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VARIABILITY OF THE ANNUAL NUMBER OF REGISTERED LANDSLIDES AND MUDFLOWS IN GEORGIA IN 1995-2024 AND THEIR EXPECTED CHANGE UP TO 2030

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Introduction

Landslides and mudflows, as a type of natural disaster, occur almost everywhere [1-4], including in Georgia, which has a wide variety of terrain [5-8]. Landslides and mudflows damage and destroy houses, roads, bridges, pipelines, and power lines, destroy agricultural land, food supplies, and seeds, and also lead to human casualties, causing death and injury due to the displacement of soil, rocks, and trees. These natural disasters cause enormous damage to infrastructure, the economy, and the natural environment, disrupting people's livelihoods [9-11].

The activation of landslides and mudflows depends on a combination of natural and anthropogenic factors. The main ones are: heavy and prolonged rainfall, rapid melting of seasonal snow cover or glaciers, which lead to waterlogging of the soil, which significantly reduces its strength and stability; the presence of steep slopes, the composition of rocks, their inclined bedding, and the presence of cracks; changes in groundwater levels and surface water regimes; earthquakes and tectonic movements that can trigger the collapse of unstable slopes; improper construction and mining work, destruction of slopes by road cuttings, excessive soil removal, massive deforestation, which reduces the binding function of plant root systems; general climatic conditions of the region, which determine the likelihood and intensity of processes that contribute to landslides and mudflows (e.g., amount of precipitation, temperature regime) [2,12-16].

Considering the importance of the problem in Georgia, in recent years work has begun to systematize data on landslides and mudflows [10,11], which will improve the quality of scientific research. In particular, in the work [17] results of statistical analysis of data from the Geological Department of the Environment Agency of Georgia on the annual number of re-activated and newly formed landslides (LS) and mudflows (MF) in Georgia for the period from 1995 to 2024 are presented. In particular, the following results were obtained. The number of landslides varies in the range from 56 to 1360 with an average annual value of 581, and mudflows – from 23 to 355 with an average annual value of 141. There is a high linear correlation between the studied parameters (the correlation coefficient is 0.81). The trends of the LS and MF values have the form of a polynomial of the seventh degree.

This study is a continuation of the work [17]. The results of the statistical analysis of the variability of the annual number of registered landslides and mudflows in Georgia in 1995-2024 and an assessment of their expected change up to 2030 are presented below.

Study area, material and methods

Study area – Georgia. The data of the Department of Geology at Georgian National Environmental Agency about registered re-activated and new landslides and mudflows number per year are used [10]. Period of observation: 1995-2024 (30 years).

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods of random events and methods of mathematical statistics for the non-accidental time-series of observations [18-20].

Forecasting the landslides and mudflows number per year was performed using the AAA version of the exponential smoothing (ETS) algorithm taking into account the periodicity in the pre-forecast time series [20].

The following designations will be used below: Mean – average values; Min – minimal values; Max – maximal values; St Dev – standard deviation; St Err – standard error; R – coefficient of linear correlation; R_k – Kendall's rank correlation coefficient; R_s – Spearmen's rank correlation coefficient; R_a – autocorrelation coefficient; Lag = 1, 2…30 years; LS – landslides number per year; MF – mudflows number per year; Forecast – forecast center point; 68%, 95%_Upp and 68%, 95%_Low – 68%, 95% of upper and lower levels of studied parameters mean values; α – the level of significance*; 1 period:* 1995-2019, 2 period: 1995-2024.

The degree of correlation was determined in accordance with [19]: very high correlation ($0.9 \le R \le 1.0$); high correlation ($0.7 \le R < 0.9$); moderate correlation ($0.5 \le R < 0.7$); low correlation ($0.3 \le R < 0.5$); negligible correlation ($0 \le R < 0.3$).

The statistical programs Mesosaur and Excel 19 were used for calculations.

Results and discussion

Results in Table 1 and Fig. 1-12 are presented.

Table 1. Values of the linear correlation coefficients and Spearman and Kendall rank correlation coefficients for time series of the number of landslides and mudflows per year in Georgia in 1995-2019 and 1995-2024.

LS			MF		
1995-2019					
R	R_K	R_S	R	R_K	R_S
0.30	0.27	0.34	0.04	0.09	0.04
α	α	α	α	α	α
0.15	0.06	0.09	No sign	No sign	No sign
1995-2024					
0.61	0.50	0.62	0.20	0.28	0.27
α	α	α	α	α	α
<0.005	<0.005	<0.005	0.25	0.03	0.14

In Table 1 data about correlation levels of the LS and MF values in Georgia in 1995-2019 and 1995-2024 are presented. As follows from Table 1, in general, the correlation of LS and MF values with years in both periods of time are positive. However, the level of all types of LS values correlations with years is higher than MF values correlations with years in both period of time ("Low correlation" and "Negligible correlation" for LS values and "Negligible correlation" for MF values in 1 period of time; "Moderate correlation" for LS values and "Negligible correlation" for MF values in 2 period of time). In general, the correlation level for the studied parameters for the second period is higher than for the first.

The level of autocorrelation in the LS time series is also higher than in MF time series (Fig. 1,2,5,6) in both periods of time.

The LS and MF time series shows two periodicity peaks – the main one ≈ 6 years and the auxiliary one ≈ 3.5-4 years in both periods of time (Fig. 3,4,7,8).

Data on the main peak periodicity values in the LS and MF time series are taken into account when conducting interval forecasting of these parameters (Fig. 9-12).

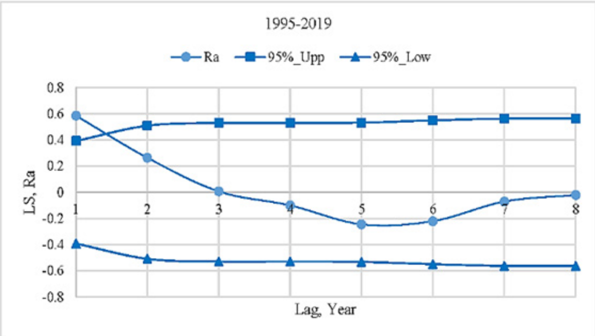

Fig. 1. Autocorrelation in the time series of observation of LS value in 1995-2019.

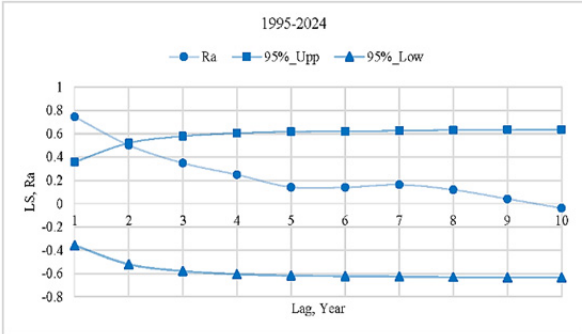

Fig. 2. Autocorrelation in the time series of observation of LS value in 1995-2024.

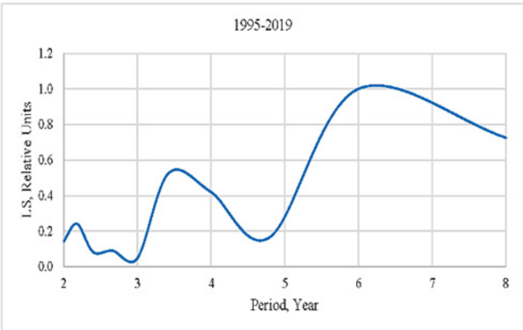

Fig. 3. Periodicity in the time series of observation of LS value in 1995-2019.

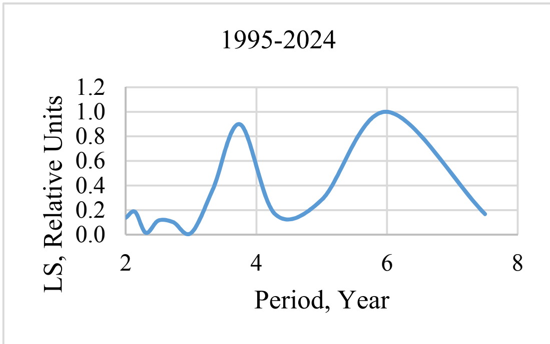

Fig. 4. Periodicity in the time series of observation of LS value in 1995-2024.

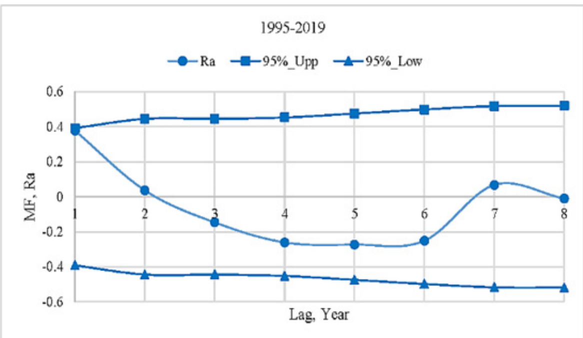

Fig. 5. Autocorrelation in the time series of observation of MF value in 1995-2019.

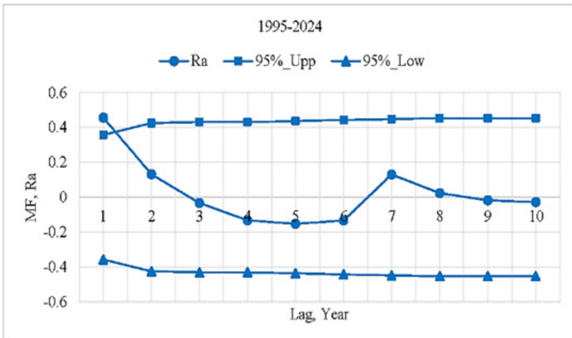

Fig. 6. Autocorrelation in the time series of observation of MF value in 1995-2024.

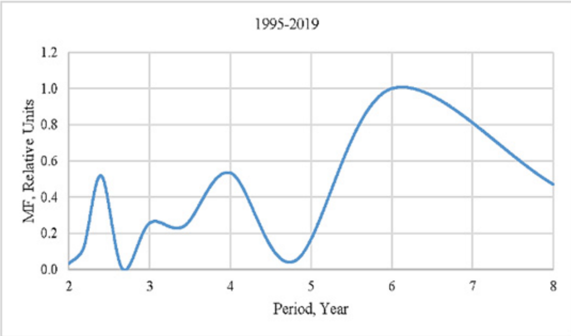

Fig. 7. Periodicity in the time series of observation of MF value in 1995-2019.

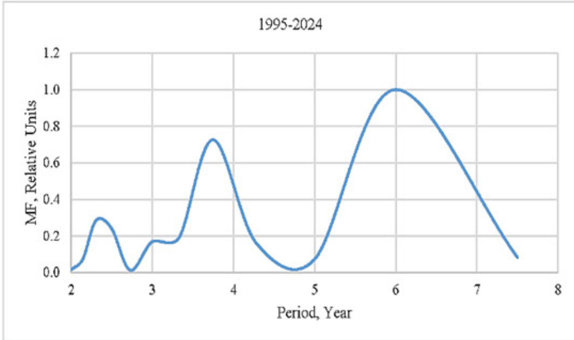

Fig. 8. Periodicity in the time series of observation of MF value in 1995-2024.

Fig. 9 and 10 present the results of test forecasting of LS and MF values for 2020-2024 using data for 1995-2019. Fig. 11 and 12 present the results of forecasting LS and MF values for 2025-2030 using data for 1995-2024.

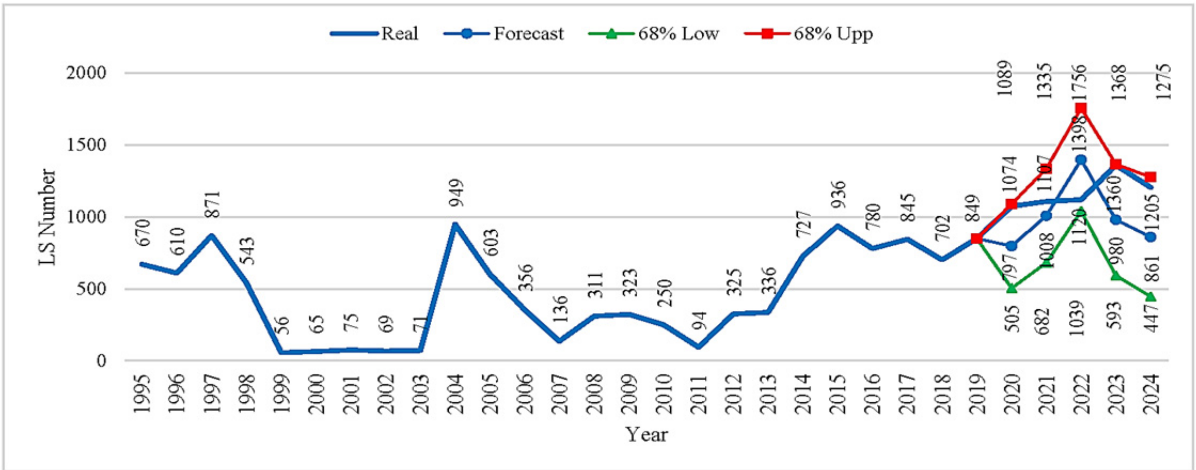

Fig. 9. Comparison of real and predicted data on LS value in 2020-2024 in Georgia.

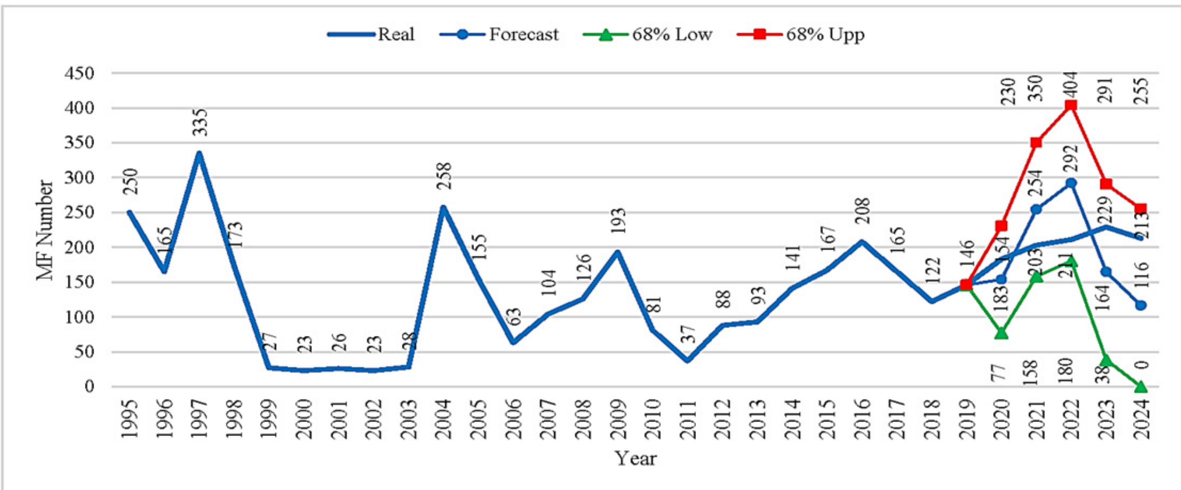

Fig. 10. Comparison of real and predicted data on MF value in 2020-2024 in Georgia.

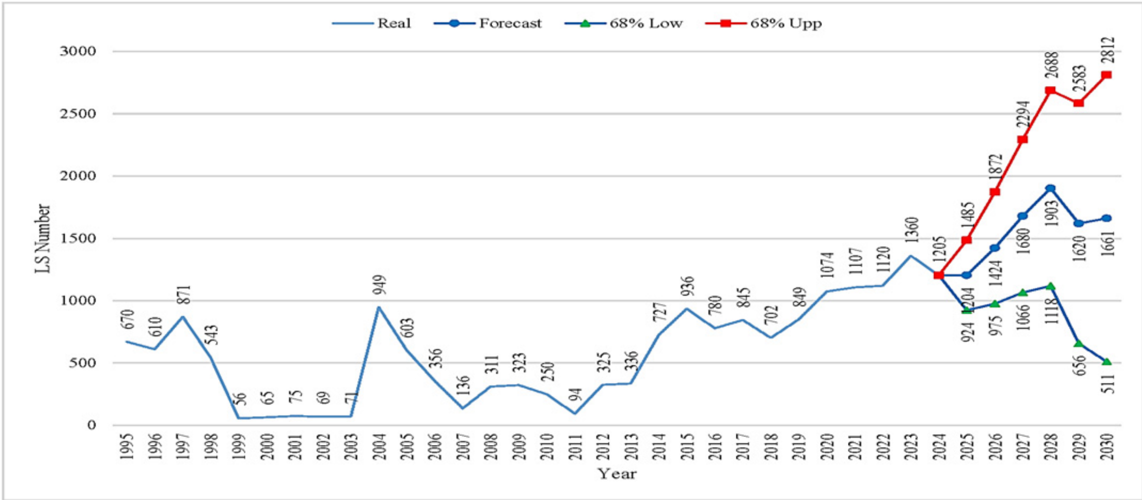

Fig. 11. Projected LS value in 2025-2030 in Georgia.

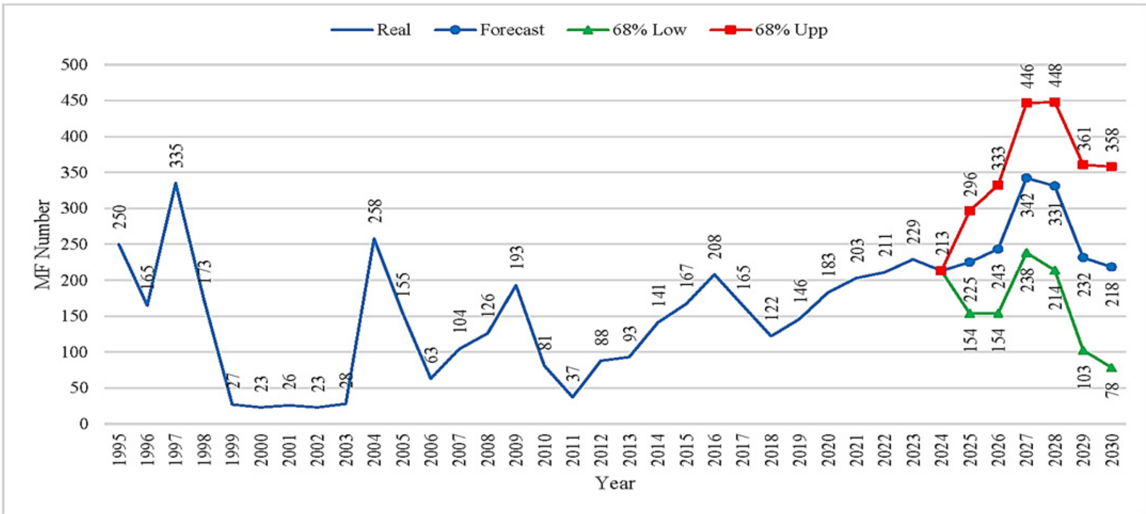

Fig. 12. Projected MF value in 2025-2030 in Georgia.

Table 2. Statistical characteristics of real and projected LS and MF values in 2020-2024 and projected LS and MF values in 2025-2030.

Parameter	Real	Forecast	68%	68%	Real	Forecast	68%	68%
Variable	LS, 2020-2024				MF, 2020-2024			
Min	1074	797	447	1089	183	116	0	230
Max	1360	1398	1039	1756	229	292	180	404
Mean	1173	1009	653	1365	208	196	91	306
St Dev	115	234	234	244	17	74	77	71
St Err	58	117	117	122	8	37	39	35
Variable	LS, 2025-2030				MF, 2025-2030			
Min		1204	511	1485		218	78	296
Max		1903	1118	2812		342	238	448
Mean		1582	875	2289		265	157	374
St Dev		240	240	518		56	62	62
St Err		107	107	232		25	28	28

A comparison of real and predicted data for both parameters revealed a satisfactory level of forecasting. For both parameters, their predicted and real values fall within a 68% prediction interval. The average real LS value is 1173 ± 58, while the predicted value is 1009 ± 117; the average real MF value is 208 ± 8, while the predicted value is 196 ± 37 (Table 2).

The average predicted LS value in 2025-2030 is 1582 ± 107, the average predicted MF value is 265 ± 25. Moreover, the average values of the confidence interval of the LS values vary from 875 ± 107 to 2289 ± 232, and the MF values - from 157 ± 28 to 374 ± 28 (Table 2).

It should be noted that as new data becomes available in the coming years, it will be possible to test the representativeness of this model for predicting LS and MF values.

Conclusion

In the near future, we plan to compare different methods for long-term and short-term landslide and mudflow forecasting, including machine learning methods.

Acknowledgments

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VARIABILITY OF THE ANNUAL NUMBER OF REGISTERED LANDSLIDES AND MUDFLOWS IN GEORGIA IN 1995-2024 AND THEIR EXPECTED CHANGE UP TO 2030

Amiranashvili A., Brocca L., Chelidze T., Svanadze D.,
Tsamalashvili T., Varamashvili N.

Abstract

The paper presents the results of a study of the variability features of the annual number of registered landslides (LS) and mudflows (MF) in Georgia in 1995-2024 and their expected change up to 2030. The stability of the time series of LS and MF values was studied by determining their correlation links over time (linear correlation, Kendall and Spearman rank correlation). The level of autocorrelation in the time series of LS and MF values was determined. The periodicity of these time series was studied. Interval forecasting of LS and MF values up to 2030 was carried out, taking into account the periodicity in the observation series.

Keywords: landslides, mudflows, natural disaster, interval forecasting.

საქართველოში რეგისტრირებული მეწყერებისა და ღვარცოფების წლიური რაოდენობის ცვალებადობა 1995-2024 წლებში და მათი მოსალოდნელი ცვლილება 2030 წლამდე

ამირანაშვილი ა., ბროკა ლ., ჭელიძე თ., სვანაძე დ., წამალაშვილი თ., ვარამაშვილი ნ.

რეზიუმე

ნაშრომში წარმოდგენილია კვლევის შედეგები, რომელიც შეისწავლის საქართველოში რეგისტრირებული მეწყერების (LS) და ღვარცოფების (MF) წლიური რაოდენობის ცვალებადობას 1995 წლიდან 2024 წლამდე და მათ მოსალოდნელ ცვლილებებს 2030 წლამდე. შესწავლილი იქნა LS და MF მნიშვნელობების დროითი სერიების სტაბილურობა მათი დროთა განმავლობაში კორელაციის განსაზღვრით (წრფივი კორელაცია, კენდალისა და სპირმანის რანგული კორელაცია). განისაზღვრა LS და MF მნიშვნელობების დროითი სერიების ავტოკორელაციის დონე. შესწავლილი იქნა ამ დროითი სერიების პერიოდულობა. ჩატარდა LS და MF მნიშვნელობების ინტერვალური პროგნოზირება 2030 წლამდე, დაკვირვების სერიების პერიოდულობის გათვალისწინებით.

საკვანძო სიტყვები: მეწყერი, ღვარცოფები, სტიქიური უბედურებები, ინტერვალური პროგნოზირება.

ИЗМЕНЧИВОСТЬ ЕЖЕГОДНОГО ЧИСЛА РЕГИСТРИРОВАННЫХ ОПОЛЗНЕЙ И СЕЛЕЙ В ГРУЗИИ В 1995-2024 ГОДАХ И ИХ ОЖИДАЕМОЕ ИЗМЕНЕНИЕ ДО 2030 ГОДА

Амиранашвили А., Брокка Л., Челидзе Т., Сванадзе Д., Цамалашвили Т., Варамашвили Н.

Реферат

В работе представлены результаты исследования особенностей изменчивости ежегодного числа регистрированных оползней (LS) и селей (MF) в Грузии в 1995-2024 годах и их ожидаемое изменение до 2030 года. Изучена устойчивость временных рядов значений LS и MF путем определения их корреляционных связей со временем (линейная корреляция, ранговая корреляция Кендалла и Спирмена). Определен уровень автокорреляции во временных рядах значений LS и MF. Изучена периодичность указанных временных рядов. Проведено интервальное прогнозирование значений LS и MF до 2030 г. с учетом периодичности в рядах наблюдений.

Ключевые слова: оползни, сели, стихийные бедствия, интервальное прогнозирование.