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The influence of contributing area parameters on the size of rock glaciers in the Southern Carpathian Mountains

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Abstract

The paper aims to determine to what extent the size of the rock glaciers (RG) in the Southern Carpathians (Romania) is influenced by their contributing area (CA) parameters. Simple linear regression (LR) and generalized linear models (GLM) were used to meet this goal, considering as independent variables the main morphometric characteristics of the contributing area. The LR coefficients revealed that the most influential variables were the width (R^2=0.57) and the size of the CA (R^2=0.51). Based on the best GLM results the size of the rock glaciers can be statistically explained quite well (R^2=0.58) by a combination of three variables: CA length, CA width, and the minimum altitude of the CA. Rock glaciers are thus complex landforms resulting from a combination of many variables (climatic, topographic and geologic) including contributing area parameters. Both LR and GLM analysis revealed that the size of the rock glaciers can only be partly explained by the characteristics of the CA. The study revealed that GLM are powerful analytical tools which give reasonable results when analysing the role of rock glaciers developmental controls.

Keywords: *rock glaciers, contributing area, linear regression, generalized linear model, Southern Carpathians*

Rezumat. Influența parametrilor morfometrici ai ariei sursă asupra dimensiunii ghețarilor de pietre din Carpații Meridionali

Lucrarea își propune să determine în ce măsură dimensiunea ghețarilor de pietre (RG) din Carpații Meridionali (România) este influențată de parametrii zonelor lor sursă (CA). Pentru a îndeplini acest obiectiv a fost folosită regresia liniară simplă (LR) și modelul liniar generalizat (GLM), utilizând ca variabile independente principalele caracteristici morfometrice ale zonelor sursă. Rezultatul regresiei liniare simple arată faprul că variabilele cele mai influente sunt lățimea (R^2=0.57) și mărimea zonei sursă (R^2=0.51). Conform celui mai bun rezultat obținut în urma aplicării GLM (R^2=0.58), mărimea ghețarilor de pietre poate fi explicată printr-o combinație de trei variabile: lungimea, lățimea și altitudinea minimă a ariei sursă. Ambele metode aplicate, atât regresia liniară simplă, cât și GLM arată că mărimea ghețarilor de pietre poate fi explicată doar parțial de caracteristicile zonei sursă. Studiul relevă faptul că GLM reprezintă un instrument analitic puternic, care oferă rezultate rezonabile în analiza rolului pe care foactorii de contol îl au asupra dezvoltării ghețarilor de pietre.

Cuvinte-cheie: *ghețari de pietre, aria sursă, regresie liniară, model liniar generalizat, Carpații Meridionali*

Introduction

Rock glaciers are characteristic landforms of high mountain systems (J.R. Janke, Regmi, Giardino & Vitek, 2013), generally considered as the most visible morphological expression of mountain permafrost occurrence (Barsch, 1996). The term designates a mixture of coarse angular debris and ice, characterized by a distinctive surface topography consisting in transversal or longitudinal flow features (e.g., furrow and ridges), indicating the differential displacement of distinct internal layers (Kaab & Weber, 2004).

Previous studies (Evin, 1987; J. R. Janke, 2007; Johnson, Thackray, & Van Kirk, 2007; Kenner & Magnusson, 2016; Olyphant, 1983; Scotti, Brardinoni, Alberti, Frattini, & Crosta, 2013) have analysed the relationships between rock glaciers characteristics and relevant environmental controlling factors. Topographic variables (e.g., aspect, elevation and slope) lithology or climate has been shown to influence rock glaciers characteristics at a variety of locations world-wide. In a recent paper, Onaca et al. (in press) have suggested that the size of the rock glaciers in the Southern Carpathians is strongly influenced by the lithology, aspect and the extent of the contributing area (CA).

Several authors have statistically evaluated the role of the CA parameters on the rock glaciers size (Bolch & Gorbunov, 2014; Brenning & Trombotto, 2006; Frauenfelder, Haeberli, & Hoelzle, 2003; J. Janke & Frauenfeldeler, 2008). Most of the studies have found a high correlation between the extent of the CA and the area of the rock glaciers (J. Janke & Frauenfeldeler, 2008; Onaca, Ardelean, Urdea, & Magori, in press). Barsch (1996) suggested that conclusive dependences should exist between the rock glacier size, the size of its source area, and the intensity of talus production in the source area. All the aforementioned studies claimed that there is a strong relation between rock glacier area and one of its CA parameters (e.g., area, width, headwall height etc.), but the correlations and regression analysis revealed that the size of the rock glaciers can only be partly explained by the characteristics of the CA.

The aim of this paper is to analyse if, and in which way, the parameters of the CA are influencing the size of the rock glaciers in the Southern

Carpathians. To achieve this goal we will first analyse the influence of each CA parameter on the rock glaciers size and finally will create a model that can best describe the relationship between the area of the rock glaciers and the parameters of their CA.

Study area

Lying in the median part of the temperate zone (45° N) the Southern Carpathians extend from west to east on approximately 250 km. Because of their highest peaks (Moldoveanu, 2544 m, Negoiu, 2535 m, Viștea Mare, 2527 m etc.) and glaciated alpine landscape they are also called the Transylvanian Alps (Fig. 1). The investigated area extends for around 14000 km^2, of which 2100 km^2 are in the periglacial alpine area. The bedrock is dominated by crystalline rocks (schists and gneisses) associated with magmatic bodies in the western part and sedimentary rocks on the peripheries.

Above 2500 m, the mean annual air temperature (MAAT) drops to less than -2°C, whereas the annual average precipitations vary between 1000-1400 mm/year above the treeline.

The Southern Carpathians are currently free of ice, but during the last glacial phase of the Pleistocene small glaciers occupied the highest valleys, sculpting glacier cirques and troughs. According to Onaca et al., in press, 306 rock glaciers are widespread between 1540 m and the highest peaks. Only 16% of the rock glaciers are considered to be intact, whereas 258 are regarded as relict (Onaca et al., in press). The initiation of the majority of the Southern Carpathian rock glaciers started in the Late glacial, whereas during the short cool episodes of the Holocene, small size rock glaciers might have occurred at high altitudes.

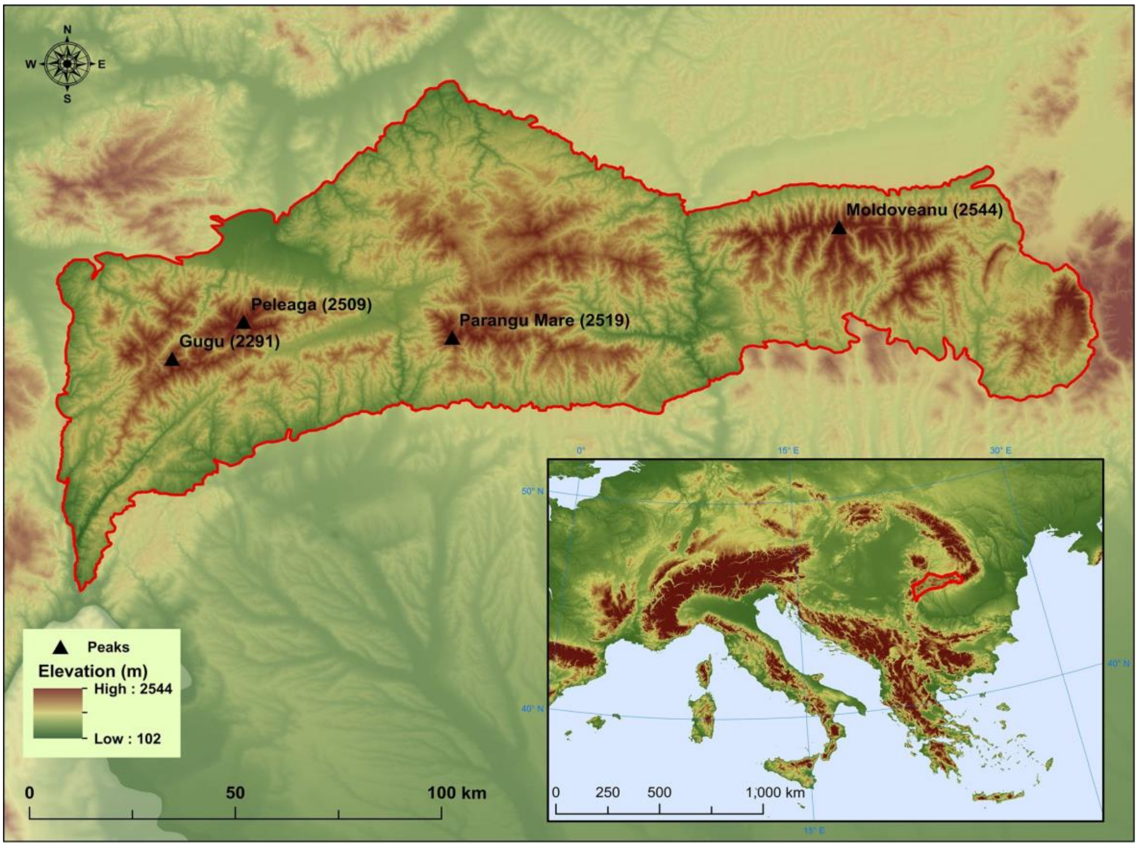

Fig. 1: The Southern Carpathians and their location in Europe

Methods

Contributing area parameters

For this study, we used the existing rock glacier database available for the Southern Carpathians. The inventory contains 306 rock glaciers and their corresponding contributing area. These were digitized, as polygons, from orthophotos at a 0.5 m spatial resolution (Onaca et al., in press). A Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) at a 30 m resolution was used to extract quantitative parameters of the contributing area.

For each contributing area the following parameters were extracted: area (ha), headwall height (m), length (m), width (m), aspect, maximum (max.), minimum (min.) and mean altitude (alt.) (m), mean slope (degree) and the potential annual incoming solar radiation (SolRad). The contributing area together with the area of the rock glaciers were automatically calculated in the ArcGIS 10 software.

The length (L) and the width (W) of the CA were measured in ArcGIS 10 using the „Measure" tool following the methodology described by Janke and Frauenfelder (2008). Thus, averages were calculated for the lengths and widths of the CA, after these were measured (Fig. 2). Based on the 30 m DEM the terrain parameters were calculated (elevation, aspect, slope and the potential annual incoming solar radiation) using ArcGIS 10. The potential annual incoming solar radiation was calculated for one year, at an interval of 30 days, every four hours. The height of the CA headwall was calculated by subtracting the minimum altitude of the contributing area from its maximum altitude (e.g. alt. max. CA - alt. min. CA). The general aspect of the contributing area was also extracted from the 30 m DEM and reclassified into 8 classes (from 1 to 8) that correspond with each CA exposition (N, NE, E, SE, S, SW, W and NW).

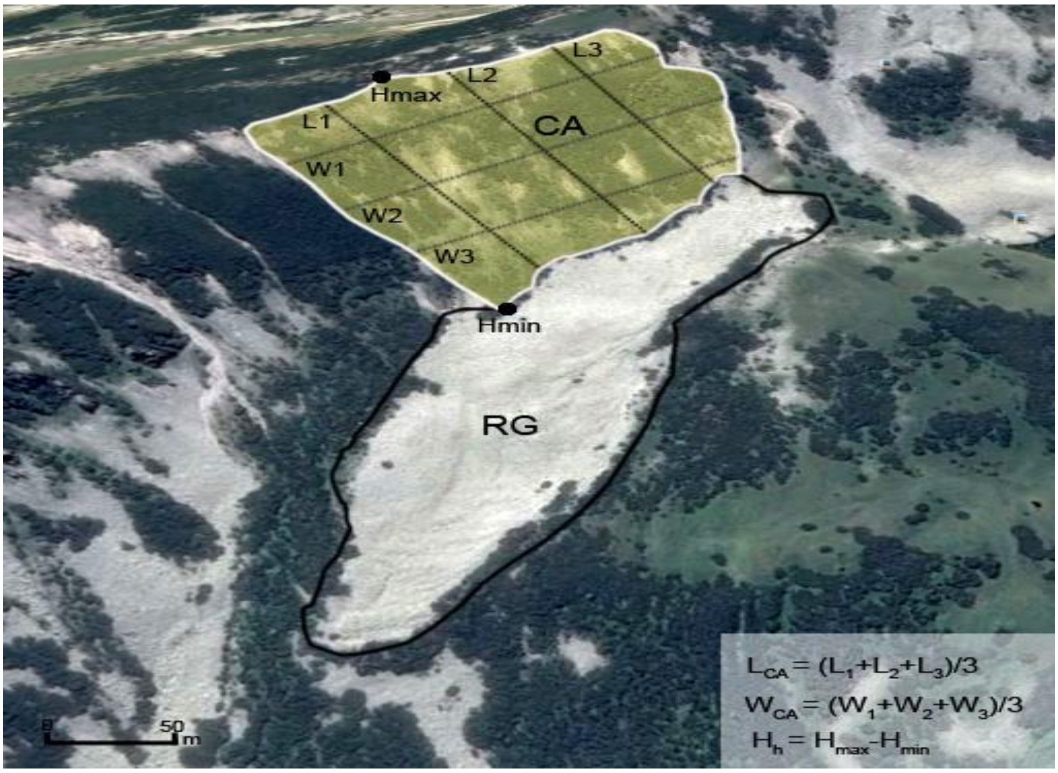

Fig. 2: Example of measurements for contributing area parameters (L - length; W - width; H – altitude)

Statistical analysis

The statistical analysis was performed in R software (R_Core_Team, 2015). In order to analyze the influence of each independent variable of CA on the rock glacier area a simple linear regression (LR) was used. While the rock glacier area was the dependent variable each CA parameter was considered the predictor variable. The ranking of the independent variable influence on RG area was established based on the R^2 score, whereas the significance of the independent variable dependency was tested using the p value with a threshold of 0.01 (Field, 2013).

General linear modelling (GLM) offers a number of advantages, compared with multiple linear regression and logistic regression. It allows the use of both dependent and independent variables as continuous data type as well as categorical. Another advantage of GLM is that the dependent variable can have a different distribution than normal, by using various function related to the type of distribution (Guisan, Edwards, & Hastie, 2002; Hjort, 2006). The general formula of the GLM is (Atkinson, Jiskoot, Massari, & Murray, 1998):

$$Y = a + bX1 + cX2 + \ldots + mXn,$$

where Y is the dependent variable, X1, X2, Xn are the independent variables, and a, b, c, m are the coefficients.

The histogram distribution of all the variables used was assessed. In order to have all the data as consistent as possible we converted all the distribution types into normal distribution using a simple logarithmic (log) transformation. Because GLM is sensitive to the collinearity of the independent variables (Atkinson et al., 1998; Gonzalez-Irusta et al., 2015), all the predictors were tested, one against the other, and the variables displaying a high correlation degree were excluded. In practical terms, collinear independent variables are variables that indicate the same geomorphological reality. Two variables were considered as being correlated when the value of the Pearson correlation test is higher than 0.70

(Hjort, Etzelmuller, & Tolgensbakk, 2010; Zimmermann NE, Edwards TC, Moisen GG, Frescino TS, & JA., 2007). For the categorical data type, the ANOVA test was used. If two predictors were correlated, only one of them, the one with a higher geomorphological significance, was considered here (Hjort, 2006). Also, the variables that show the same characteristics (e.g. min., max. or mean slope) of the CA were used only once in the same model.

Because we already tested the influence of CA parameters on RG area we decided to build the model by adding, one by one, the independent variables until the model cannot be improved any more. We considered this approach more appropriate for our analysis than the more popular stepwise regression with backward elimination (Crawley, 1993; Hjort & Marmion, 2008). After each iteration, the model was tested by the R^2 result of the regression and the AIC (Akaike information criterion). The R^2 shows how good the regression line fits the data and the AIC shows the relative quality of the statistical models based on the information lost (Field, 2013). Although it is difficult to generalize for different models that are used in different scientific fields, it is generally accepted that in order to be considered a valuable model the R^2 value calculated for it should be at least 0.5, whereas models with a R^2 greater than 0.7 are very good. In case of the AIC test lower values suggest a better model.

In order to validate the best model, we used two approaches. Firstly we tested the significance of the independent variables using the significance coefficient, p, with a threshold of 0.01. The second validation method used was the residuals plot. This method shows the distribution of the residuals against a center value. For a model to be considered correct the distribution of the residuals should be in relation to the central value and it shouldn't reveal any trend in the data (Field, 2013).

Results

The mean planar area of the 306 investigated CAs was 7.3 ha, almost two-third larger than the mean area of the corresponding rock glaciers (Onaca et al., in press). The contributing areas appear to be wider than longer whereas their mean slope ranges between 15° and 49° (Table 1). The mean elevation of the 306 analysed entities is 2092, whereas the majority of the CAs headwall heights are greater than 100 m.

In total we tested a number of nine variables. Out of them, three (mean alt., SolRad and mean slope) were not significant at p=0.01. The statistical results displayed in Table 2 suggest that the rock glaciers area is strongly influenced by the width of the CA (R^2=0.57) and the CA size (R^2=0.51) and just slightly dependent on the headwall height (R^2=0.34). In all three cases the relations are significant at the 99 percent confidence interval. A weaker relation was found between the rock glacier area and the length of the CA (R^2=0.23).

Table 1: Summary statistics of the morphometric characteristics of the contributing area parameters

	CA variables					**Headwall height**	**RG area**
	Length	**Width**	**Slope**	**Altitude**	**Area (ha)**		
Minimum	48	60	15	1681	0.5	39	0.2
Maximum	675	1590	49	2392	42.8	474	40.9
Mean	235	342	31	2092	7.3	179	4.2
Standard deviation	120	195	4	136	6.3	87	4.7

Table 2: Regression coefficients of contributing area parameters; (marked values are significant at the significance level p=0.01). (p-value = probability value).

	CA parameters								
RG area	CA size	Length	Width	Headwall height	Min. altitude	Max. altitude	Mean altitude	Mean radiation	Mean slope
R^2-values	**0.511**	**0.232**	**0.572**	**0.342**	**0.027**	**0.026**	-0.003	0.004	-0.001

Table 3: Correlation between CA variables (Pearson test) and ANOVA test (for aspect) (* significant at p<0.05 level, ** significant at p<0.01 level)

	Length	Width	Height	min. alt.	max. alt.	mean alt.	SolRad	slope mean	aspect
Area (ha)	**0.800**	**0.807**	**0.808**	-0.051	0.403	0.191	-0.046	0.075	**0.000 ****
Length		0.396	**0.800**	-0.028	0.430	0.210	0.034	0.096	**0.007 ****
Width			0.569	-0.052	0.264	0.124	-0.129	0.013	**0.001 ****
Height				-0.141	0.444	0.162	-0.108	0.355	**0.012 ***
min.alt.					**0.819**	**0.948**	0.057	0.062	0.781
max. alt.						**0.949**	-0.006	0.250	0.236
mean alt.							0.028	0.156	0.585
SolRad								-0.241	0.119
slope mean									0.230

Considering that not a single CA parameter was identified as controlling the rock glacier area, we applied GLM in order to test the cumulative influence of variables on the rock glacier area. After testing the collinearity, a number of strongly correlated variables were eliminated. Because between the CA size and its length, width and headwall height is a very strong positive correlation, when the CA size was used the others were not (Table 3). In a similar manner the aspect is also correlated with the CA size, length, width and headwall height and again these were not considered together within a model. A strong correlation exists also between the CA length and its headwall height (Table 3). Therefore, in case of the models in which the aspect was considered, as an independent variable, any of the four variables above-mentioned were not used, and the reverse was also true. The altitudes (min., max. and mean) are correlated to each other and therefore when building the model only one of these was considered.

After completing the statistical analysis three valid models were obtained (Table 4). The differences between AIC values are not very high (694-590) (Table 4), but allowed us to choose more objectively the best model. In a similar manner the greatest R^2, was used for achieving a reasonable statistical fit. It can be easily noticed that in two models we met both CA width and CA length. According to the AIC and the R^2 values the final model is composed of three variables and has the final formula:

Y = 1.2676863120 + 0.0021655386 * **Length** + 0.0030827924 * **Width** - 0.0009297971 * **Min. Altitude**,

where Y is the dependent variable (rock glacier area), the numbers are coefficients and the others are the independent variables.

Table 4. A comparison of the three best obtained models for the rock glaciers area

GLM model	AIC	R2
CA size + CA mean alt.	694	0.41
CA length + CA width + CA min. alt.	**590**	**0.58**
CA length + CA width	600	0.57

Validation

Regarding the significance coefficient, all the variables within the final model proved to be significant (Table 5). The most significant is the CA width while the least significant is the minimum altitude of the CA.

Regarding the spatial distribution of the errors for the final model (CA Length + CA Width + CA min. alt.) no pattern was noticed, suggesting the absence of systematic errors in the modelling process (**Fig. 3**). The points have a relatively equal distribution on both sites of the median line and no obvious pattern can be observed.

Table 5 Summary of the GLM model (* significant at $p<0.05$ level, ** significant at $p<0.01$ level)

Independent variables	Intercept	Significance for each variable
Length + Width + min. alt.	0.01917 *	Length 0.00000 **
		Width 0.00000 **
		min. alt. 0.00045 **

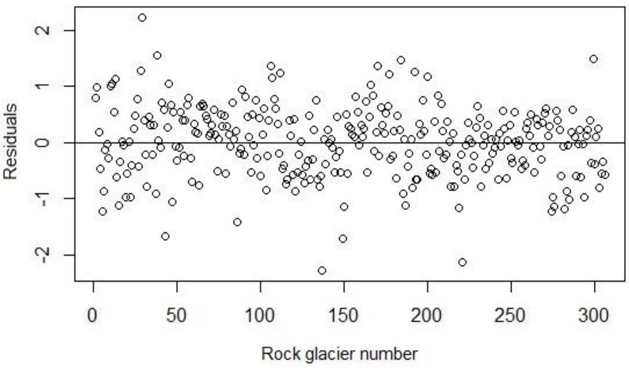

Fig. 3: Residual plot for the GLM

Discussion

Several other studies outlined the importance of contributing area characteristics for rock glaciers development. Humlum (2000) assessed the headwall retreat rates in case of West Greenland rock glaciers, whereas J. Janke & Frauenfeldeler, 2008 examined the relationship between rock glaciers and their contributing areas in the Front Range Mountains in the US Mountain West. Bolch & Gorbunov, 2014 analysed the characteristics and origin of rock glaciers based on the dependence between rock glaciers size and topographic (including CA parameters) and climatic variables in the Tien Shan Mountains. In all the aforementioned studies the extent of both the rock glaciers and their CA were much greater than the ones presented in this study. For example the mean area of the rock glaciers in the West Greenland is two times greater than the size of the Southern Carpathian rock glaciers, whereas in the Tien Shan Mountains this is eight times larger. When comparing the contributing areas extent, the mean values presented here (7.3 ha) are again much lower than what was reported elsewhere: 11.9 ha in West Greenland (Humlum, 2000), 420 ha in Tien Shan (Bolch & Gorbunov, 2014) or 19.4 ha in Front Range (J. Janke & Frauenfeldeler, 2008).

Similarities were identified when comparing the calculated headwall heights in the Southern Carpathian with the reported similar data in West Greenland. Humlum (2000) calculated a mean value of the headwall height of 188 m for talus rock glaciers and 190 m for debris rock glaciers whereas in the Southern Carpathian the mean value of the headwall height was 179 m.

Like in the Southern Carpathians, in the Front Range, the CA size (R2=0.55) and the CA width (R2=0.48) (J. Janke & Frauenfeldeler, 2008) appear to have the greatest influence on the rock glacier area. These results are similar with our findings, the only difference is that the order of importance is reverse in our case. In our study the most important factor is the CA width (R2=0.57) followed by the CA size (R2=0.51). This finding can be used as an argument to support the idea that there are more variables influencing the RG area but the most important seem to be the CA width and CA size.

The influence of the CA size on the RG area can be, somehow, easily explained. The RG are periglacial landforms of debris-transport systems in the alpine areas, meaning that they are feeding on, are maintained and grown with the contribution of their source area (Barsch, 1996). According to this statement is more likely that larger CA to correlate positively with larger rock glaciers. In the Southern Carpathian the size of the rock glaciers is also influenced by lithology and aspect (Onaca et al., in press), whereas the bedrock fracturing of the headwalls was not considered because of the lack of suitable data. The rock type and the weathering rates were mentioned as controlling the size of the rock glaciers in other studies too (J. Janke & Frauenfeldeler, 2008; Matsuoka & Ikeda, 2001).

In the present study the headwall height also had an important influence on the RG area (R^2=0.34). The LR coefficient revealed here was much more significant than the corresponding (R^2=0.08) reported for the Front Range (J. Janke & Frauenfeldeler, 2008), or even Tien Shan Mountains (R^2=0.28). The relatively good relationship between headwall height and rock glacier area suggest that headwalls with great heights are capable to deliver larger amounts of materials compared to those headwalls with moderate heights.

The generalized linear models (GLM) have been used in a series of studies on geomorphologic topics ranging from landslides (Goetz, Guthrie, & Brenning, 2011; Vorpahl, Elsenbeer, Marker, & Schroder, 2012) to solifluction (Hjort, Ujanen, Parviainen, Tolgensbakk, & Etzelmuller, 2014) and permafrost distribution (Boeckli, Brenning, Gruber, & Noetzli, 2012). In this paper we assessed the controlling role of CA parameters on RG size for the first time. The results reported here and in the aforementioned studies proved the capacity of GLM to better explain the complex geomorphologic phenomena, than the simple linear regression (Goetz, Brenning, Petschko, & Leopold, 2015; Hjort et al., 2014).

Conclusions

The statistical results obtained from this generous morphometric database for the Southern Carpathian rock glaciers contributing area led to four main conclusions. Firstly, the contributing area dimensions (size, length and width) are considerably smaller than elsewhere (e.g. Front Range, Tien Shan, and West Greenland). Only the headwall height, slope and elevation may be compared up to a point with others elsewhere. Secondly, rock glaciers are complex landforms resulting from the combination of many topographic, climatic and lithological variables.

The CA width and area together with the headwall height play a significant role in controlling the development and the extent of the rock glaciers in the Southern Carpathians. Thirdly, the GLM proved to be a reliable tool to statistically explain the role of rock glaciers developmental controls. Our model was evaluated to have a reasonable fit (R^2 = 0.58) in our approach to test the cumulative influence of CA variables on the rock glacier area. Finally, both LR and GLM analysis revealed that the size of the rock glaciers can only be partly explained by the characteristics of the CA.

References

Atkinson, P., Jiskoot, H., Massari, R., & Murray, T. (1998). Generalized linear modelling in geomorphology. *Earth Surface Processes and Landforms, 23*(13), 1185-1195.

Barsch, D. (1996). *Rockglaciers. Indicators for the present and former geoecology in high mountain environments*. Berlin: Springer.

Boeckli, L., Brenning, A., Gruber, S., & Noetzli, J. (2012). A statistical approach to modelling permafrost distribution in the European Alps or similar mountain ranges. The *Cryosphere, 6*(1), 125-140.

Bolch, T., & Gorbunov, A. P. (2014). Characteristics and Origin of Rock Glaciers in Northern Tien Shan (Kazakhstan/Kyrgyzstan). *Permafrost and Periglacial Processes, 25*(4), 320-332.

Brenning, A., & Trombotto, D. (2006). Logistic regression modeling of rock glacier and glacier distribution: Topographic and climatic controls in the semi-arid Andes. *Geomorphology, 81*(1-2), 141-154.

Crawley, M. (1993). GLIM for Ecologists. Oxford: Blackwell.

Evin, M. (1987). Lithology and fracturing control of rock glaciers in southwestern Alps of France and Italy. *Rock Glaciers. Allen and Unwin, London*, 83-106.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*: Sage.

Frauenfelder, R., Haeberli, W., & Hoelzle, M. (2003). *Rockglacier occurrence and related terrain parameters in a study area of the Eastern Swiss Alps*. In: Phillips, M., Springman, S., Arenson, L., 8th International Conference on Permafrost, Proceedings 1, Zürich. Swets & Zeitlinger, Lisse, 275-280.

Goetz, J. N., Brenning, A., Petschko, H., & Leopold, P. (2015). Evaluating machine learning and statistical prediction techniques for landslide susceptibility modeling. *Computers & Geosciences, 81*, 1-11.

Goetz, J. N., Guthrie, R. H., & Brenning, A. (2011). Integrating physical and empirical landslide susceptibility models using generalized additive models. *Geomorphology, 129*(3-4), 376-386.

Gonzalez-Irusta, J. M., Gonzalez-Porto, M., Sarralde, R., Arrese, B., Almon, B., & Martin-Sosa, P. (2015). Comparing species distribution models: a case study of four deep sea urchin species. *Hydrobiologia, 745*(1), 43-57.

Guisan, A., Edwards, T. C., & Hastie, T. (2002). Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling, 157*(2-3), 89-100.

Hjort, J. (2006). *Environmental factors affecting the occurrence of periglacial landforms in Finnish Lapland: a numerical approach.* (Academic dissertation), University of Helsinki, Helsinki.

Hjort, J., Etzelmuller, B., & Tolgensbakk, J. (2010). Effects of Scale and Data Source in Periglacial Distribution Modelling in a High Arctic Environment, western Svalbard. *Permafrost and Periglacial Processes, 21*(4), 345-354.

Hjort, J., & Marmion, M. (2008). Effects of sample size on the accuracy of geomorphological models. *Geomorphology, 102*(3-4), 341-350.

Hjort, J., Ujanen, J., Parviainen, M., Tolgensbakk, J., & Etzelmuller, B. (2014). Transferability of geomorphological distribution models: Evaluation using solifluction features in subarctic and Arctic regions. *Geomorphology, 204*, 165-176.

Humlum, O. (2000). The geomorphic significance of rock glaciers: estimates of rock glacier debris volumes and headwall recession rates in West Greenland. *Geomorphology, 35*(1-2), 41-67.

Janke, J., & Frauenfeldeler, R. (2008). The relationship between rock glacier and contributing area parameters in the Front Range of Colorado. *Journal of Quaternary Science, 23*(2), 153-163.

Janke, J. R. (2007). Colorado Front Range rock glaciers: Distribution and topographic characteristics. *Arctic Antarctic and Alpine Research, 39*(1), 74-83.

Janke, J. R., Regmi, N. R., Giardino, J. R., & Vitek, J. D. (2013). Rock glaciers. In J. Shroder, R. Giardino & J. Harbor (Eds.), *Treatise on Geomorphology* (Vol. vol. 8, Glacial and Periglacial Geomorphology, pp. 238–273). San Diego, CA: Academic Press.

Johnson, B. G., Thackray, G. D., & Van Kirk, R. (2007). The effect of topography, latitude, and lithology on rock glacier distribution in the Lemhi Range, central Idaho, USA. *Geomorphology, 91*(1-2), 38-50.

Kaab, A., & Weber, M. (2004). Development of transverse ridges on rock glaciers: Field measurements and laboratory experiments. *Permafrost and Periglacial Processes, 15*(4), 379-391.

Kenner, R., & Magnusson, J. (2016). Estimating the Effect of Different Influencing Factors on Rock Glacier Development in Two Regions in the Swiss Alps. *Permafrost and Periglacial Processes*.

Matsuoka, N., & Ikeda, A. (2001). Geological control on the distribution and characteristics of talus-derived rock glaciers. *Annual report of the Institute of Geoscience, University of Tsukuba, 27*, 11-16.

Olyphant, G. A. (1983). Computer-simulation of rock-glacier development under viscous and pseudoplastic flow. *Geological Society of America Bulletin, 94*(4), 499-505.

Onaca, A., Ardelean, F., Urdea, P., & Magori, B. (in press). Southern Carpathian rock glaciers: inventory, distribution and environmental controlling factors. *Geomorphology*.

R_Core_Team. (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. Retrieved from https://www.R-project.org/

Scotti, R., Brardinoni, F., Alberti, S., Frattini, P., & Crosta, G. B. (2013). A regional inventory of rock glaciers and protalus ramparts in the central Italian Alps. *Geomorphology, 186*, 136-149.

Vorpahl, P., Elsenbeer, H., Marker, M., & Schroder, B. (2012). How can statistical models help to determine driving factors of landslides? *Ecological Modelling, 239*, 27-39.

Zimmermann NE, Edwards TC, Moisen GG, Frescino TS, & JA, B. (2007). Remote sensing-based predictors improve distribution models of rare, early successional and broadleaf tree species in Utah. *Journal of Applied Ecology, 44*, 1057–1067.

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Changes of the karst landscape and epikarst system in the area of the Tapolca karst terrains, North-West Balaton Highlands, Hungary

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Abstract

The caves in Hungary have been protected for a long time. The current national legislation on nature conservation states that all known and unknown caves are under ex lege protection but the karst areas above them are not. The territories above the caves can be owned by the state but also some of them belong to private owners, thus a great diversity of economic activities are conducted on them. Anthropogenic activities endanger both directly and indirectly the caves environment and the karst ground waters. The damages and pollution of caves take place through the epikarst systems which are in direct connection with the topographic ground surface. Therefore, it is of special significance to emphasize the natural processes taking place in epikarstic systems as well as to analyze the changes within epikarst terrains caused by human impacts. The effects of human impacts on epikarst system in the area of the Tapolca karst were analyzed both by field and laboratory methods. The historical evolution of land cover and land use was assessed related to the impact on the abiotic elements (soil and karstic cover-deposit, water) in Tapolca area. The intrinsic vulnerability was assessed using the semi-quantitative COP Method. The results show high resource vulnerability in all analyzed epikarstic sites.

Keywords: *karst system, land cover, intrinsic vulnerability, human impacts, epikarst, karst aquifer*

Schimbări în peisajul carstic și în sistemul epicarstului din zona carstică Tapolca, nord-vestul ținutului muntos Balaton, Ungaria

Rezumat. Protecția peșterilor are o lungă tradiție în Ungaria. Conform legislației naționale curente referitoare la conservarea naturii, toate peșterile din Ungaria sunt protejate de lege dar nu și terenurile carstice aflate deasupra lor. În cadrul teritoriilor carstice, deopotrivă aflate în proprietatea statului și în proprietate privată, au loc diferite activități economice care degradează și amenință direct și indirect calitatea mediului endocarstic și a depozitelor acvifere carstice. Degradarea și poluarea peșterilor are loc prin intermediul sistemului epicarstic, aflat în conexiune directă cu suprafața topografică. Din acest motiv este extrem de importantă cunoașterea proceselor naturale care au loc în sistemele epicarstice în relație cu schimbările cauzate de impactul antropic. Efectele impactului antropic asupra sistemului epicarstic Tapolca au fost analizate pe baza observațiilor de teren și a analizelor de laborator. Evoluția istorică a modului de acoperire a terenului a fost evaluată în relație cu impactul generat asupra mediului abiotic (sol și depozite carstice, apă) în zona Tapolca. Vulnerabilitatea intrinsecă a fost evaluată aplicând metoda semicantitativă COP. Rezultatele obținute arată că vulnerabilitatea resurselor carstice este extrem de ridicată în toate siturile epicarstice analizate.

Cuvinte-cheie: *sistem carstic, acoperirea terenurilor, vulnerabilitatea intrinsecă, impact antropic, epicarst, acvifer carstic.*

Introduction

Karst is a unique, non-renewable resource with significant biological, hydrological, mineralogical, scientific, cultural, recreational, and economic values (BC Ministry of Forests, 2003). On the other hand, karst terrains are very sensitive areas. Their sensitivity is attributed to the system of the three-dimensional effect area (Parise & Pascali, 2003; Ford & Williams, 2007; Parise, 2010). The human activities can produce intentionally or not severe impacts, often with irreparable damages in karst terrains. For example, land degradation caused by deforestation and overgrazing lead to soil erosion and destruction of the epikarst. Mining activities and limestone quarrying processes conduct to irreversible changes of landscape and karst features, and disturb karst groundwater resources. Whichever groundwater is vulnerable to human activity, because no groundwater is completely isolated from the above-ground environment. The degree of vulnerability depends on environmental and hydrogeological conditions, contaminant types and the time-scale of interest.

The distinctive hydrology and landforms of karst create a very special environment (Parise & Gunn, 2007) which distinguishes them from fissured and porous aquifers. Carbonate rocks that crop out and contain karst aquifers are extremely vulnerable to contamination (Ducci, 2007). Consequently, the transport of pollutants within karst aquifers may be