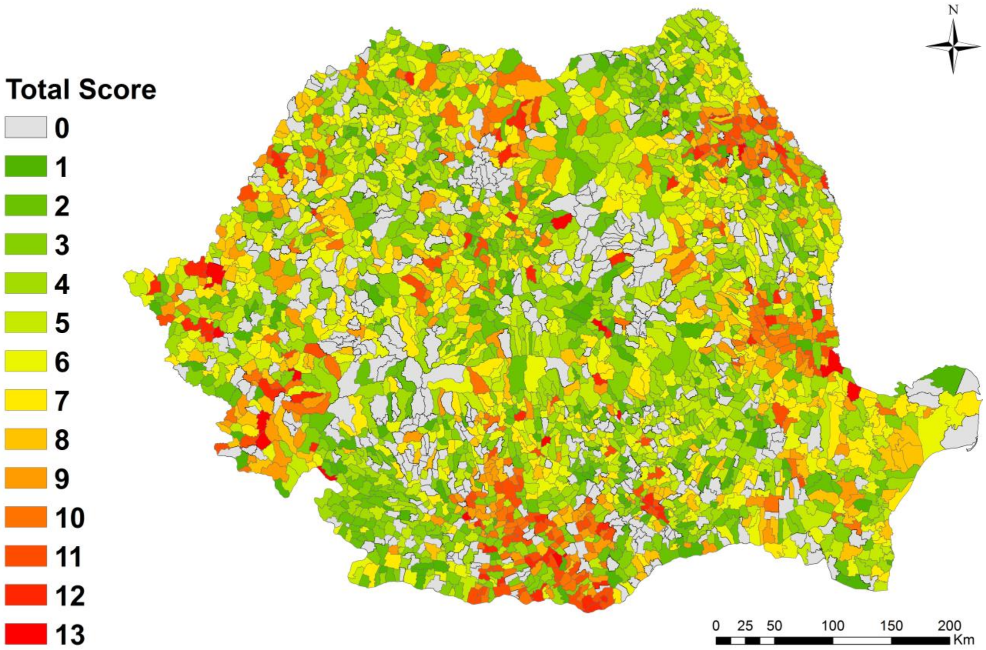

Fig. 8: Total score for the e-government of local administrative units in Romania

Regarding the geographical distribution of online public information by local administrative units in Romania, one can observe areas with a low level in counties such as Harghita (13.20% - total average of content and support indicators by local administrative unit), Gorj (16.97%), Hunedoara (20.07%), Covasna (20.80%) or Dambovita (21.61%). Possible explanations could be the poverty existing in the counties, the high proportion of profound rural settlements or even the ethnical distribution of population. On the other hand, the highest values characterize the counties of Teleorman (57.46%), Iasi (55.43%), Galati (55.05%) and Olt (53.78%).

It is notable that for the purpose of our study we did not use any indicators regarding the accessibility or design of the websites, although we also found that on the websites of local administrative units the emphasis is on copying some visual functionality rather than representing the values underlying them (Karkin & Janssen, 2014; Norton, 2007). Developing countries such as Romania have a reduced degree of organization of the websites, as the main aim of the developers is to upload the information and not to make it accessible to the public, hiding it in secondary sections of the websites which are harder to access (Marlin-Bennett & Thornton, 2012).

Romania has a value of the E-Government Development Index (EGDI) of only 0.5632, value above the world average (0.4721), making it a country with a high EGDI, but also one of the lowest in the European Union (EU average 0.7300), surpassing only Bulgaria (United Nations, 2014). This is determined by the reduced values of the Online Service Component – 0.4409 (EU Average – 0.5695) and the Telecommunication Infrastructure Component, although the values of the Human Capital Component (0.8100) are rather high.

Romanian authorities are confronted with a process of modernization and restructuration for enforcing the technology of information and communication. As recommended by the Digital Agenda for Europe, local authorities should develop online methods for information or public services, increasing therefore the transparency and efficiency of the institution (Georgescu & Popescu, 2014). This comes particularly challenging as the Romanian urban network appears to be insufficiently developed in terms of number of towns versus the total population and surface (Mitrică, Săgeată, &

Grigorescu, 2014), the large number of rural local administrative units making the efforts of developing an efficient system of online public information difficult.

Conclusion

Although numerous studies exist assessing the websites of local administrative units, few of them have focused on mapping the geographic distribution or patterns of the analyzed public information indicators. Our study approached especially the information presented on the websites of local administrative units, using this as input data in evaluating local administrative units after the public information they make available to the general public in the online environment.

Results allowed us to identify a series of aspects characterizing the transparency of public information. The main correlation reveals a direct connection between the rank of the local administrative units and the level of public information, both in the quantity of information available as well in the frequency of updates.

We also identified a series of irregularities such as the absence of building permits or the general urban plan, information often given to the public only upon request. Administrative indicators are the most present on websites, with information diverse such as contact data, composition of the local council and its decisions. Only 0.54% of the local administrative units have all the indicators we analyzed.

The small proportion of information present on the websites of local administrative units can be explained by a series of factors such as the lack of interest and knowledge of both the authorities and the population, a reduced level of organization for the website and its deficient visibility, the low level of penetration for technologies of information and communication in the profound rural settlements.

All these obstacles are characteristic to developing countries and represent opportunities for future studies assessing the degree in which public information reaches the population, an indicator of the development of e-government in Romania. Considering the large percent occupied by rural settlements in Romania, this lack of information for low ranked settlements can lead to problems. We acknowledge that Romania has a large opportunity in the number of specialists which can construct the e-government system, but it is must also face serious challenges in the development and penetration of infrastructure, especially in rural environments.

One of the main challenges is to develop a state-of-the art support infrastructure that will allow the enforcement of e-government principles in all regions of Romania, but also increasing the involvement and understanding of employees in the local administration on the importance of e-government in their relation to the public.

We suggest that future research should concentrate on finding additional factors that will be consistent in developing improved indicators of the distribution of e-government in Romania. Mapping the distribution of such indicators can be of great importance as results should be presented to higher ranked authorities in an easily understandable manner.

Acknowledgments

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Changing dimensions of literacy scenario and their determinants in India: a geographical perspective

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Abstract

The present study is attempted under four points. The first point discusses the regional trends and patterns of literacy rate by decades since 1951. The second examines the trends of literacy rate by inter-states and union territories in the study area during 1951-2011. The third observes the distribution pattern and male-female literacy differentials during 2011, while the fourth explains the factors which influence the literacy level in the study area. The study reveals that the total literacy of India increased from 18.33 per cent to 73.00 from 1951 to 2011. All the states showed positive growth in literacy rate, especially Kerala (93.91 per cent) and Mizoram (91.58 per cent) having the highest growth. The male (96.1 per cent) and female (92.1 per cent) literacy was found to be the highest in Kerala (96.1per cent). The present study concludes that lower gross enrolment ratio and high dropout rates are chief determinants of literacy in the study area. The study is based upon suitable statistical techniques to analyze the data. Finally, some suggestions have been given to enhance the level of literacy rate that may result into positive socio-cultural transformation.

Keywords: *demographic behaviour, disparity in literacy, literacy differentials, spatial perspective*

Rezumat. Evoluția ratei alfabetizării în India și factorii determinanți: o perspectivă geografică

Studiul de față se bazează pe patru puncte. Primul punct prezintă tendințele regionale și modelele ratei de alfabetizare pe decenii din 1951. Cel de-al doilea punct analizează tendințele ratei de alfabetizare pe state și teritorii din zona de studiu în perioada 1951-2011. Cel de-al treilea prezintă modelul de distribuție și diferențele de alfabetizare pe genuri masculin-feminin în 2011, în timp ce al patrulea punct explică factorii care influențează nivelul de alfabetizare în zona de studiu. Studiul arată că alfabetizarea totală în India a crescut de la 18.33% la 73.00 % din 1951 până în 2011. Toate statele au avut o creștere pozitivă a ratei de alfabetizare, în special Kerala (93.91%) și Mizoram (91.58%) având de altfel și cea mai mare creștere. Alfabetizarea masculină (96,1%) și cea feminină (92,1%) a avut cele mai mari valori în Kerala (96.1%). Studiul de față concluzionează că ratele brute de școlarizare cele mai mici și ratele abandonului școlar cele mai mari sunt determinanți principali ai alfabetizării în zona de studiu. Studiul se bazează pe tehnici statistice adecvate de analiză a datelor. În cele din urmă, s-au făcut unele sugestii pentru a spori nivelul ratei de alfabetizare, care pot determina o transformare socio-culturală pozitivă.

Cuvinte-cheie: *comportament demografic, disparitate în procesul de alfabetizare, diferențe de alfabetizare, perspectivă spațială*

Introduction

Census of India 2011 is the fifteenth unbroken series since 1872 and the seventh census after independence. It is believed that any development plan prepared for the wellbeing of the society in any specific region is more or less ineffective after a gap of ten years due to changes occurred in demographic structure and its associated set up. Therefore, Census in regular interval of ten years is mandatory and new planning will take place according to the needs of the society and demographic behaviour (Pant, 2013). Literacy is one of the basic determinants of socio-economic development attained by a human group. Literacy and education are like oxygen for human beings in contemporary technology driven world and knowledge economy (Siddiqui, Hussain & Hannan, 2011). It is pre-eminently the possession of the dominant classes which they use to legitimize and maintain their position. It is a cultural capital which they invest to 'reproduce' themselves. In fact, literacy is a powerful help for developing thinking ability and to reduce or limit literacy is to impair the ability to think. In particular, literacy supports three things: abstract thinking, logical thinking and memory. Literacy is an effective instrument for social and economic development and national integration. It is considered as an important social indicator, because people with higher levels of literacy rate tend to have healthier life styles, less disease and generally a better quality of life (Siddiqui & Hannan, 2011). Literacy rate forms an important demographic element and is a good measure of human progress towards modernization. As per definition of the Census of India 2001 and 2011, a person who can both read and write with understanding in any language is taken as literate. All children below the age of 7 years have been treated as illiterate. In the 1961 and 1971 Censuses, children below the age of 5 years were treated as illiterate (Hannan, 2013).

The most basic measurement of educational status of a people is literacy. High level of physical and mental status of population of a country is a pre-requisite for its economic, social and political advancement. That is why literacy rate is considered to be a good indicator of development in any given society. Directive Principles of Constitution of India ask the state to provide free and compulsory education for all the children until they complete fourteen years of age. The National Policy on Education (1968) had also stressed the need for strenuous efforts for early fulfilment of the goal laid down in the Constitution in this respect. The Constitutional Amendment Act of 1976 put education in the concurrent list i.e. the official list of subjects for which the Centre and the State government assume joint responsibility. The national policy on education, 1986 focused on: universal enrolment in Elementary Schools; universal retention of children up to fourteen years of age; and a substantial improvement in the quality of education to enable all children to achieve a high level of 3-Rs: reading, writing and arithmetic (Ghosh, 1985).

The literacy rates in a country or region are affected largely by the historical, economic, social and cultural determinants. It is observed that if the rate of literacy transition was low, the economic development slowed down while the economic development was rapid if the literacy transition was fast. The literacy rate or the educational status in any area may be determined largely, by a variety of historical, social and economic factors. Closely associated with this is the factor of cost of education. In the less developed countries where education is not free and the cost of education is high, the cost of imparting education to the children becomes an important determinant of literacy. India is a poor country. Most of its social groups live a life of extreme misery without even the essentials of life available to them. A vast majority of people live in slums and in extremely filthy surroundings. They remain below the poverty line and lead a life of starvation. Under these conditions, they are too poor to think and avail any education at all. It is difficult to expect children belonging to the families that lie below the poverty line to go to schools, especially when they can start helping the family in its pursuits of making a living. The experience of India in this regard reveals that even if education is made compulsory and free, the extremely poor families prefer their children to help in making an earning, how so ever meagre it may be rather than sparing them for schools. In case of female children, who cannot be sent outside to work, they stay at home to look after younger children in the family when the parents go outside the work (Hannan, 2015). One notable feature of India's population is that the females lag far behind the males in term of literacy. Such male-female differentials in literacy were the product of the country's history and its socio-economic-political milieu. Largely farm-based economic setup, general poverty, caste-based social structure, prejudices against female's mobility, education, and employment, limited facilities for schooling, poor infrastructure in schools, proxy teacher, high incidence of dropouts and child marriages are some of the factors that may have contributed to the slow pace of literacy transition in the country. Added to the list was one most prominent factor of high rate of natural increase of population that keeps on adding large number of illiterates every year (Chandna, 2009).

Although the growth in educational facilities has been somewhat satisfactory, yet the rate of improvement in literacy has not been sufficient to reduce the disparity in male-female literacy. It is often argued that, despite planned and concentrated efforts, both gender and regional disparities could be seen as a part of wider regional imbalances that existed as a result of India's varied socio-cultural and historical past. In India, the education of girls has historically lagged behind that of boys (Agrawal & Aggarwal, 1994; Sengupta & Guha, 2002; Bandopadhyay & Subrahmaniam, 2010; Das & Mukherjee, 2008; Hannan & Siddiqui, 2015).

Objectives

The present study is attempted under four points. First point discusses the regional trends and patterns of literacy rate by decades since 1951. Second examines the trends of literacy rate by inter-states and Union Territories in the study area during 1951-2011. Third observes distributional pattern and male-female literacy differentials during 2011, and fourth explains the factors which influence on literacy level in the study area.

Study Area

India as a whole has been chosen as study area for the present research work and the boundary of a states / UT has been considered as the unit of study.

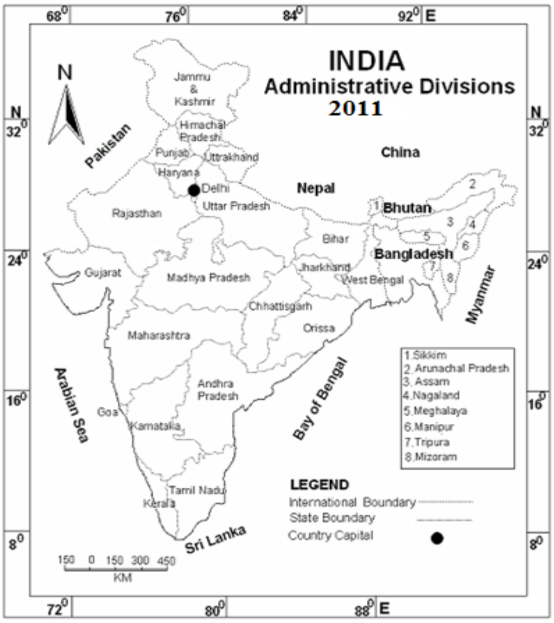

Fig. 1: Administrative divisions of India in 2011 (source: Census of India, 2011)

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The country comprises twenty-eight states and seven union territories (Census, 2011). It lies entirely in the Northern Hemisphere. India is the second most populous country in the world (Khan et. al, 2009). According to the 2011 Indian Census, the total population of India was 1,21 billion (17.5 per cent of world's populations, out of which 68.84 per cent was rural and the remaining 31.16 per cent was classified as urban).

The general density of population was 382 persons per square kilometer. The general sex ratio, that is the number of females per thousand males, was 940, while in rural areas it was 947 and in urban areas 926. The literacy rate was 74.04 per cent. The percentage of literacy in rural and urban population was 68.91 per cent and 84.98 per cent, respectively.

Data and Methods

The present paper is entirely based on secondary sources of data on states obtained from Census of India publications, reports, memoirs, gazetteers, and records of various offices collected from different published and unpublished sources. Apart from the demographic data for the years 1951-2011, obtained from the Census of India the relevant non-demographic data have also been obtained from publications of the Ministry of Home Affairs, Government of India, New Delhi. For understanding and explaining the regional pattern of occurrence of a geographic fact and its trends of regional readjustments a reference to the past therefore becomes not only relevant, but quite essential. In fact, the entire study has taken the form of an interpretation of what have emerged on the maps and arranged in tables. On the basis of tables and processed data, different maps have been prepared with application of GIS-Arc view programme (version 3.2) to show the patterns of inter-state variations in the literacy rate of population in India. The literacy rate of population in the union territories of India has not been shown in the maps, but the degree of determinants of literacy rate of population in all the union territories has been studied and their per cent values have been given in table 2 & 3. For showing the literacy rate simple percentage has been calculated. Subsequently, choropleth maps have been prepared to bring out the real contrast picture more effectively. A careful selection of the class intervals to decide the categories drawn on the maps are based on the mean and standard deviations technique. Correlation techniques were applied to test the linear relationship between literacy rate and selected explanatory variables.

Differentials in literacy are calculated by using the following formula-

MFD=MLR-FLR

Where,

MFDL= Male-female differential of Literacy Rate.

MLR=Male literacy rate.

FLR= Female literacy rate.

General, Rural and Urban Trends of Literacy Rate in India (1951-2011)

General literacy rate from 1951 to 1961, increased by 9.97 per cent points, during the following periods (1961 to 1971, 1971 to 1981, 1981 to 1991, 1991 to 2001 and 2001 to 2011) it has increased by about 6.15, 9.12, 8.64, 12.59 and 8.2 per cent points respectively. The pace of educational growth geared up in successive years and by the end of 2011, the total literacy level was 73.00 per cent, whereas it was 80.90 per cent for males and 64.60 per cent for females. The general trends of rural literacy rates show that during 1951 -1961 it increased from 10.4 per cent points in India. The rate rose to more than 5 per cent points in 1971, 1981, 1991, 2001 and 2011. An accelerating rate of rural literacy rate was recorded during the five decades (1961-2011), it was 68.91 per cent persons, 78.57 per cent for male and 58.75 per cent for females in 2011 in the country. In 1951, the urban literacy rate was 34.60 per cent, and it respectively rose to 54.40 per cent in 1961. This development continued to next decadal year (1971) with 60.20 per cent. The same pattern of increase with different magnitudes was observed in the succeeding decadal years (1981-2011). The trends in rural and urban male and female literacy rates have, by and large, been the same as those noted above in respect of the general literacy rates (Table 1).

Regional Distributional Pattern of Literacy Rate in India 2011

The distribution of literacy rates (persons, males and females) is marked by regional variations over space in 2011 in India. Generally, literacy rate in India is 73.00 per cent; it is 80.9 per cent for males and 64.6 per cent for females (Table 3). The literacy rate is marked by notable regional variation in its distributions in India. The method of classifying the literacy rate into three categories of medium, high and low invariably has been that of standard deviation and mean. In this method, levels of literacy rate by state have been arranged in ascending order and their mean and standard deviations have been worked out.

Table 1 Trends of Literacy Rate in India in per cent (1951-2011)

Census Years	Total			Rural			Urban		
	P	M	F	P	M	F	P	M	F
1951	18.33	27.20	8.86	12.10	19.00	4.90	34.60	45.60	22.30
1961	28.30	40.40	15.40	22.50	34.30	10.10	54.40	66.00	40.50
1971	34.45	46.00	22.00	27.90	48.60	15.50	60.20	69.80	48.80
1981	43.57	56.40	29.80	36.00	49.60	21.70	67.20	76.70	56.30
1991	52.21	64.10	39.30	44.70	57.90	30.60	73.10	81.10	64.00
2001	64.80	75.30	53.70	58.70	70.70	46.60	79.90	86.30	72.90
2011	73.00	80.90	64.60	68.91	78.57	58.75	84.98	89.70	79.92

Source: Census of India, 2011, Ministry of Home Affairs, Office of the General Registrar, Govt, of India, New Delhi.

P: Persons; M: Males; F: Females

Note:

(*) For 1951, the population male, female and persons refer to effective literacy rates and the breakup of Rural; urban and male-female components are crude literacy rates.

(1) Literacy rate for 1951, 1961 and 1971 Census relates to population aged five years and above. The rates for the 1981, 1991, 2001and 2011 census relate to population aged seven years and above.

(2) The 1981 literacy rate exclude Assam, where Census could not be conducted and the 1991 literacy rate exclude Jammu & Kashmir, where census could not be conducted due to disturbed conditions.

(3) The 2001 census, literacy rate excludes entire Kachh district, Morvi, Maliya-Miyana and Wankaner talukas of Rajkot district, Jodiya talluka of Jamnagar district of Gujarat state and entire Kinnaur district of Himachal Pradesh where population enumerate of census of India, 2001, could not be conducted due to natural calamities.

Table 2 States/ Union Territories Wise Trends of Literacy Rate in India in per cent (1951-2011)

S. N	States/Union Territories	1951	1961	1971	1981	1991	2001	2011
1	Jammu & Kashmir	NA	12.95	21.71	30.64	NA	55.52	68.74
2	Himachal Pradesh	NA	NA	NA	NA	63.86	76.48	83.78
3	Punjab	NA	NA	34.12	43.37	58.51	69.65	76.68
4	Uttarakhand	18.93	18.05	33.26	46.06	57.75	71.62	79.63
5	Haryana	NA	NA	25.71	37.13	55.85	67.91	76.64
6	Rajasthan	8.5	18.12	22.57	30.11	38.55	60.41	67.06
7	Uttar Pradesh	12.02	20.87	23.99	32.65	40.71	56.27	69.72
8	Bihar	13.49	21.95	23.17	32.32	37.49	47.00	63.82
9	Sikkim	NA	NA	17.74	34.05	56.94	68.81	82.2
10	Arunachal Pradesh	NA	7.13	11.29	25.55	41.59	54.34	66.95
11	Nagaland	10.52	21.95	33.78	50.28	61.65	66.59	80.11
12	Manipur[a]	12.57	36.04	38.47	49.66	59.89	70.53	79.85
13	Mizoram	31.14	44.01	53.80	59.88	82.26	88.80	91.58
14	Tripura	NA	20.24	30.98	50.10	60.44	73.19	87.75
15	Meghalaya	NA	26.92	29.49	42.05	49.1	62.56	75.48
16	Assam	18.53	32.95	33.94	NA	52.89	63.25	73.18
17	West Bengal	24.61	34.46	38.86	48.65	57.70	68.64	77.08
18	Jharkhand	12.93	21.14	23.87	35.03	41.39	53.56	67.63
19	Odisha	15.80	21.66	26.18	33.62	49.09	63.08	73.45
20	Chhattisgarh	9.41	18.14	24.08	32.63	42.91	64.66	71.04
21	Madhya Pradesh	13.16	21.41	27.27	38.63	44.67	63.74	70.63
22	Gujarat	21.82	31.47	36.95	44.92	61.29	69.14	79.31
23	Maharashtra	27.91	35.08	45.77	57.24	64.87	76.88	82.91
24	Andhra Pradesh	NA	21.19	24.57	35.66	44.08	60.47	67.66
25	Karnataka	NA	29.80	36.83	46.21	56.04	66.64	75.6
26	Goa	23.48	35.41	51.96	65.71	75.71	82.01	87.4
27	Kerala	47.18	55.08	69.75	78.85	89.81	90.86	93.91
28	Tamil Nadu	NA	36.39	47.40	54.39	62.66	73.45	80.33
Union Territories								
29	Chandigarh	NA	NA	70.43	74.80	77.81	81.94	86.43
30	Delhi	NA	61.95	65.08	71.94	75.29	81.67	86.34
31	Daman & Diu	NA	NA	NA	NA	71.2	78.18	87.07
32	Dadra & Nagar Haveli	NA	NA	18.13	32.90	40.71	57.63	77.65
33	Lakshadweep	15.23	27.15	51.76	68.42	81.78	86.66	92.28
34	Pondicherry	NA	43.65	53.38	65.14	74.74	81.24	86.55
35	Andaman & Nicobar Island	30.30	40.07	51.15	63.19	73.02	81.30	86.27
All India		18.33	28.30	34.45	43.57	52.21	64.84	74.04

Source: Census of India (1951- 2011), Ministry of Home Affairs, Office of the General Registrar, Govt of India, New Delhi.

NA: Not Available

a- India and Manipur figures exclude those of the three sub-division viz. Mao Maram, Poamata and purul of Senapati district of Manipur as census result of 2001 in these three sub-division were cancelled due to technical and administrative reasons.

Note: Literacy rates for 1951, 1961, and 1971 Census relate to population aged five years and above. The rates for the 1981, 1991, 2001 and 2011 Censuses relate to the population aged seven years and above. The literacy rate for 1951 in case of West Bengal relates to total population including 0-4 age group. Literacy rates for 1951 in respect of Chhattisgarh, Madhya Pradesh and Manipur are based on sample population.

Forum geografic. Studii și cercetări de geografie și protecția mediului
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In India, it is recorded to be 73.00 per cent, 80.00 per cent and 64.6 per cent respectively for persons, male and females. It is observed that there are seven identifiable states with high level of literacy rate (Fig. 2A). They are Kerala (94.00 per cent), Mizoram (91.3 per cent), Goa (88.7 per cent), Tripura (87.2 per cent), Himachal Pradesh (82.8 per cent), Maharashtra (82.3 per cent), and Sikkim (81.4 per cent). These states are scattered all over the study area. The states of medium category of literacy rates are Tamil Nadu (80.00 per cent), Nagaland (79.6 per cent), Manipur (79.2 per cent), Uttarakhand (78.8 per cent) and Gujarat (78.00 per cent) - they are located in the eastern and scattered parts of the study area. A region of low level of literacy rate (below 75.86 per cent) is concentrated in north eastern and north western part of India. These states are West Bengal (76.30 per cent), Punjab (75.8 per cent), Haryana (75.6 per cent), Karnataka (75.4 per cent), Meghalaya (74.4 per cent), Odisha (72.9 per cent), Assam (72.2 per cent), Chhattisgarh (70.3 per cent), Madhya Pradesh (69.3 per cent), Uttar Pradesh (67.7 per cent), Jammu & Kashmir (67.2 per cent), Andhra Pradesh (67.00 per cent), Jharkhand (66.4 per cent), Rajasthan (66.1 per cent), Arunachal Pradesh (65.4 per cent) and Bihar (61.8 per cent).

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Table 3 Literacy Rate in per cent by Sex in India, 2011

Sl. No	States/Union Territories	Persons	Males	Females	Gender Gap
1	Jammu & Kashmir	67.2	76.8	56.4	20.4
2	Himachal Pradesh	82.8	89.5	75.9	13.6
3	Punjab	75.8	80.4	70.7	9.7
4	Uttarakhand	78.8	87.4	70	17.4
5	Haryana	75.6	84.1	65.9	18.2
6	Rajasthan	66.1	79.2	52.1	27.1
7	Uttar Pradesh	67.7	77.3	57.2	20.1
8	Bihar	61.8	71.20	51.5	19.7
9	Sikkim	81.4	86.6	75.6	11.0
10	Arunachal Pradesh	65.4	72.6	57.7	14.9
11	Nagaland	79.6	82.8	76.1	6.7
12	Manipur	79.2	86.1	72.4	13.7
13	Mizoram	91.3	93.30	89.3	4.0
14	Tripura	87.2	91.5	82.7	8.8
15	Meghalaya	74.4	76.0	72.9	3.1
16	Assam	72.2	77.8	66.3	11.5
17	West Bengal	76.30	81.7	70.5	11.2
18	Jharkhand	66.4	76.8	55.4	21.4
19	Odisha	72.9	81.6	64.0	17.6
20	Chhattisgarh	70.3	80.3	60.2	20.1
21	Madhya Pradesh	69.3	78.7	59.2	19.5
22	Gujarat	78.0	85.8	69.7	16.1
23	Maharashtra	82.3	88.4	75.9	12.5
24	Andhra Pradesh	67.00	74.9	59.1	15.8
25	Karnataka	75.4	82.5	68.1	14.4
26	Goa	88.7	92.6	84.7	7.9
27	Kerala	94	96.1	92.1	4.0
28	Tamil Nadu	80.00	86.8	73.4	13.4
Union Territories					
29	Chandigarh	86.00	90.00	81.2	8.8
30	Delhi	86.2	90.9	80.8	10.1
31	Daman & Diu	87.1	91.5	79.5	12.0
32	Dadra & Nagar Haveli	76.2	85.2	64.3	20.9
33	Lakshadweep	91.8	95.6	87.9	7.7
34	Pondicherry	85.8	91.3	80.7	10.6
35	Andaman & Nicobar Island	86.6	90.30	82.4	7.9
All India		73.00	80.9	64.6	16.3

Data Source: Census of India, 2011, Ministry of Home Affairs, Office of the General Registrar, Govt, of India, New Delhi

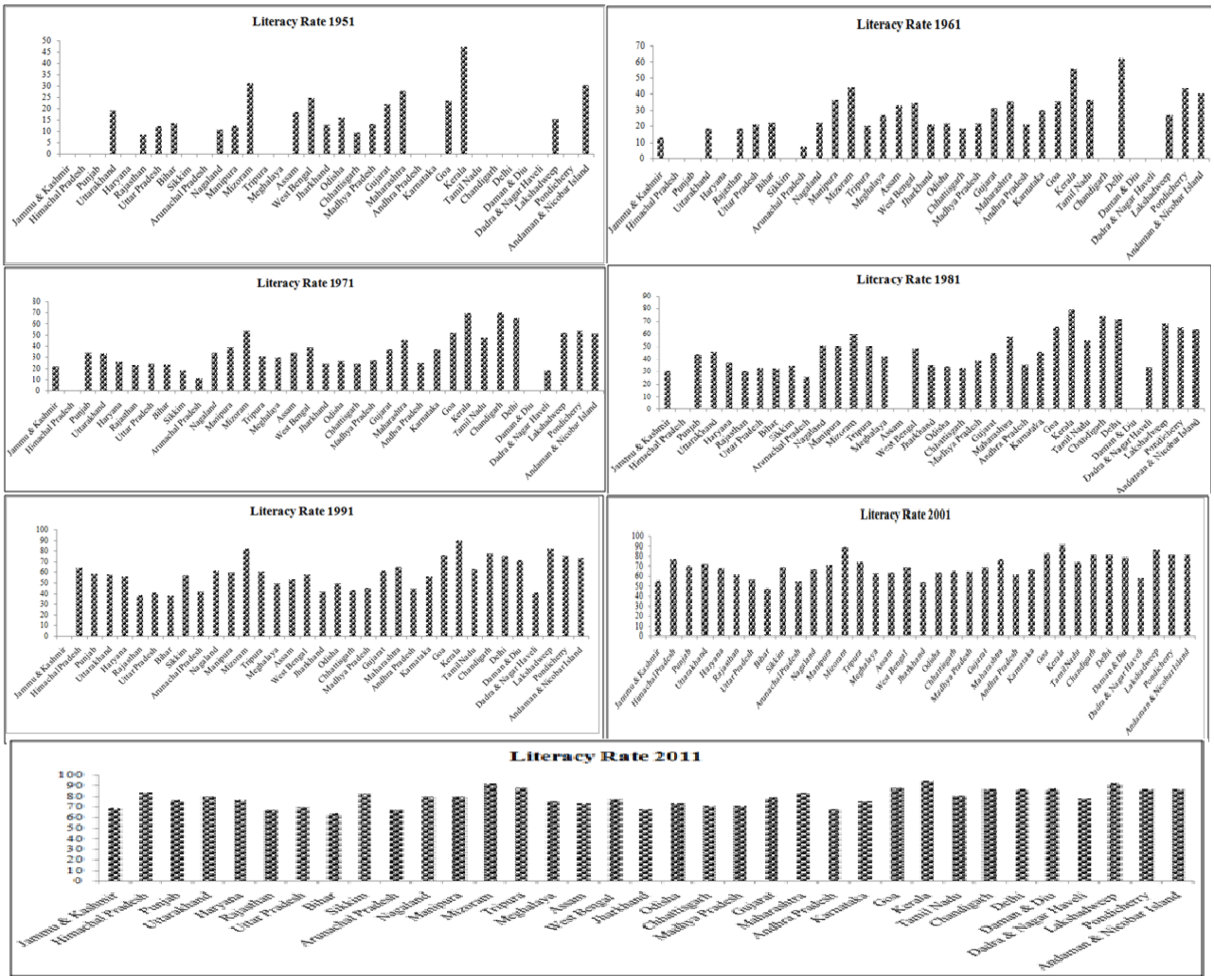

Fig.2: Decade and States/ Union Territories (UT) Wise Bar Graph of Literacy Rate in India (1951-2011)

There is a wide regional difference in male literacy rate among all the states of the study area. Male literacy rate is arranged into three degrees of high, medium and low rate. High male literacy rate is observed in ten states in the study area. These states are Kerala (96.1 per cent), Mizoram (93.3 per cent), Goa (92.6 per cent), Tripura (91.5 per cent), Himachal Pradesh (89.5 per cent), Maharashtra (88.4 per cent), Uttarakhand (87.4 per cent), Tamil Nadu (86.8 per cent), Sikkim (86.6 per cent) and Manipur (86.1 per cent). Most of these states having a small population although having high literacy do not contribute much to the overall literacy of the nation The states of high literacy rates are located in north-eastern, north and south-western part. There are two states with medium level of literacy rate located in north western part (Fig 2B). These states are Gujarat (85.8 per cent) and Haryana (84.1 per cent). The states of low literacy rates are located all over the study area. They are Nagaland (82.8 per cent), Karnataka (82.5 per cent), West Bengal (81.7 per cent), Odisha (81.6 per cent), Punjab (80.4 per cent), Chhattisgarh (80.3 per cent), Rajasthan (79.2 per cent), Madhya Pradesh (78.7 per cent), Assam (77.8 per cent), Uttar Pradesh (77.3 per cent), Jammu & Kashmir (76.8 per cent), Jharkhand (76.8 per cent), Meghalaya (76.0 per cent), Andhra Pradesh (74.9 per cent), Arunachal Pradesh (72.6 per cent), Bihar (71.20 per cent). They account for major share of literates in the country.

The states of high female literacy rates are Kerala (92.1 per cent), Mizoram (89.3 per cent), Goa (84.7 per cent), Tripura (82.7 per cent), Nagaland (76.1 per cent), Himachal Pradesh (75.9 per cent), Maharashtra (75.0 per cent) and Sikkim (75.6 per cent). They are located in north-eastern, south-western and northern part of India. The medium level of female literacy rate is observed in seven states, which are scattered over southern, northern and eastern part of the study area (Fig. 3C).

The states against the female literacy rates are Tamil Nadu (73.4 per cent), Meghalaya (72.9 per cent), Manipur (72.4 per cent), Punjab (70.7 per cent), West Bengal (70.5 per cent), Uttarakhand (70.00 per cent) and Gujarat (69.7 per cent). Low level of female literacy rate is recorded in the states

Forum geografic. Studii și cercetări de geografie și protecția mediului
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of Karnataka (68.1 per cent), Assam (66.1 per cent), Haryana (65.9 per cent), Odisha (64.0 per cent), Chhattisgarh (60.2 per cent), Madhya Pradesh (59.2 per cent), Andhra Pradesh (59.1 per cent), Arunachal Pradesh (57.7 per cent), Uttar Pradesh (57.2 per cent), Jammu & Kashmir (56.1 per cent), Jharkhand (55.4 per cent), Rajasthan (52.1 per cent) and Bihar (51.5 per cent), it is scattered all over the study area. These states account for major share of female literates in the study area.

Gender Gap in Literacy Rate in India, 2011

It needs no reiteration that female literacy is the key to all aspects of development. The narrowing of the gender gap in the literacy rate is the key to a vibrant India (Bhargava, 2001). At the National level, the literacy rate for persons was 73.00 per cent, for males 80.9 per cent and for females 64.6 per cent in 2011.

An examination of the gender gap in literacy rates for 2011 reveals that at the study area it was recorded to be 16.3 per cent. As seen from Table 3, the gender gap was in the range of 3.1 to 27.1 per cent points in Meghalaya and Rajasthan, respectively. There were ten states which recorded gender gap below 11.09 per cent for the study area.

Figure 4 shows the graded distribution of state by gender gap into high, medium and low.

The western margin is occupied by the states of high rate of gender gap in literacy (above 14.06 per cent). Jammu-Kashmir (20.4 per cent), Uttarakhand (17.4 per cent), Uttar Pradesh (20.1 per cent), Bihar (19.7 per cent) and Jharkhand (21.4 per cent) in eastern part of the study area also belong to the same group.

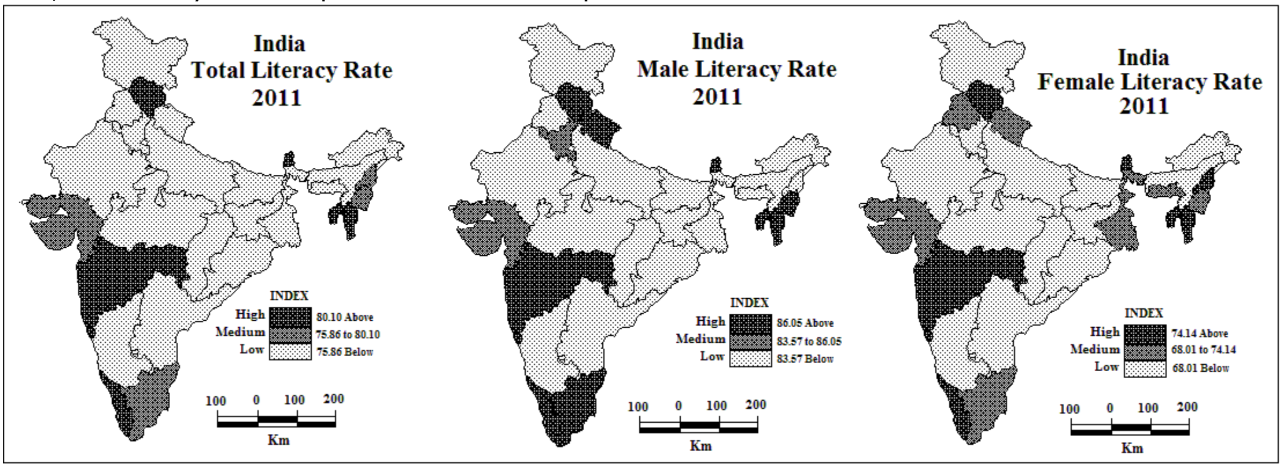

Fig. 3: Literacy Status in India, 2011

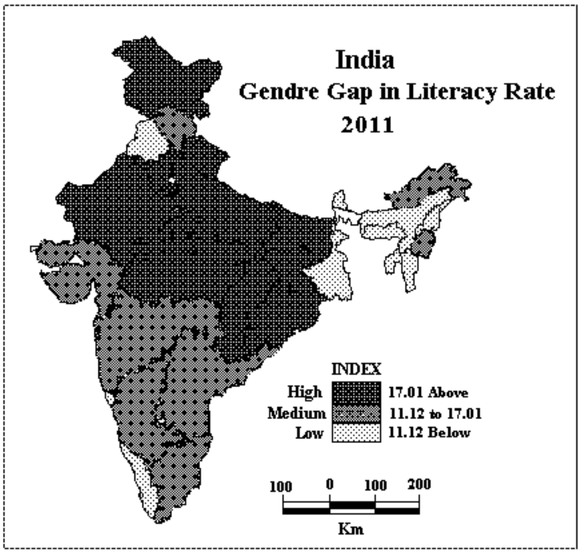

Fig. 4: Gender gap in literacy rate, 2011

The state with low gender gap of below 11.09 per cent makes noticeable region in the eastern part of the study area and including Punjab (9.7 per cent), Goa (7.9 per cent) and Kerala (4.0 per cent). In southern margin, beginning from from Tamil Nadu (13.4 per cent), Karnataka (14.4 per cent), Andhra Pradesh (15.8 per cent) and Maharashtra (12.5 per cent) and including Himachal Pradesh (13.6 per cent), Arunachal Pradesh (14.9 per cent) and Manipur (13.7 per cent) show medium level of gender gap (17.01 to 11.09 per cent) in literacy rate in India. However, a common feature remained in almost all the states of the country- the gender gap in literacy rate has slightly reduced with increase in literacy rates of females.

Relationship Between Literacy Rate and Other Selected Independent Variables

In the present investigation for causal analysis of the literacy status a list has been prepared for thirty-one different independent variables (Table 4) that influence on may not influence the literacy status of population in the twenty-eight state and seven Union Territories of the study area (India). In this regard a correlation matrix is computed as shown in Table 4, among total literacy rate, male literacy rate, female literacy rate and gender gap in literacy rate and the independent variables tested, with the assumption that linear relationships existed in all the cases. The testing of simple associations between literacy level and each of the individual variables is shown in Table 4. Among the variables, the coefficients of correlation of four variables have recorded positive significant relationship with literacy rate (Y1).

They are X5 (gross enrolment ratio for girls in the 6th to 8th grade) having direct relationship at 5 per cent significance level, X7 (gross enrolment ratio for boys in the 9th to 10th grade) has positive relation at 5 per cent significant level, X8 (gross enrolment ratio for girls in the 9th to 10th grade) having positive significant at 1 per cent level with literacy rate, X9 (gross enrolment ratio for total in the 9th to 10th grade) is positively correlated with literacy rate at 1 per cent significant level.

Tabel 4 Result of Correlation (r) among Selected Variables Influencing on Literacy Status in India, 2011

Variables		Literacy Rate Y_1	Male Literacy Rate Y_2	Female Literacy Rate y_3	Gender Gap Y_4
X_1	Gross Enrolment Ratio for Boys in Class I-V	-0.111	-0.209	-0.035	-0.166
X_2	Gross Enrolment Ratio for Girls in Class I-V	-0.149	-0.245	-0.074	-0.134
X_3	Gross Enrolment Ratio for Total in Class I-V	-0.128	-0.225	-0.052	-0.153
X_4	Gross Enrolment Ratio for Boys in Class VI-VIII	0.292	0.356	0.025	-0.067
X_5	Gross Enrolment Ratio for Girls in Class VI-VIII	.378*	.391*	0.363	-0.237
X_6	Gross Enrolment Ratio for Total in Class VI-VIII	0.342	.380*	0.313	-0.156
X_7	Gross Enrolment Ratio for Boys in Class IX-X	.394*	.513**	0.314	-0.012
X_8	Gross Enrolment Ratio for Girls in Class IX-X	.592**	.636**	.547**	-0.303
X_9	Gross Enrolment Ratio for Total in Class IX-X	.506**	.590**	.442*	-0.162
X_{10}	Gross Enrolment Ratio for Boys in Class XI-XII	0.103	0.223	0.022	0.206
X_{11}	Gross Enrolment Ratio for Girls in Class XI-XII	0.258	0.337	0.197	0.01
X_{12}	Gross Enrolment Ratio for Total in Class XI-XII	0.18	0.283	0.107	0.115
X_{13}	Dropout Rate for Boys in class I-X	-.472*	-.538**	-.409*	0.159
X_{14}	Dropout rate for Girls in class I-X	-.466*	-.525**	-.408*	0.017
X_{15}	Dropout rate for Total in class I-X	-.474*	-.537**	-.413*	0.167
X_{16}	Pre-Primary/Pre Basic Schools	-0.28	-0.343	-0.219	0.028
X_{17}	Primary Schools / Junior Basic Schools	-.638*	-0.615	-0.626	0.454
X_{18}	Middle Schools /Senior Basic Schools	-0.37	-0.278	-0.425	0.514
X_{19}	High Schools /Post Basic schools	-0.405	-0.354	-0.414	0.344
X_{20}	Pre-Degree / Junior Colleges/ Higher Sec. Schools	-0.429	-0.287	-.505*	.617*
X_{21}	Arts, Fine Arts, Social Work, Science & Commerce	-.424*	-0.38	-.425*	0.358
X_{22}	Engineering/ Technology/ Architecture	-0.167	-0.132	-0.171	0.17
X_{23}	Medical/ Nursing	-0.017	0.009	-0.026	0.057
X_{24}	Education/Teacher Training	0.095	0.167	0.054	0.082
X_{25}	Technical Education	-0.144	-0.051	-0.191	0.292
X_{26}	Total Colleges	-0.258	-0.233	-0.257	0.211
X_{27}	College for General Education	-.482*	-.411*	-.494*	.449*
X_{28}	College for Professionals Education	-0.115	-0.066	-0.136	0.176
X_{29}	Other (Including Research Institutions	-0.202	-0.136	-0.229	0.027
X_{30}	Universities/ Universities Level Institutes Provisional	-0.279	-0.162	-0.335	.435*
X_{31}	Polytechnics	-0.003	0.013	-0.047	0.001

Source: Calculation is based on State Level Published Data, Census of India, 2011 and Data, Ministry of Home Affairs, Office of the General Registrar, Government of India, New Delhi

Note: **Significance at 1 per cent level and *Significance at 5 per cent level.

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Besides, six variables have negative significant relationship with literacy rate at 5 per cent level. They are X13 (dropout rate for boys in the 1st to 10th grade), X14 (dropout rate for girls in the 1st to 10th grade), X15 (dropout rate for total in the 1st to 10th grade), X17 (primary schools/ junior basic schools), X21 (Arts, Fine Arts, Social Work, Science & Commerce) and X27 (college for general education).

Five variables showed a significant positive correlation with male literacy rate Y2. They are X5 (gross enrolment ratio for girls in the 6th to 8th grade) at 5 per cent significant level, X6 (gross enrolment ratio for total in the 6th to 8th grade) at 5 per cent significance level, X7 (gross enrolment ratio for boys in the 6th to 8th grade) at 1 per cent degree impact level, X8 (gross enrolment ratio for girls in the 6th to 8th grade) at 1 per cent significant level, X9 (gross enrolment ratio for total in the 9th-10th grade) is positively correlated with male literacy rate Y2, at 1 per cent significant level. Male literacy rate Y2 negative association with four variables, they are X13 (dropout rate for boys in the 1st to 10th grade) significant at 1 per cent level, X14 (dropout rate for girls the 1st to 10th grade) significant at 1 per cent level, X15 (dropout rate for total in the 1st to 10th grade) at 1 per cent significance level, X27 (college for general education) at 5 per cent level of significance level.

Two variables showed a significant positive correlation with female literacy Y3 at 1 and 5 per cent significance level. They are: X8 (gross enrolment ratio for girls in the 9th and 10th grade), X9 (gross enrolment ratio for total in the 9th and 10th grade) and six variables are negatively associated with female literacy Y3, they are X13 (dropout rate for boys in the 1st to the 10th grade), X14 (dropout rate for girls in the 1st to the 10th grade), X15 (dropout rate for total in the 1st to the 10th grade), X20 (pre-degree/junior colleges/ higher sec. schools), X21 (Arts, Fine Arts, Social Worker, Science & Commerce), X27 (college for general education) at 5 per cent level of significant. Three variables of X20 (pre-degree/junior colleges/ higher sec. schools), X27 (college for general education), X30 (universities/ universities level Institutes) are positively correlated with gender gap at 5 per cent level of significance.

Conclusion and Suggestions

It is a matter of great concern that even with a very liberal definition of literacy; India has 80.9 per cent male literate population and only 64.6 per cent female literate population. Historically, a variety of factors have been found to be responsible for poor female literacy rate, i.e. gender based inequality, social discrimination and economic exploitation, occupation of girl child in domestic chores, low enrollment of girls in schools, low retention rate and high dropout rate, etc. Programmes like National Literacy Mission, initiated in 1988, for imparting functional literacy has been instrumental for increasing female literacy in the country.

It is clear that there has been a significant improvement in the literacy levels of both males and females with the latter having an edge, which helped in reducing the gap and disparity in male-female literacy. The fruits of this major achievement are bound to have positive bearing on our society. In this respect, performance of Chhattisgarh, Rajasthan and Madhya Pradesh during 1991-2001, and Dadra & Nagar Haveli, Bihar and Tripura during 2001-11, stand out for their remarkable progress in literacy rates.

It is a matter of concern that, despite noticeable improvement in female literacy, the States/UTs of Arunachal Pradesh, Bihar, Chhattisgarh, Haryana, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, Uttarakhand and Dadra & Nagar Haveli did not make any progress towards the reduction of gender disparity these have continued to show more disparity than the national average. Bihar, Rajasthan and Jharkhand remain the three states with the highest disparity. On the other hand, the States/UTs of Chandigarh, Tripura, Andaman & Nicobar Island, Goa, Nagaland, Lakshadweep, Kerala, Meghalaya and Mizoram have achieved more than 90 per cent equality in terms of male-female literacy. Most of these states are smaller in population and therefore do not contribute largely in the female literacy of the country.

It seems that disparity in literacy is linked to the socio-cultural and economic background of the region. Most of the States/UTs with higher disparity are from the north India and are part of other (Bihar, Madhya Pradesh, Rajasthan, and Uttar Pradesh) States. Gross enrollment ratio and dropout rates are the chief determinants of literacy level in the study area. It tends to derive fact that improvement in literacy contributed significantly in narrowing down the disparity. Also, the disparity is greater in the States/UTs where literacy level is low i.e., gender disparity is inversely correlated to the literacy level. Hence, any programme aimed at removing disparity should focus its attention on literacy development missions.

It is observed that States/UTs with low literacy rates have, in general, achieved more decadal increase in literacy rates as compared to the States/UTs with higher literacy rates. This may be attributed to two factors: (i) government intervention in comparatively backward States/UTs, and (ii) States/UTs with higher literacy rates might be working on educational development and quality of education. The analysis of data suggests that in the Indian society, the increase in male literacy is followed by increase in female literacy which results in decrease in gender disparity in literacy. Hence, to reduce gender disparity, a holistic approach needs to be adopted; focus on female alone may not result in desired results. Large variety of vocational courses particularly for girls, who do not intend to continue their general education beyond elementary or secondary stage, should be introduced. Government should set up new schools and colleges at district and state levels. The establishment of several committees is highly needed to ensure proper utilization of funds allotted to improve literacy rate.

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