7 Natural Disasters (Mudflow, Landslide, Etc.)

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Abstract

This chapter presents the general overview of natural hazards, hazardous risks, and preventions in Georgia. In Georgia, landslide-gravitational hazards take main place, causing damage to widespread territory, and economic loss. Georgia is one of the most vulnerable sides of mountainous countries, with the rate of debris/mudflow activation, their development scale, return period, and catastrophic results. Several major seismic zones can be defined in Georgia, first of all, the main ridge of the Greater Caucasus and Javakheti volcanic plateau, the Adjara-Trialeti ridge fault system is also characterized by a history of destructive earthquakes.

Negative effects by the natural disasters have reached a colossal scale across our planet, including Georgia. Economic loss to the economy reaches tens of billions US dollars annually. There is a big number of victims.

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Protection of the population against geological calamities in most mountainous countries of the world, safe operation of infrastructure objects, and survival of the lands from destruction have become one of the most significant social-economic, demographic and ecological problems. This was why at the World Conference on Disaster Reduction held in 2005 (Hyogo, Japan) and in 2015 (Sendai, Japan) the identification, assessment, and monitoring of disaster risks and development of early warning mechanisms, drafting of risks maps, and development the indicators to reduce disaster risks, insecurity and adaptation were named as the major trend of 2005–2030. The normative base adopted in Georgia, which is a mountainous country, fully responds to the Framework for Action adopted at the Conferences and is realized by considering the financial and technical resources of the country (Tsereteli et al. 2015).

Georgia is one of the most complicated regions of the world's mountainous areas, with the development of disaster geological processes, with their return period, negative results inflicted on the population, agricultural lands, and infrastructural facilities (National Report about Environment Condition 2014).

Natural hazards followed by two different events and results:

1. Negative meteorological phenomena (tropical cyclones, hurricanes, storms, and atmospheric precipitation and air temperature positive and negative sharp deviations from multi-year

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average norms) in the lower layers of the atmosphere;

2. Hazardous geological processes on the surface of the earth and its crust (landslides, debris/mudflows, sea coast, riverbank erosion, rock avalanches, rockfalls, volcanoes, earthquakes, etc.).

Thousands of settlements, land plots, roads, oil and gas pipelines, high voltage power transmission towers, mining-tourist complexes, etc. are periodically affected by the strong impact of geological disasters (often catastrophic results). Almost all landscapes and geographical zones are located in the natural hazard risk zone—from the Black Sea to the mountain area. Socio-economic results caused by landslides, rockfall/rock avalanches, debris/mudflows, sea coast and riverbank erosion, floods, and flashflood cover all areas of human activity (Figs. 7.1 and 7.2).

Difficult situation occurs in mountain zones of Georgia, where the activation of the disaster is very high, causes resettlement of households. In 2011–2017 1290 households were resettled to geologically stable areas (eco-migrants) from 6984 families assessed by the department of Geology of the National Environmental Agency. In 1995–2017, 141 people were killed as a result of geological disaster.

In the last period activation and development of natural disasters, in the background of extremely sensitive geological environment caused by:

1. The intensification of high-intensity earthquakes in the Caucasus (1988—Spitak, 1991—Racha-Imereti, 1992—Pasanauri-Barisakho, 2002—Tbilisi, 2009—Oni, 2010—Vani).
2. On the background of global climate change increase in the frequency of negative meteorological events (primarily atmospheric precipitation, temperature, and humidity) and the quantitative increase in favor of the average long-term indicators;

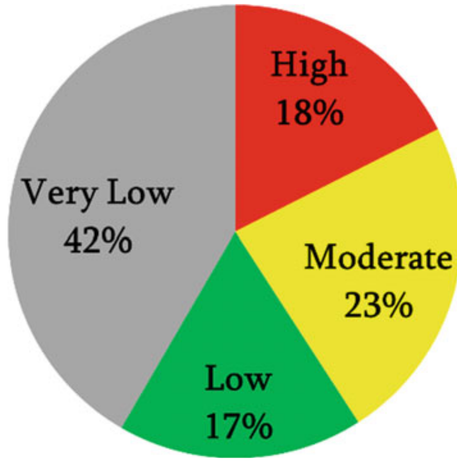


Fig. 7.2 Percentage of settlement under geological hazard risk (Informational Geological bulletin 2018)

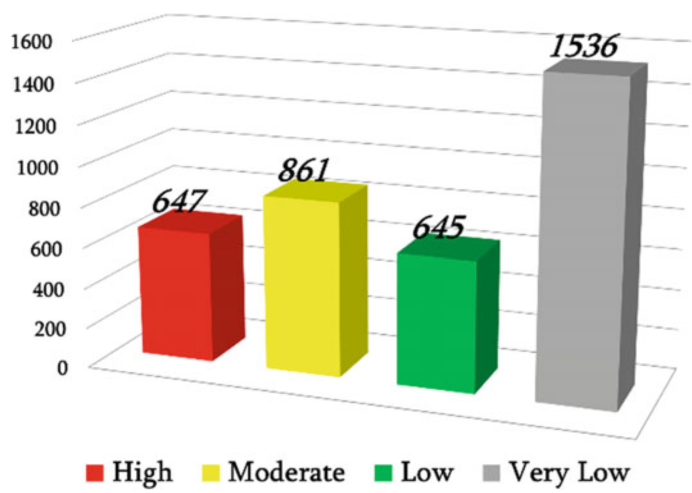


Fig. 7.1 Total number of settlements under geological hazard risk (Informational Geological bulletin 2018)

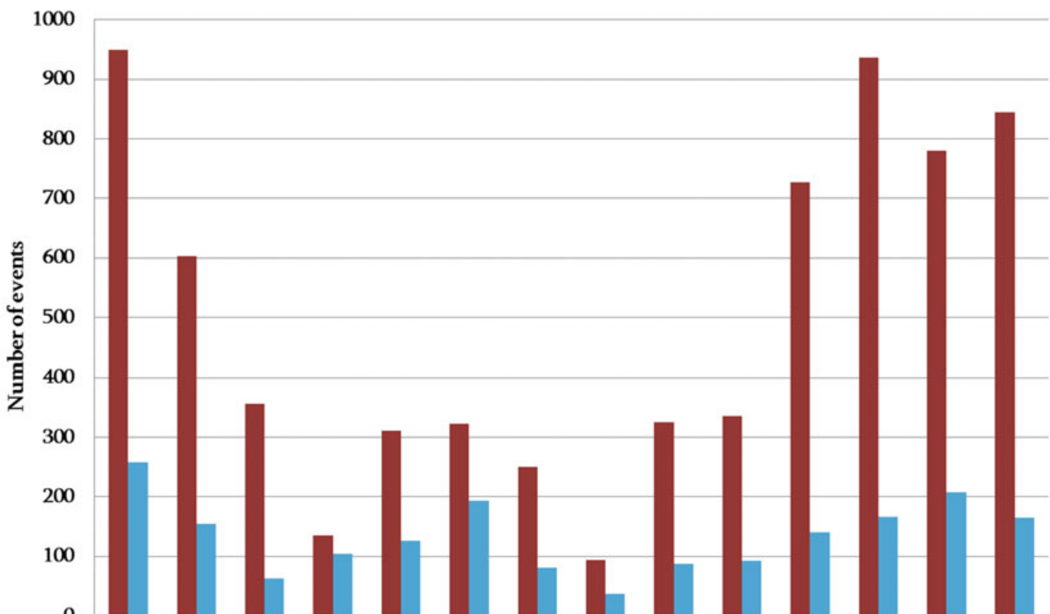
3. Human's large-scale impacts on the environment and its balance sheets, such as population construction and reconstruction of new infrastructure objects in geodynamically complicated areas, cutting the slope, deforestation, etc. Studies have confirmed that the population settles in temporary stabilized landslide bodies, debris/mudflow alluvial fans, and flood plains without proper geological assessment.
4. The risk of geological disaster increases by the low level of readiness, inadequate awareness of the expected geological disasters, their activation trends, and results (Gaprindashvili et al 2016; Tsereteli et al 2012).

According to the Department of Geology of the National Environmental Agency, in the years 2004–2017, the scale of activation of landslide and debris/mudflow processes in the territory of Georgia increased significantly (Fig. 7.3). According to the data of 2017, 18% of Georgia's settlements (647 points) are under high risk of geological processes (Informational Geological Bulletin 2018).

In recent years several natural geological catastrophic events have been observed in Georgia that accompanied loss of human beings and large ecological damage. Among them are:

In Tbilisi during 13–14 June 2015 heavy rainfall in the riv. Vere basin area and its tributaries caused a drastic increase in the water level and triggered/activated large-scale landslide and debris-flow events. This put the Tskneti-Samadlo and Tsnketi-Akhaldaba motorways out of order. Residential buildings and miscellaneous infrastructural facilities, buildings, and Tbilisi Zoo are located at the low elevations in the riv. Vere Gorge was significantly damaged or/and totally destroyed. 23 persons died during the disaster (National Environmental Agency 2015; Gaprindashvili 2016) (Fig. 7.4).

On May 17 and August 20, 2014, catastrophic debris/mudflow process occurred in the area of junction of rivers Tergi and Devdoraki-Amali,



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Landslide	949	603	356	136	311	323	250	94	325	336	727	936	780	845
Debrisflow	258	155	63	104	126	193	81	37	88	93	141	167	208	165

Fig. 7.3 Recorded landslide and Debris/Mudflow event in Georgia (2004–2017)

Fig. 7.4 Akhaldaba "big" Landslide (Tbilisi), June 2015 (Photo by G. Gaprindashvili)

which completely paralyzed functioning of infrastructure objects having strategic meaning for the country. Debris flow have damaged Georgian military road, "North–South" connecting 700 and 1200 mm gas pipelines, knocked down transmission line, means of transportation, isolated base of border guards, customs point, residence of Georgian Patriarchate, also caused 10 victims (including foreign citizens)—(Gaprindashvili and Gaprindashvili 2015).

On June 18, 2011, catastrophic landslide/debris-flow process occurred in the area of Rikoti pass (Central Georgia), which destroyed infrastructure objects and causes eight victims (Fig. 7.5).

7.1 Landslide-Gravitational Hazards

In Georgia, landslide-gravitational hazards take main place, causing damage to widespread territory and economic loss. The morphological and climatic areas of their development are indefinite—from lowland seaside to high mountainous alpine-nival zones. In Georgia, it is recorded around 53 000 Landslide-gravitational phenomena, damages more than 1.5 million hectares of land. Under the landslide hazard risk are around 55% of settlements, 25% of the roads, oil and gas pipelines. In Georgia over 80% of the total damage to the population and infrastructural facilities was inflicted by the geological disaster (Figs. 7.6 and 7.7).

The damage inflicted by landslide to Georgia's economy will be determined by several tens of millions of dollars in terms of background development, hundreds of millions in extreme activation, and sometimes even billions.

In recent times such broad scaled development/reactivation of landslide-gravitational events are conditioned by:

- Positive deviation of landslide triggering negative hydro-meteorological phenomena (precipitation, humidity) from average multi-annual norm on the overall background of geological and climatic changes;
- High technogenic pressing on the geological environment without considering an assessment of its resistance. In this regard, there is a very difficult situation on the area of Tbilisi territory, where if in 2000 year 60 landslides

Fig. 7.5 Debris flow in Rikoti Pass (Khashuri Municipality), June 2011 (Photo by G. Gaprindashvili)

Fig. 7.6 Landslide in Sheshelidze str. (Tbilisi), April 2016 (Photo by G. Gaprindashvili)

were recorded (according to the Geological Monitoring Information Newsletter), by the 2017 year this number exceeds three hundred;
- Intensification of earthquakes in Caucasus Region;

All kinds and types of landslide-gravitational events known in geodynamics find their development place on the territory of Georgia: starting from the simplest, deformations of which do not beyond the aeration zone, to the deepest (tens of meters). Also, certain landslide areas (from units to hundreds of hectares) and volumes (from several thousands to the tens and hundreds of cubic meters) are changed in large diapason.

Today, the number of general-theoretical, regional, and targeted (special) classifications of landslide-gravitational phenomena in Earth Science has exceeded hundreds. All of them are different with fullness and authenticity of the

Fig. 7.7 Landslide in Khulo municipality, April 2013 (Photo by G. Gaprindashvili)

process (geology, structure, structure, mechanism, kinematics, morphology and et al.) and to some extent deserve attention.

The regional classification of landslide events in Georgia is based on the principle of the main mark of the process of bas-deferential factor, which witnesses the mechanism of bringing out the landslide equilibrium conditions. Accordingly, we have the following group of landslides:

1. ***Coastal (Basic) Landslides***—originated on the Black Sea coast, along the banks of large rivers and reservoirs, as a result of erosive and abrasive cutting.
2. ***Climatogenic Landslides*** dominate all other types of landslides and are primarily formed into the slope of the sedimentary deposits, triggered by meteorological events;
3. ***Tecto-Seismogenic Landslide-Gravitational Phenomena*** that differ substantially from all other genetic types according to the formation conditions and motion emissions, characterize the development and localization of active tectonic faults in different ranges;
4. ***Karst-Sufic Landslides***.
5. ***Cryogenic Landslides***—characterized by zonal development and are characteristic of any alpine-area zone;
6. ***Technogenic (Anthropogenic)*** landslides are formed by wrong activities of people (cutting the slope et al.), which leads to a violation of relief-based homoseastism.

From last decades of the twentieth century, this regularity had been disrupted and their activation regime takes place almost every year above accepted background in most regions and is characterized by frequent explosions, huge economic losses, and casualties. The clear confirmation of this is incomplete data (1995–2017 years) gained from analyses of regional monitoring studies by Department of Geology of National Environmental Agency, which was mostly conducted in settlements. In this period 10,001 activated and just created landslides were recorded, their direct loss exceeded 380.72 million US dollars, and 47 people were killed (Table 7.1).

During 2003–2005, 2008–2011 and 2014–2015 many landslide events occurred over almost the entire territory of Georgia with various degrees of intensity. Critical situations occurred in Rach-Lechkhumi, Svaneti, Racha-Lechkhumi, Achara, Mtskheta-Mtianeti, Guria, and Kakheti mountainous regions, as well as in Tbilisi, Samtskhe-Javakheti, Samegrelo, and the Imereti foothills. Individual territories of Shida and Kvemo Kartli also fell under the average risk hazard zone.

Table 7.1 Recorded landslides, economic and human loss (1995–2017)

Year	Recorded events	Economic Loss (mln. GEL)—1 GEL—0.4 USD	Human Loss		Year	Recorded events	Economic Loss (mln. GEL)—1 GEL—0.4 USD	Human Loss
1	2	3	4		1	2	3	4
1995	670	132.00	6		2007	136	20.50	0
1996	610	80.30	3		2008	311	48.00	8
1997	871	102.00	2		2009	323	63.50	1
1998	543	67.00	5		2010	250	21.70	3
1999	56	12.00	1		2011	94	Unk	3
2000	65	13.00	1		2012	325	Unk	1
2001	75	15.00	0		2013	336	Unk	0
2002	69	13.80	1		2014	727	Unk	0
2003	71	14.50	3		2015	936	35.0	4
2004	949	147.00	4		2016	780	Unk	0
2005	603	96.00	0		2017	845	Unk	0
2006	356	70.50	1		Total	10,001	951.8	47

Source Department of Geology, NEA

The territory of Georgia is divided into seven conditional areas by damage caused by landslide-gravitational events and hazards risk:

1. The area with ***very high*** coefficient of damage (0.7–0.9) caused by landslide phenomena and with very high dynamic potential of development, includes: the Black Sea coast of Abkhazia, tertiary zone of Racha-Lechkhumi Syncline depression, Upper Imereti raised horst, foothills of Adjara-Imereti, mountainous Adjara;
2. The area with ***high*** coefficient of damage (0.5–0.7) caused by landslide phenomena and with notable risk of development, includes: left bank of river Psou of Sochi-Adler depression, small tuberiferous zone of Okriba, foothills of Guria region, Dusheti municipality;
3. The area with ***significant*** coefficient of damage (0.3–0.5) caused by landslide phenomena and with notable risk of development, includes: Foothills of Adjara, mountainous Guria region, northern slope of Trialeti range with Akhaltsikhe depression, hilly zone of northern Kolkheti side, the territory of Tbilisi and Asureti;
4. The area with ***moderate*** coefficient of damage (0.2–0.3) caused by landslide phenomena and with probability of significant development, includes: Trtialeti range, the erosive relief of middle and high mountainous gorges in the Jurassic clay shale, chalk, and Paleocene Flysch distribution zones, peripheral area of Shida Kartli depression, foothills of Tsiv-Gombori range;
5. The area with ***low*** coefficient of damage (0.01–0.1) caused by landslide phenomena and with significant risk of gravitational phenomena, includes: Mesozoic period's zones of the southern slope of Caucasus constructed with volcanogenic and carbonate formation, river Iori plateau, the left side of river Iori characterized with hilly terrain, the adjacent territories of to Khrami and Loki massifs.
6. The area with ***very low*** coefficient of damage (≥ 0.01) caused by landslide phenomena, with limitation of their possible development, and notable risk of gravitational phenomena includes: Javakheti volcanogenic highland, axial zone constructed with crystal rocks of Caucasus, massifs of Khrami. Loki and

Kelasuri, terraces of the rivers Mtkvari and Khrami in the Marneuli—Gardabani plain area;

7. The area is practically ***no danger*** by landslide events and with their local development on small territories, on the banks of large rivers, and on sides of irrigation channels includes Kolkheti lowland, Inner Kartli, Gardabani, Alazani, and Iori areas presented by low plain-terraces.

7.2 Debris/Mudflows

The Caucasus Region and especially Georgia are one of the most vulnerable sides of mountainous countries, with the rate of debris/mudflow activation, their development scale, return period, and catastrophic results. In Georgia we meet all genetic type debris/mudflows. Almost 30% of territory is under this type of hazard risk. All the settlements, which are located in the flood plains and adjacent territory are under hazard risk (Figs. 7.8, 7.9). Debris/Mudflows periodically damage high-ways and other infrastructure objects, and agricultural lands. In Georgia, debris/mudflows are recorded in up to 3000 rivers/gorges (Fig. 7.10). In 1995–2017, 94 people died and economic losses reached 738 million GEL (Table 7.2).

Since 2011, there have been several natural disasters in Georgia, which unfortunately accompanied loss of human beings. Among them are:

- The catastrophic debris flow developed on the territory of Rikoti Pass on June 18, 2011, which killed eight people.
- On 17 May and 20 August 2014, the Amali-Devdoraki debris-flow disaster in Dariali Gorge, Kazbegi municipality (victim—10 people);
- On 13–14 June 2015, In Tbilisi Natural catastrophic processes developed in riv. Vere Gorge (victim—23 people);

Geomonitoring studies have confirmed activation of debris/mudflow hazards from the last decade of the twentieth century. This is proven by the statistical information (Source: Department of Geology, NEA) in 1995–2017 (Table 7.2).

The territory of Georgia is divided into nine conditional areas by damage caused by debris/mudflow processes, and according to the hazard risk which is based on syncretic synergism of the elements, which are part of geological environment system, characterized by

Fig. 7.8 Debris/mudflow in Amali-Devdoraki gorge (riv. Tergi, Kazbegi) (photo by G. Gaprindashvili)

Fig. 7.9 Debris/mudflow in Tbilisi (photo by G. Gaprindashvili)

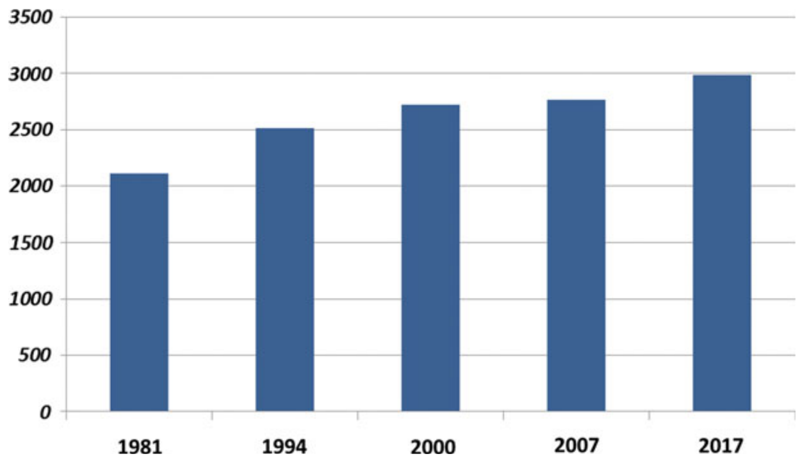


Fig. 7.10 Recorded Debris/mudflow events in Georgia by year

extremely complex multifactorial features and debris-flow processes stimulating factors:

1. The area with ***very high*** damage probability and with high risk of recurrence (Ks-0.8–0.9), includes: Low and middles-sized mountains constructed with Molasse sediments of Intermountain Belt of Eastern Georgia, Upper parts of riv. Rioni, Tskhenistkali, Tergi, Aragvi basins. Transformation of debris/mudflows takes place almost every year (daily rainfall 30–50 mm and more). Often it is repeated several times in a year.
2. The area with ***high*** damage probability and hazard risk (Ks-0.6–0.8), includes: Area constructed with flusch rows and Mesozoic shale of north and south slopes of central and eastern segments of the Caucasus, highland of Adjara of Lesser Caucasus, also right bank of riv. Mtkvari (Tbilisi city). Debris flows recurrence period once in 2–3 years. Wide range of released materials volume—0.1–0.2 mln.m^3.
3. The area with ***significant*** probability of damage by debris-flow transforming rivers and hazard risk (Ks-0.5–0.6) includes Trialeti and Meskheti ranges, middle and upper part of the river Kodori (western Caucasus), and river Bzipi basins. Debris flows recurrence period once in 3–5 years. The volume of material released by debris flows from thousands of cubic meters to amounts 0.5–1.0 mln. m^3.

Table 7.2 Recorded debris/mudflows, economic and human loss (1995–2017)

Year	Recorded Debris/Mudflow events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss	Year	Recorded Debris/Mudflow events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1	2	3	4	1	2	3	4
1995	250	96.0	12	2007	104	11.5	1
1996	165	27.0	5	2008	126	15.0	8
1997	335	44.0	7	2009	193	16.5	3
1998	173	20.0	6	2010	81	5.5	2
1999	27	4.5	0	2011	37	9.8	8
2000	23	3.0	0	2012	88	54.3	5
2001	26	4.0	0	2013	93	Unknown	0
2002	23	2.5	2	2014	141	165.0	10
2003	28	4.0	0	2015	167	210.0	19
2004	258	28.0	2	2016	208	Unknown	0
2005	155	9.0	4	2017	165	Unknown	0
2006	63	9.0	0	Total	2929	738.6	94

Source Department of Geology, NEA

4. The area with ***moderate*** risk of debris-flow hazards (Ks-0.3–0.5), includes middle part of the rivers Rioni, Tskhenistskali, Enguri, and Kodori basins, headwaters of river Kvirila basin, low and middles-sized mountain zone of Aphazeti Caucasus, the basin of river Algeti, Trialeti range on the territory of Tbilisi city, lowlands of Adjara. Debris flows recurrence period once in 3–10 years.
5. The area with ***limited*** debris flow hazard risk (ks-0.1–0.3), includes: lowland zone of raised horst of the Dzirula, Khrami, and Loqi, Foothills of Guria and Imereti, debris flows in the basins of rivers Psou, Sandripshi, and Zhoekvara take place once in 3–7 years, the volume of released material amounts 5-10,000 m^3.
6. The area with ***low*** probability of damage caused by debris-flow processes and hazard risk (Ks- 0.01–0.1), includes areas constructed by carbonate rocks of low and middle-sized mountains of Racha, Askhi, Khvamli, Arabika, and rivers Bzipi and Kodori, foothills of Guria and Adjara.
7. The area with ***very low*** probability of damage caused by debris-flow processes and hazard risk (Ks- < 0.01), includes: Iori Plateau and part of the downstream river Mtkvari;
8. The area ***weak*** probability of damage caused by debris-flow processes and hazard risk includes Akhalkalaki plateau and volcanogenic highland of Javakheti.
9. The area, where is ***no danger*** by debris-flow hazard risk, includes Kolkheti lowland and Black Sea coast, plains of Eastern Georgia, Kartli, and Alazani.

7.3 Earthquake

Georgia is situated in a seismically active region within the Caucasus, which is one of the most seismically active regions in the Alpine-Himalayan collision belt (Westen Van et al. 2012, Westen Van et. al 2018).

The instrumental period of seismic observation began in the Caucasus at the very beginning of the twentieth century. Since then, several earthquakes have occurred, which caused human loss and damage to infrastructure objects. In 1920 in Gori (Shida Kartli region) occurred earthquake with magnitude of 6.2, caused death of 150 people. Strong destructive earthquake occurred in 1988 in Spytak (Armenia) with magnitudes up to 7, intensity 9 (MSK scale), during this earthquake 25,000 people were killed, and 50,000 were injured. In 1991, the Racha earthquake (M = 7.2), more than 200 people were killed and approximately 60,000 were left homeless. The damage covered thousands of square kilometers. Also, capital of Georgia, Tbilisi, is subjected to high seismic risk, which was proven by the 25 April 2002 (Westen Van et al. 2012, Westen Van et al. 2018).

With the launch of antisemic construction in the future, it will be possible to avoid devastating consequences of earthquakes. But there is no second danger—the activation of landslide and mudflow events triggered by earthquakes, which often arise in areas with significant geotectonic areas. With the earthquakes of 1991–1992, about 20 thousand new landslides and rockfall events were activated, lot of debris material was accumulated in the river gorges, and plenty of cracks was created on the ground. In the negative impact zone of these events, up to 1500 hectares of land were found, with 100 victims; village Khakhieti was buried under 70 million cubic meter volume landslide, riv. Kvirila gorge (near village Perevi) was blocked by 50 mln m^3 material. In Village Chordi (Oni municipality) immediate impact of the earthquake two houses were damaged, but giant landslides triggered by earthquake destroyed 70 communal villages. Also, Beloti and Satskhenisi villages (Tskhinvali zone) were totally destroyed. Large-scale landslides developed in Zhashkhva and Bajikhevi villages (Oni municipality) areas. The landslide blocked the riv. Patsa gorge (riv. Didi Liakhvi tributary) after partially break of dam debris flow and flashfloods flooded riv. Didi Liakhvi banks and inundated villages situated on the low terraces (Tatashidze et al 2000).

The activation of landslide-gravitational phenomena triggered by earthquakes was noted outside the epicenter almost throughout Georgia. Tens of millions of cubic meters of landslides developed in Adjara, Lechkhumi, Svaneti, Mtskheta-Mtianeti regions and et al. (Tatashidze et al 2000).

7.4 Flood-Flashflood

The territory of Georgia is characterized by floods and flash floods. Floods take place less rapidly, due to runoff from sustained precipitation or rapid snowmelt exceeding the capacity of a river's channel. Flash floods result from heavy precipitation or sudden releases from an upstream impoundment created behind a dam, landslide, or glacier (Westen Van et al. 2012, Westen Van et al. 2018).

Rivers that are mainly fed by snowmelt or glacial meltwater from the Caucasus. After intense precipitation it causes flood. Rivers that originate on the southern slopes of the Caucasus, where seasonal snow exists, are characterized by spring and summer floods and autumn flash floods. Rivers that originate from the western part of Central Georgia's mountains are characterized by spring floods and summer-autumn flash floods. Rain-fed flash floods occur in the Kolkheti lowlands, the Caucasus Mountains nearby Kolkheti lowland, and in the Meskheti Range. Many rivers in Eastern Georgia and Ajara show flash flood behavior (Westen Van et al. 2012, Westen Van et al. 2018).

Many floods and flashfloods occurred in Georgia, which caused human loss and damage to infrastructure objects. For example: riv, Rioni floods in 1895 and 1922 that caused death of people and huge economic damage. Riv. Mtkvari flod in Tbilisi in 1968 on April 18–19 with a peak discharge of 2,450 m^3/s (Westen Van et al. 2012, Westen Van et al. 2018).

The 1987 flood of the Lower Rioni River. On January 21, 1987, the Rioni River breached the northern embankment at the village of Sagvichao. Many settlement areas were flooded, leading to some casualties, and huge damage to the local agricultural sector (Westen Van et al. 2012, Westen Van et al. 2018).

Data analysis shows that floods and flash floods are characteristic of almost all the rivers of Georgia. Among them are very high risks:

Imereti, Samegrelo, Guria, Mtskheta-Mtianeti region, also riv. Mtkvari and Alazani left bank. The average return period of floods until 1995 was 3–5, from 1995 to 2–20, and in 2007–2013 between 7–23. Since 1995, 64 people have died (Table 7.3).

Snow Avalanches are characteristic of the medium and high mountainous zones of Georgia and put large material losses in Svaneti, mountainous Adjara, Racha, Tusheti, Mtskheta-Mtianeti population, and infrastructural objects. Causing significant destruction, and human loss. Over 1986–1988, 330 snow avalanche events in Svaneti, caused more than 100 victims. Most active zones are western and central sections of the Caucasus and mountainous Adjara. The formation and dissemination of snow avalanches (including catastrophe) mainly cause the surface of the terrain, with high inclination, peculiarities of vegetation, and meteorological elements. However, the arrival of snow avalanches occurs in the forestry areas. This is confirmed by the destroyed forest (240–300 ha) in the riv. riv. Nenskra, Nakra, Laskadura basins in 1987. Snow avalanches are also triggered by artificial cutting of the forest, which often ends with tragic results. The classic example of this is the 1972 year disaster in village Ghurta (Khulo municipality), in 1987 tragedy of Mulakhi (Mestia municipality), where the hazards destroyed both villages and killed 77 people.

The peculiar activity of snow avalanches in the mountainous regions of Georgia has been observed since 1970. Their massive arrival is recorded in 1972, 1975, 76, 1986–88, 1992, 2996–98, and 2014–2017 (Table 7.4). The massive atmospheric precipitation of the massive arrival of catastrophic snowflakes is significantly higher than the many norms and mainly coincides with periods of intrusion into the Atlantic cyclones. According to the Road Service in 1996, snow avalanche in Adjara mountainous area arrived at 40 places, 105 in Svaneti and 149 times in Kobi-Gudauri section of military road, which resulted in road blocking for 42 days. In Gudauri-Kobi section, in 1997, snow avalanche collapsed 120 times and killed five people, while the road was blocked for 40 days. In 1998, the avalanche activated 54 times, and auto-traffic movement was stopped for 22 days.

Erosive Processes In terms of the protection and rational use of land in Georgia, the most important place is to fight against erosion, as in the country's low level, there is no longer a possibility for new land acquisition and arable land without increasing large capital investment.

Table 7.3 Recorded flood and flash Table flood events between 1995–2017 (NEA 2015; Van Westen et al 2012)

Year	Recorded flood-flashflood events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss		Year	Recorded flood-flashflood events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1995	4	3.2	1		2007	7	40.3	1
1996	11	28.5	1		2008	16	38	3
1997	12	38	0		2009	20	30	5
1998	2	2	1		2010	18	20.7	3
1999	8	30.5	1		2011	23	35.1	9
2000	2	2	0		2012	15	32	5
2001	4	4.1	0		2013	8	20	0
2002	16	78.7	0		2014	13	10	3
2003	6	4.2	2		2015	11	112	22
2004	10	20.5	1		2016	18	10	1
2005	20	80	4		2017	27	15	0
2006	8	15	1		Total	279	669.8	64

Table 7.4 Recorded Snow Avalanches (1995–2017)

Year	Recorded events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss		Year	Recorded events	Economic loss (mln. GEL)—1 GEL—0.4 USD	Human loss
1995	8	3.2	2		2007	10	3	1
1996	6	3.8	3		2008	4	1.9	0
1997	10	4.2	0		2009	6	2.8	2
1998	9	3.9	2		2010	8	2.4	1
1999	12	3.7	1		2011	6	1.9	1
2000	7	2.1	1		2012	15	3.6	1
2001	6	3.5	1		2013	8	1.2	0
2002	8	1.5	0		2014	23	8	4
2003	8	2.1	2		2015	18	4	1
2004	10	4.8	1		2016	25	6	3
2005	14	4.5	3		2017	28	4	5
2006	12	2.5	0		Total	261	78.6	35

Source National Environmental Agency

Nearly all morpho-climatic zones have a risk of adverse impact on water erosion processes. Ranging from high mountain ranges to plain.

Two types of erosion are distinguished by the nature and manifestation of water erosion formation:

1. Linear or riverbed erosion—they are characterized by concentrated flows; It can be distinguished by the river erosion, which is characterized by constant action and dilapidated erosion—is distinguished by periodic interval, spatial and time bounding; At certain stages of development, it decides its action;
2. The slope erosion, which does not have a fixed bed and the surface runoff, produce flatness (area), so-called "fluid denudation", which is called "soil erosion" by soil scientists.

Among them, the slope (area) erosion and expansion of the landfall in the mountainous zone with high energy potential of relief (large inclination of the surface > 25–45°) and high division coefficient (> 2.0–5.0 km/km^2). In addition, the slope of almost all the first three-row rivers (semi-classification) is 10–25° and more, which is directly defined by the bedrock erosion. According to the General Scheme of Georgia Against Erosion Measures drawn up for 1981–2000, erosion of arable lands was 30%, nowadays this indicator has increased almost twice. The direct reason for this is to increase in "accelerated anthropogenic" erosion processes and negative meteorological phenomena. If we rely on the criteria of erosion classification, then it turns out that erosion intensity indicator of the lands of the mountainous terrain in Georgia will be entirely in the borders of high and catastrophic classes. This is due to the large gradient areas located on land and soil cover almost completely washed out, soil production rocks directly exposed on the surface, and their biogenic restoration, in spite of optimal landscape and climatic conditions, need many years.

According to M. Daraselia In the western part of Georgia, soil erosion annually covers 1000 hectares and according to M. Kharaishvili, 100–140 tons of soil are washed in 1 ha territory, and in 150–200 tons in Western Georgia. During the heavy rains, soil wash processes increase up to 300–500 tone. It is established that river Rioni every year in the sea produces 10 million tons of highly fertile soil. Four Black Sea River basins (Bzipi, Kodori, Enguri, and Chorokhi) Annual solid waste is 17760 thousand tons, while the total number of solid sediments of the Kolkheti rivers exceeds 100 million m^3 (Geography of Georgia 2000).

The “accelerated” slope erosion on the surfaces of large slopes occurs at highly cutted forest areas, especially in subalpine zones, which in most cases lead to the overall degradation of this zone and lowering the upper boundary of the forest by 300–800 m. Studies have shown that in the same landscape-geologic conditions, cutting edge of the forest slopes deep erosion coefficient equal 3–5 km on km^2, while this coefficient does not exceed 0.2–0.5 km on km^2 in the slopes of the foothills formed by molasses sediments.

The existence of vegetation is directly dependent on the quantitative and qualitative indicators of liquid and solid runoff rivers.

Fig. 7.11 River Bank erosion in Khobi Municipality, 2009 (photo by G. Gaprindashvili)

Fig. 7.12 River Bank erosion in Tbilisi city, 2015 (photo by G. Gaprindashvili)

Studies have shown that if in the case of Georgia's rivers 34% of forests, the coefficient of solid run was 0.94%, in 52% it decreased to 0.65 and in 80%—0.15.

There is a greater risk of highly fertile lands in the wake of the intense ***river bank erosion*** of almost all river basins in the Georgian plain and lowland area not only during the critical horizons of erosive washing during the floods but during the normal regime of the river flow (Figs. 7.11, 7.12). As a result, dozens and hundreds of lands are damaged every year and this rate increases during the floods. Intensive riverbank erosion is along the riv. Rioni, Alazani, Aragvi, Tskhenistskali, Mtkvari and Kodori gorges.

The riverbank erosion is almost always accompanied by small coastal landslides. Hundreds of hectares of land are lost, infrastructure objects (roads, railways, oil and gas pipelines et al.), which are situated along the river banks are damaged, and also population is under risk. It is estimated that the damage inflicted to the country's economy directly by riverbank erosion processes varies from 40–100 million dollars per year.

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