1st International Scientific Conference "Modern problems in Geophysics", Proceedings,
ISBN 978-9941-36-434-1, ISSN 3088-4349, Tbilisi, Georgia, November 6-8, 2025

STATISTICAL ANALYSIS OF THE ANNUAL NUMBER OF REGISTERED LANDSLIDES AND MUDFLOWS IN GEORGIA IN 1995-2024

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

[*]M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, Tbilisi, Georgia
[**]Research Institute for Geo-Hydrological Protection, Perugia, Italy
[***]A. Janelidze Geological Institute of I. Javakhishvili Tbilisi State University, Tbilisi, Georgia
avtandilamiranashvili@gmail.com

Abstract. *The 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.*

Key Words: *landslide, debris flow, natural disaster, risk assessment, statistical analysis.*

Introduction

Landslides and mudflows are a type of natural disaster that are common almost everywhere [1-4], including in Georgia [5-8]. Landslides and mudflows damage roads and bridges, destroy residential buildings and structures, lead to power line shutdowns, pose a threat to human health and life, cause significant material damage, etc. [9-11].

The activation of landslides and mudflows depends on many factors – slope steepness, lithology, vegetation, precipitation, etc. Accordingly, a large number of studies have been and are being conducted to study the relationships between these processes and these factors [3,12].

Given 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. This paper presents the results of statistical analysis of thirty-year time series of annual landslide and mudflow events in Georgia, published in the bulletins of the Geological Department of the Environment Agency of Georgia [10]

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 [13, 14].

The following designations will be used below: Mean – average values; Min – minimal values; Max – maximal values; Range = Max – Min; St Dev – standard deviation; C_v – coefficient of variation, %; R^2 – coefficient of determination; R – coefficient of linear correlation; K_{DW} – Durbin-Watson statistic; α – level of signification; x – number of year, 1-1995, … 30 – 2024; LS – landslides number per year; MF – mudflows number per year.

The curve of trend is an equation of the regression of the connection of the investigated parameter with the time at the significant value of the determination coefficient and such values of K_{DW}, where the residual values (Res) are accidental.

Results

Results in Fig. 1-3 and Tables 1-2 are presented.

In Fig. 1 data about the annual number of landslides and mudflows in Georgia from 1995 to 2024 and in Table 1 statistical characteristics of these parameters are presented.

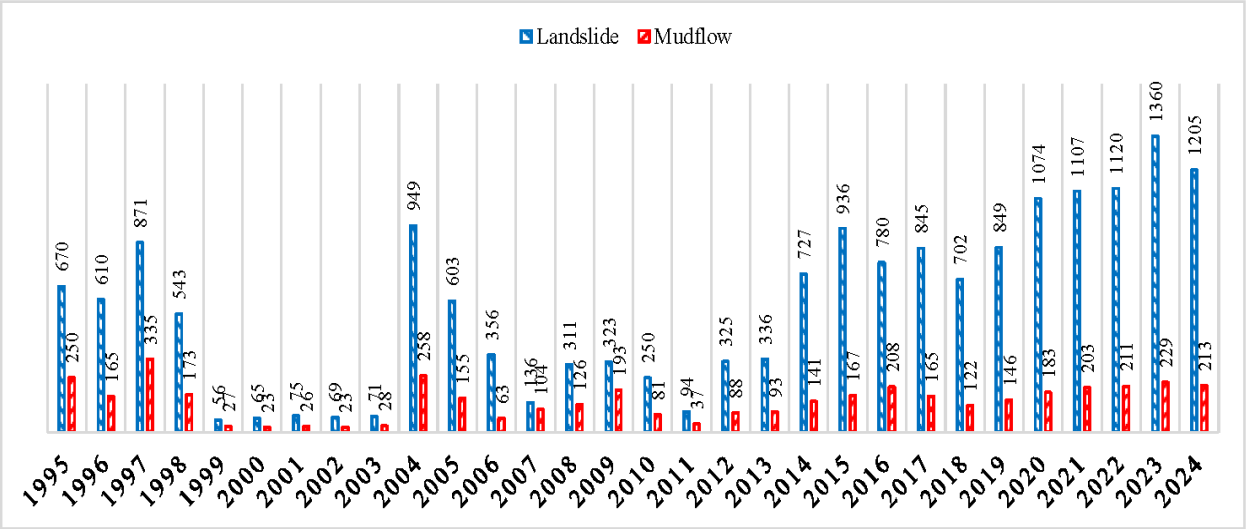

Fig. 1. Number of landslides and mudflows per year in Georgia from 1995 to 2024 [10].

Table 1. Statistical characteristics of LS and MF numbers in Georgia from 1995 to 2024

Variable	LS	MF
Max	1360	335
Min	56	23
Range	1304	312
Mean	581	141
St Dev	397	81
C_v, %	68.3	57.5
	Correlation Matrix	
LS	1	0.81
MF	0.81	1

As follows from Fig. 1 and Table 1 the number of landslides varies in the range from 56 to 1360 with an average annual value of 581, and the mudflows – from 23 to 355 with an average annual value of 141. The variation coefficient for LS and MF, respectively, is 68.3 % and 57.8 %. Between the studied parameters there is a high linear correlation connection (R = 0.81).

Trends of time series of LS and MF values have the form of a polynomial of the seventh degree (Table 1, Fig. 2 and 3). In Table 2 data on coefficients of the regression equation of the time series of the landslides and mudflows numbers per year in Georgia in 1995-2024 are presented.

Fig. 2 and 3 show graphs of real values, trends and random components of the time-series under study.

Table 2. Coefficients of the regression equation of the time series of the landslides and mudflows numbers per year in Georgia in 1995-2024.

$Y = a \cdot x^7 + b \cdot x^6 + c \cdot x^5 + d \cdot x^4 + e \cdot x^3 + f \cdot x^2 + g \cdot x + h$

Variable	LS	MF
a	4.67E-05	1.50E-05
b	-0.00503	-0.00167
c	0.214609	0.073752
d	-4.57933	-1.64238
e	50.91851	19.16392

f	-273.141	-108.763
g	517.521	226.481
h	423.2351	104.5595
R^2	0.73	0.493
K_{DW}	1.51	1.91
α	0.05	0.05

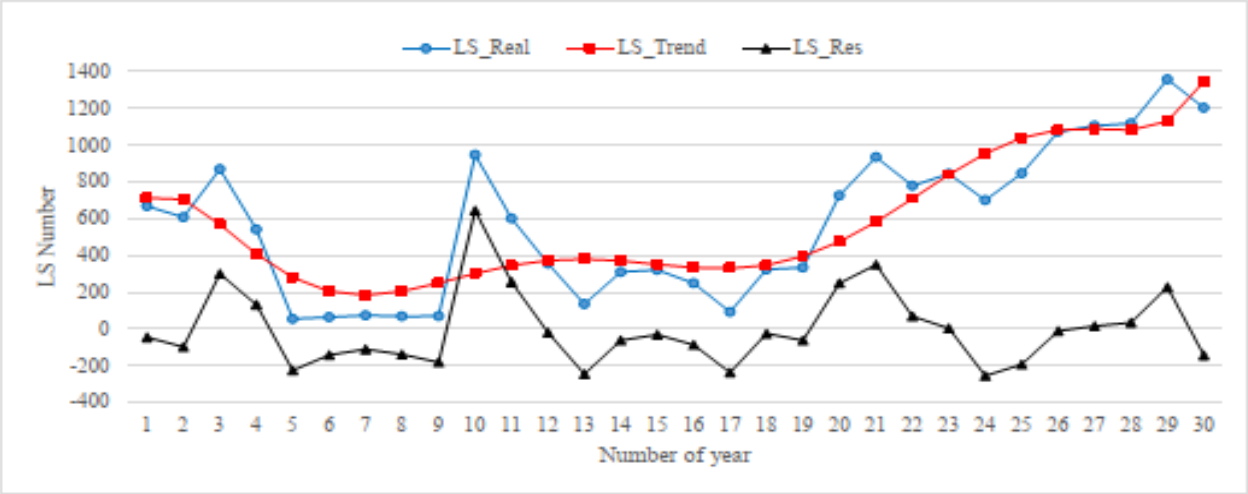

Fig. 2. Trend of the landslides number per year in Georgia in 1995-2024.

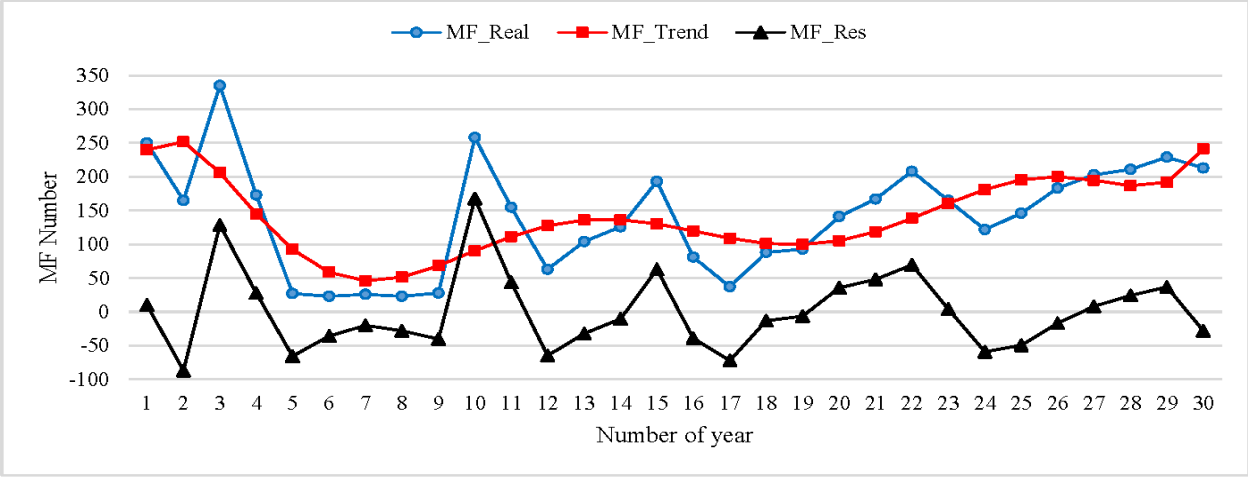

Fig. 3. Trend of the mudflows number per year in Georgia in 1995-2024.

Note that between the random components of the time-series of LS and MF, the linear correlation coefficient is 0.87.

Conclusion

In the near future, we plan to study the periodicity of landslide and mudflow time series with the aim of using these data to forecast these time series for several years. We also plan to compare different methods for long-term and short-term landslide and mudflow forecasting, including machine learning methods.

Acknowledgments

This work was supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG), Grant number FR-23-5466, “Machine Learning Approach to the Landslide Activation Prediction in Georgia”.

References

1. Aleotti P., Chowdhury R. Landslide Hazard Assessment: Summary. Rev N Perspect. // Bull Eng. Geol. Env. 58, 1999, pp. 21–44.
2. Li H., Samsudin N. A. A Systematic Review of Landslide Research in Urban Planning Worldwide. // Nat Hazards, 121, 2025, pp. 6391–6411. https://doi.org/10.1007/s11069-024-07064-4
3. Alcántara-Ayala I. Landslides in a Changing World. // Landslides, 2025. https://doi.org/10.1007/s10346-024-02451-1
4. Dalğıç S., Karimov E. Investigation of Landslide Mechanism in the Balaban Landslide Area using 3D Numerical Modelling. // Int. Journal of Sustainability and Risk Control, Vol.1, No 2(2), Baku, Azerbaijan, September 2025, pp. 31-35.
5. Varazanashvili O., Tsereteli N., Amiranashvili A., Tsereteli E., Elizbarashvili E., Dolidze J., Qaldani L., Saluqvadze M., Adamia Sh., Arevadze N., Gventcadze A. Vulnerability, Hazards and Multiple Risk Assessment for Georgia. // Natural Hazards, Vol. 64, Number 3, 2012, pp. 2021-2056. DOI: 10.1007/s11069-012-0374-3, http://www.springerlink.com/content/9311p18582143662/fulltext.pdf.
6. Fourth National Communication of Georgia Under the United Nations Framework Convention on Climate Change. // Chapter 4.9 Geological Hazards in Georgia, Tbilisi, 2021, pp. 278-286.
7. Gaprindashvili M., Tsereteli E., Gaprindashvili G., Kurtsikidze O. Landslide and Mudflow Hazard Assessment in Georgia. // In: Bonali F.L., Pasquaré Mariotto F., Tsereteli N. (eds) Building Knowledge for Geohazard Assessment and Management in the Caucasus and other Orogenic Regions. NATO Science for Peace and Security Series C: Environmental Security. Springer, Dordrecht, 2021. https://doi.org/10.1007/978-94-024-2046-3_14
8. Amiranashvili A., Elizbarashvili E., Gaprindashvili G., Varazanashvili O., Fuchs S. Statistical Analysis of Parameterized Landslide Data in Georgia from 1900 to 2022. // Reliability: Theory and Applications, ISSN 1932-2321, Special Issue № 6 (81), Part-2, Vol. 19, 2024, pp. 812 – 818. https://doi.org/10.24412/1932-2321-2024-681-812-818
9. Froude M., Petley D., Global Fatal Landslide Occurrence from 2004 to 2016. // Nat. Hazards Earth Syst. Sci., 18, 2018, pp. 2161–2181.
10. Geological Bulletins. 2016-2025, (in Georgian). https://nea.gov.ge/c/Departments/Geology
11. Varazanashvili O., Gaprindashvili G., Elizbarashvili E., Basilashvili Ts., Amiranashvili A., Fuchs S. The First Natural Hazard Event Database for the Republic of Georgia (GeNHs). // Catalog, 2023, 270 p. http://dspace.gela.org.ge/handle/123456789/10369; DOI: 10.13140/RG.2.2.12474.57286
12. Amiranashvili A., Chelidze T., Svanadze D., Tsamalashvili T., Tvauri G., Study of the Relationship Between the Mean Annual Sum of Atmospheric Precipitation and Re-Activated and New Mudflow Cases in Georgia. // Journal of the Georgian Geophysical Society, e-ISSN: 2667-9973, p-ISSN: 1512-1127, // Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 26(1), 2023, pp. 19–29.
https://ggs.openjournals.ge/index.php/GGS/article/view/6958; DOI: https://doi.org/10.48614/ggs2620236958
13. Kendall M.G., Time-series. // Moscow, 1981, 200 p., (in Russian).
14. Hinkle D. E., Wiersma W., Jurs S. G., Applied Statistics for the Behavioral Sciences. // Boston, MA, Houghton Mifflin Company, ISBN: 0618124055; 9780618124053, 2003, 756 p.
15. Aliyev V., Pkhovelishvili M., Archvadze N., Gasitashvili Z., Hybrid Risk Review. // Int. Journal of Sustainability and Risk Control, Vol.1, No 1(1), Baku, Azerbaijan, June 2025, pp. 12-23.