STATISTICAL ANALYSIS OF PARAMETERIZED LANDSLIDE DATA IN GEORGIA FROM 1900 TO 2022

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Abstract

Some results of statistical analysis of parameterized landslide (LS) data (the number of landslides and their areas) for 11 regions of Georgia (Autonomous Republic of Adjara, Guria, Imereti, Kakheti, Kvemo Kartli, Mtskheta-Mtianeti, Samegrelo-Zemo Svaneti, Racha-Lechkhumi and Kvemo Svaneti, Samtskhe-Javakheti, Shida Kartli, Tbilisi) from 1900 to 2022 are presented. Landslides count for Georgia is 1325, total area - 526.3 km². The area of individual landslides varies in the range from 0.0005 km² (Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti) to 12.0 km² (Shida Kartli). In particular, the following results were obtained. Map of distribution of landslides number and their areas for different regions of Georgia is presented. Repeatability of the number of landslides and also their total area for different ranges of LS areas is study; the highest frequency of landslides in the study area falls on the range of their areas 0.0005-0.05 km² (41.5%), the smallest - on the range 5.01-12.0 km² (0.38%); the highest frequency of the total area of landslides falls on the range of their areas 1.01-2.0 km² (26.1%), the smallest – on the range 0.0005-0.05 km² (1.8%). The average annual shares of the total area of landslides from the area of study regions is calculated; this share in Guria (0.288%) and Adjara (0.281%) is significantly higher than in other regions - respectively, 5.05-4.9 times more than in Shida Kartli and 28.8-28.1 times more than in Samegrelo-Zemo Svaneti. The relative coefficient of the total area of landslides (RC) for individual region is calculated. RC = (Landslides average area in region/Sum average landslides area in all regions)/(Region area/All regions area); the RC value for Guria and Adjara, respectively, is 6.26 and 6.13 and 3.6-3.5 times more than in Shida Kartli and 27.2-26.7 times more than in Kvemo Kartli and Samegrelo-Zemo Svaneti. The relative landslide risk ratio for the population of study regions (RLR) was calculated. RLR = RC·(Region population/All regions population). The highest RLR value is observed for Adjara (0.60); for Guria and Tbilisi - 0.17 each (approximately 3.5 times less). The lowest RLR values are observed for Racha-Lechkhumi and Kvemo Svaneti (0.007).

Keywords: natural disaster, dangerous geological processes, landslides, landslides area.

I. Introduction

Landslides are a type of natural disaster. Landslide processes are widespread almost everywhere, including in Georgia, and are dangerous due to damage to residential buildings, roads, infrastructure, etc., often accompanied by human casualties [1-4]. In particular, according to

incomplete data [5,6], in Georgia in 1996-2020 the total number of reactivated and new cases of landslides was about 12000. Therefore, the study of landslide processes in this country has always been and is given special attention [7–9].

An analysis of extensive material on landslides in Georgia showed that there is not so much systematic data about this natural phenomenon. In connection with the above, we collected the most reliable values of the main parameters of landslides, determined on the basis of the totality of available information. These included the date of occurrence (year, month, day), time of occurrence (hour), location of occurrence (geographical coordinates), magnitude and intensity [7,10], where appropriate, affected area and associated losses (number of fatalities; casualties in economic terms). As a result of this work, the first systematic catalog in Georgia was created for this natural phenomenon, as one of the five natural disasters (landslides, debris flows, flash floods, windstorms and hailstorms) [11,12].

The Landslide Catalog contains 1636 events for the period from 1900 to 2022, including, in particular, data on their areas.

At this stage of research, the results of a statistical analysis of data on the number of landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 are presented.

II. Study area, material and methods

Study area is Georgia and their 11 regions (Autonomous Republic of Adjara, Guria, Imereti, Kakheti, Kvemo Kartli, Mtskheta-Mtianeti, Samegrelo-Zemo Svaneti, Racha-Lechkhumi and Kvemo Svaneti, Samtskhe-Javakheti, Shida Kartli and Tbilisi).

Table 1: *Study area, population, period of observations and height range on landslides emergence in Georgia.*

Region	Region, Abbr	Regional center	Area, km²	Population (thous.)	Period of observations	Number of years	LS height range (m,a.s.l.)
Autonomous Republic of Adjara	Adj	Batumi	2919	363	1968-2022	21	2-1846
Guria	Gur	Ozurgeti	2033	102	1979-2022	13	28-553
Imereti	Im	Kutaisi	6516	442	1940-2022	26	21-965
Kakheti	Kakh	Telavi	11310	300	1974-2022	10	440-1974
Kvemo Kartli	KK	Rustavi	6528	436	1977-2022	8	285-1361
Mtskheta-Mtianeti	M-M	Mtskheta	6785	93	1963-2022	28	497-3773
Samegrelo-Zemo Svaneti	S-ZS	Zugdidi	7441	288	1900-2017	28	33-2384
Racha-Lechkhumi and Kvemo Svaneti	R-L KS	Ambrolauri	4690	26	1966-2022	35	354-1838
Samtskhe-Javakheti	S-J	Akhaltsikhe	6413	142	1973-2022	14	797-2468
Shida Kartli	Sh K	Gori	3429	244	1971-2022	14	509-1000
Tbilisi	Tb	Tbilisi	504	1259	1973-2022	25	437-1376
Georgia	Geo	Tbilisi	58567	3695	1990-2022	60	2-3773

In Table 1 information on the above mentioned study area, population [https://en.wikipedia.org/wiki/Administrative_divisions_of_Georgia_(country)], period of observations and height range on landslides emergence in Georgia are presented. In particular, the area of the studied regions vary from 504 km² (Tbilisi) to 11310 km² (Kakheti); population vary from 26 thousand (Racha-Lechkhumi and Kvemo Svaneti) to 1259 thousand (Tbilisi)

[https://www.geostat.ge/en]; period of observations - from 1990 to 2022; number of years of observations - from 8 (Kvemo Kartli) to 35 (Racha-Lechkhumi and Kvemo Svaneti). In general, in Georgia, the study area is 58567 km², population – 3695 thousand and the number of years of observations is 60. The height of landslides emergence in Georgia vary from 2 to 3773 meters.

The work used catalog data [12] on the landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 (1375 cases in total).

In the proposed work the analysis of data is carried out with the use of the standard statistical analysis methods.

The following designations will be used below: Mean – average values; Max - maximal values; Min – minimal values; St Dev - standard deviation; St Err - standard error; Low and Upp – lower and upper levels of the confidence interval of the mean within standard error; LS – landslide. RC - relative coefficient of the total area of landslides in region; RC = (Landslides average area in region/Sum average landslides area in all regions)/(Region area/All regions area). RLR - relative landslide risk ratio for the population of study regions; RLR = RC·(Region population/All regions population).

III. Results

The results in Fig. 1-6 and Table 2 are represented.

In Fig. 1 map of distribution of landslides number and their areas for different regions of Georgia is presented. In Table 2 statistical characteristics of Fig. 1 data is represented.

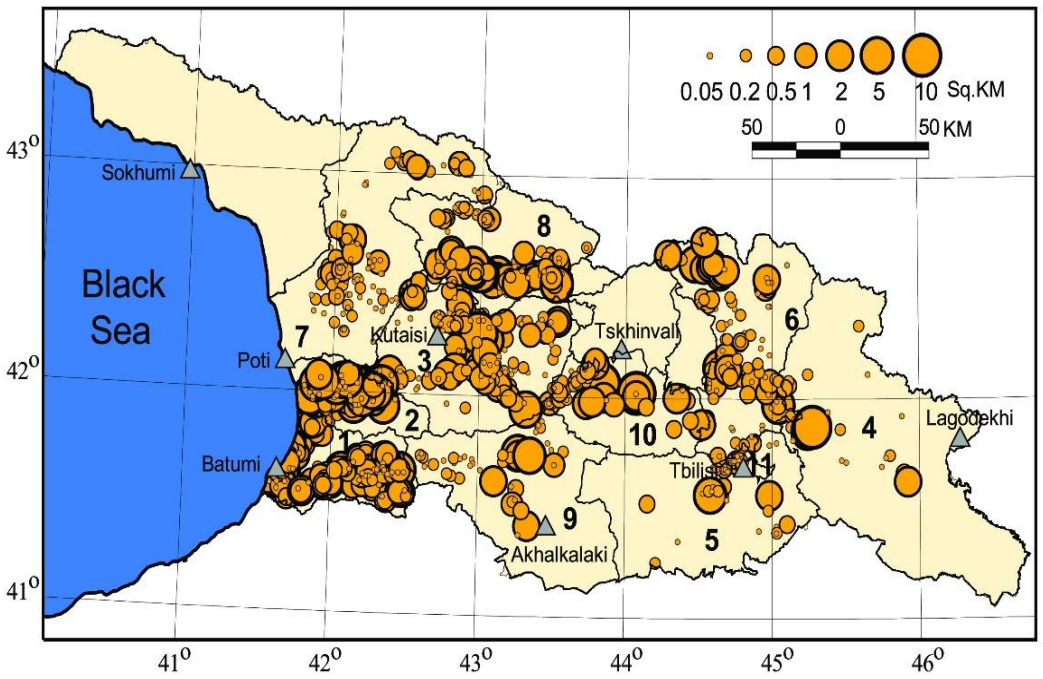


Figure 1: *Distribution of landslides area in Georgia*
1 – Autonomous Republic of Adjara, 2 – Guria, 3 – Imereti, 4 - Kakheti, 5 - Kvemo Kartli, 6 - Mtskheta-Mtianeti, 7 - Samegrelo-Zemo Svaneti, 8 - Racha-Lechkhumi and Kvemo Svaneti, 9 - Samtskhe-Javakheti, 10 - Shida Kartli, 11 - Tbilisi.

As follows from Fig. 1 and table 2, the distribution of the number of landslides and their areas on the territory of Georgia is extremely uneven. In particular, LS count vary from 23 (Kvemo Kartli) to 300 (Autonomous Republic of Adjara). LS count for Georgia is 1325. The area of individual landslides varies in the range from 0.0005 km² (Imereti, Samegrelo-Zemo Svaneti, Samtskhe-Javakheti) to 12.0 km² (Shida Kartli).

Table 2. *Statistical characteristics of landslide areas in different regions of Georgia (km²).*

Region	Adj	Gur	Im	Kakh	KK	M-M
Min	0.001	0.0007	0.0005	0.00132	0.0017	0.001
Max	2.7	3.7	8.4	6.0	2.2	4.1
Mean	0.57	0.97	0.35	0.49	0.24	0.32
St Dev	0.53	1.16	0.88	1.30	0.51	0.57
St Err	0.031	0.133	0.064	0.259	0.108	0.050
Total area	172.5	76.0	65.6	12.6	5.5	41.5
LS count	300	78	189	26	23	131
Region	S-ZS	R-L KS	S-J	Sh K	Tb	Geo
Min	0.0005	0.001	0.0005	0.001	0.001	0.0005
Max	2.0	4.0	3.0	12.0	0.8	12.0
Mean	0.16	0.28	0.32	0.50	0.05	0.40
St Dev	0.26	0.54	0.66	1.53	0.13	0.76
St Err	0.022	0.034	0.095	0.174	0.018	0.021
Total area	21.5	74.1	15.5	38.7	2.8	526.3
LS count	138	260	49	78	53	1325

The total landslides area changes from 2.8 km² (Tbilisi) to 172.5 km² (Autonomous Republic of Adjara). For Georgia the total landslides area is 526.3 km². On average, the area of landslides vary from 0.05 km² (Tbilisi) to 0.97 km² (Guria). In Georgia as a whole, this area is 0.40 km².

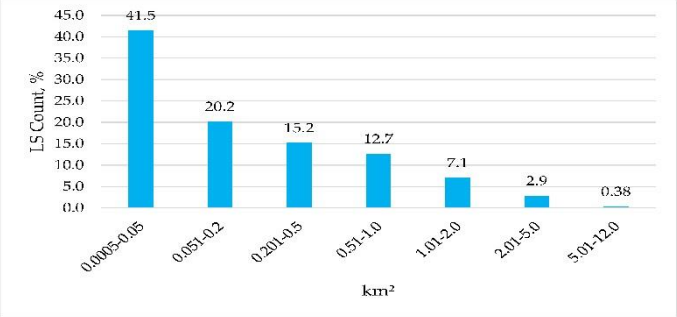


Figure 2: *Repeatability of the number of landslides at different ranges of their areas.*

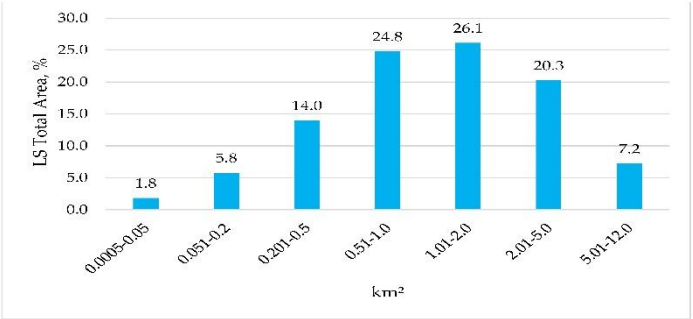
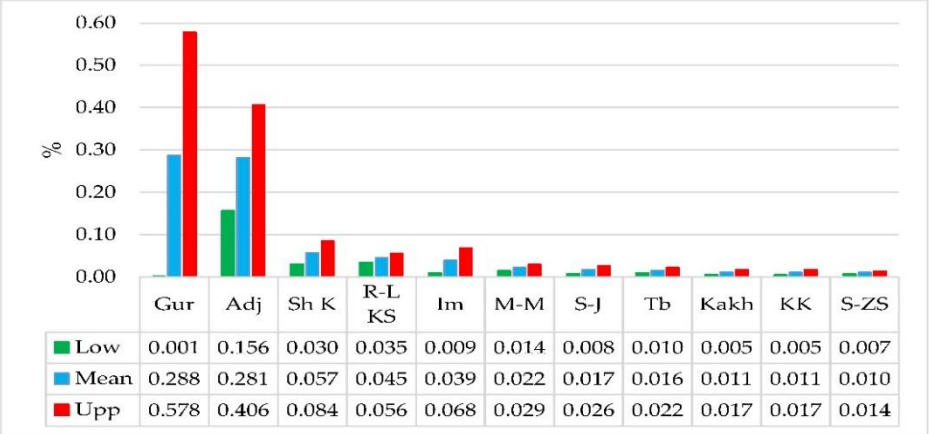


Figure 3: *Repeatability of the total area of landslides for different ranges of their areas.*

From Fig. 2 it follows that the highest frequency of landslides in the study area falls on the range of their areas 0.0005-0.05 km² (41.5%), the smallest - on the range 5.01-12.0 km² (0.38%). At the same time, as shown in Fig. 3, the highest frequency of the total area of landslides falls on the range of their areas 1.01-2.0 km² (26.1%), the smallest – on the range 0.0005-0.05 km² (1.8%).



	Gur	Adj	Sh K	R-L KS	Im	M-M	S-J	Tb	Kakh	KK	S-ZS
Low	0.001	0.156	0.030	0.035	0.009	0.014	0.008	0.010	0.005	0.005	0.007
Mean	0.288	0.281	0.057	0.045	0.039	0.022	0.017	0.016	0.011	0.011	0.010
Upp	0.578	0.406	0.084	0.056	0.068	0.029	0.026	0.022	0.017	0.017	0.014

Figure 4: *Mean annual share of the total area of landslides from the area of the region.*

Taking into account that the studied regions have different areas, we calculated the average annual shares of the total area of landslides from the area of these regions (Fig. 4). As follows from Fig. 4, this share in Guria (0.288%) and Adjara (0.281%) is significantly higher than in other regions: respectively, 5.05-4.9 times more than in Shida Kartli and 28.8-28.1 times more than in Samegrelo-Zemo Svaneti.

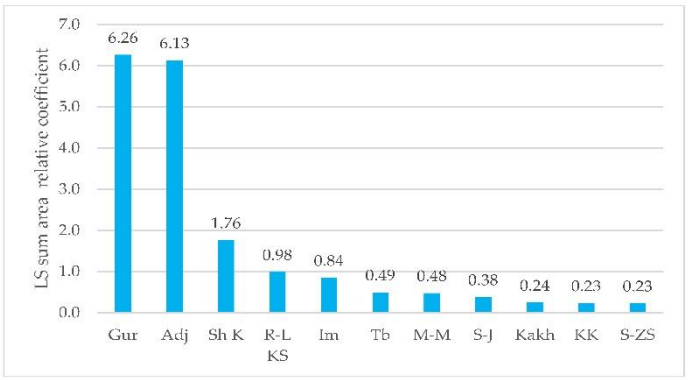


Figure 5: *Relative coefficient of the total area of landslides for different regions of Georgia.*

Taking into account that the amount of systematic data on landslides in Georgia is much lower than the total recorded amount (for example, about 5% in 1996-2020 [5,6,12]), we calculated the relative coefficient of the total area of landslides RC for individual regions (Fig. 5). As follows from this figure, the RC value for Guria and Adjara, respectively, is 6.26 and 6.13 and 3.6-3.5 times more than in Shida Kartli and 27.2-26.7 times more than in Kvemo Kartli and Samegrelo-Zemo Svaneti.

Figure 6: *Relative landslide risk ratio for populations of different regions of Georgia.*

Finally, taking into account the number of inhabitants in the study regions of Georgia, the relative landslide risk ratio (RLR) for the population of these regions was calculated (Fig. 6). As follows from Fig. 6, the highest RLR value is observed for Adjara (0.60); for Guria and Tbilisi - 0.17 each (approximately 3.5 times less). The lowest RLR values are observed for Racha-Lechkhumi and Kvemo Svaneti (0.007).

IV. Discussion

Landslide (LS) processes are widespread almost everywhere and are dangerous due to damage to residential buildings, roads, infrastructure, etc., often accompanied by human casualties. This problem is also very relevant for Georgia. According to incomplete data the total number of landslide on the territories of Georgia in 1996-2020 was near 12000 [5,6]. Therefore, the study of landslide processes in Georgia has always been and is given special attention.

An analysis of extensive material on landslides in Georgia showed that there is not so much parameterized data about this natural phenomenon. In connection with the above, by us made the first systematic catalog in Georgia was created for this natural phenomenon, as one of the five natural disasters (landslides, debris flows, flash floods, windstorms and hailstorms) [11,12].

The Landslide Catalog contains 1636 events for the period from 1900 to 2022, including, in particular, data on their areas. At this stage of research, a statistical analysis of data on the number of landslides and their areas for 11 regions of Georgia in the period from 1990 to 2022 carried out (1325 LS events).

In particular, it has been quantitatively confirmed that in terms of relative landslide-hazardous area, the most vulnerable regions are Guria and Adjara, significantly exceeding all other regions. In terms of the level of landslide risk for the population of these regions, Adjara is the most unfavorable, followed by Guria and Tbilisi.

V. Conclusion

In the near future, we plan to conduct a statistical analysis of such LS catalog parameters as magnitude, intensity, economic loss. In addition, it became possible to significantly improve the quality of mapping the territory of Georgia using parameterized data on landslides, to clarify the quantitative relationships of landslides with various geological, geophysical and atmospheric processes (in particular, with precipitation [13]). We also plan to continually update the catalog data as new information becomes available [14,15].

Acknowledgments

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