Georgian Geographical Journal

Natural Events Related to Hydrological Processes and Ways to Avoid Them in the Tourist Area of Adjara

Georgian Geographical Journal, 2026, 6(1) 21-28

DOI:
https://journals.4science.ge/index.php/GGJ

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Citation: Gorgijanidze, S.; Jincharadze, G.; Pipia, M.; Silagadze, M.; Gulashvili, Z.; Beglarashvili, N.; Kobakhidze, N. Natural Events Related to Hydrological Processes and Ways to Avoid Them in the Tourist Area of Adjara. *Georgian Geographical Journal* 2026, 6(1), 21-28. https://doi.org/10.52340/ggj.2026.06.01.04

Abstract

Tourism is one of the world's priority economic sectors. It plays an important role in the country's economic and social development, which is an important direction of sustainable development. Georgia is distinguished by its tourism potential. Its natural conditions and historical and ethnographic landmarks contribute to the development of tourist-recreational resources. In Georgia, the Achara region is distinguished by the beauty of the Black Sea coast and mountainous regions. According to geostat data, the region is visited annually by more than 2 million visitors. It is also important to consider the natural events that occur every year in Achara against the background of climatic warming and cause considerable damage. This has a negative effect on the tourism sector of the region. In addition, Achara is distinguished by the abundance of atmospheric precipitation. As a result, Floods and debris flows occur frequently (2002, 2005, 2007, 2012, 2022 and 2023). There are many examples of them. Therefore, it is necessary to observe the natural hydrological events that occur in the Achara region. Understanding their mechanisms and analysing their frequency are essential for hazard forecasting. Such a forecast, depending on the seasons of the year, will lead to positive results in the future for the tourist potential and sustainable development of tourism in the administrative unit of Achara.

Keywords: hydrology, flood, debris flow, atmospheric precipitation

Introduction

Tourism means traveling for vacation, spending free time or business purposes. It is one of the priority fields in the world. Vacation planning is an important process for any employed person. Today, tourism extends to virtually every part of the world. In high mountains, seacoasts, arctic or hot deserts. Today, tourism is one of the most global and popular industries, which is constantly dynamically growing and developing in different directions. This is the reason for the formation of different types and directions of tourism, because tourists have diverse interests, expectations and travel preferences, tastes, and needs, which must be satisfied with diverse tourist offers. It determines the economic and political situation of the country, which is an important direction of sustainable development. Therefore, it is necessary to study all the places, determine the expected threats and risks, to protect the residents and tourists there from the potential natural hazards.

It should be noted that Georgia is distinguished by its tourism potential. Its natural conditions and historical-ethnographic landmarks contribute to the development of touristic-recreational resources. Their intensive use began in 1960. Many tourist facilities were built to serve both local and foreign tourists. Until 1990, all districts were involved in tourism activities. The modern tourism development policy is aimed at fully utilizing and filling tourist facilities, which are presented in the form of hotels, family homes, hostels, camping sites and sanatoriums. At the same time, it was more developed,

according to modern standards and the synthesis of historical culture. It is important that the local population is actively involved in the tourism industry, which increases the country's economic stability and demands.

For the first time, seven tourist regions were created in Georgia: Abkhazia, Adjara, Kolkheti, Shovi-Utsera, Borjomi-Bakuriani, Tbilisi and East Caucasus. Later, some districts were expanded. (Geography of Georgia, 2000) Over the years, all regions have been involved and are actively receiving the flow of tourists. This gives a big profit for the country's economy. Among these tourist regions, Adjara stands out, because the region has always fascinated visitors with the beauty of the Black Sea coast and mountainous regions. According to Geostat data, more than 2 million visitors visit the region every year, which makes the tourism-economic potential here increasingly important. According to the data

Figure 1. St. Batumi, multi-storey hotels (photo by A. Turmanidze)

of 2022-2023, the number of local and foreign visitors reached 1210.6 thousand visitors in 2022, and 2468.5 in 2023. The distribution of guests took place in 491 places of accommodation, while the number of guests in hotels was distributed to 1345.6 people (Fig. 1) (National Statistics Office of Georgia, n.d.).

But here we should mention the natural events that occur in Adjara every year against the background of climatic warming and cause many losses. This has a negative effect on the tourism sector of the region. In addition, Adjara is distinguished by the abundance of atmospheric precipitation (4500-5000 mm). They contribute to the development of landslides, rockfalls, floods and debris flows. Avalanches are also common in the mountains during winter. The years 2012-2016 were characterized by a lack of snow, during which many avalanches occurred in mountainous Adjara, causing destruction and damage. Unfortunately, there were also victims. These processes are happening both in the past and now. Batumi, the capital of Adjara, is significant, which is always flooded because of active storms over the years.

Study area

Adjara is historical-geographical region of Georgia, which is located in the valley of Acharistskali. The territory of the Adjara region has rich history. It was inhabited since ancient times. Except cultural monuments from different periods, there is wonderful nature here, in the form of sunny seacoasts and mountainous Adjara. The region has a humid subtropical climate. With warm winters and cool summers. Rivers are mostly fed by atmospheric precipitation. The flora and fauna are also diverse because both sea and mountain landscapes are represented.

Adjara is in the extreme south-west of Georgia, in the valley of the Acharistskali River, on the coast of the Black Sea. It is bordered by Guria in the north, Akhaltsikhe in the east, and the state of Turkey in the south. Its administrative center is Batumi. The Autonomous Republic of Adjara includes the municipalities of Batumi, Khulo, Keda, Kobuleti, Shuakhevi and Khelvachauri. The highest peak of Adjara is Mount Kanli (3007m), which is located on the Arsiani ridge. The main river of the region is Acharistskali. Its tributaries are: Kavreta, Khokhnistskali, Agaristskali, Chvanitskali, Chirukhistskali and Skhalta. Adjara also has rivers: Kintrishi, Chakvistskali, Korolistskali, which flow straight to the Black Sea. The Kobuleti-Chakvi ridge, which divides this side into mountainous and coastal zones, plays a decisive role in the formation of Adjara's microclimate. Due to its influence, coastal Adjara has a humid subtropical climate with warm winters and hot summers. In mountainous Adjara, the climate is less humid, and winters are generally less snowy. The average summer temperature in coastal areas

is 22-24℃, in the mountains - 17-21℃. In winter, it is 4-6℃ in the plains, 3-2℃ in the highlands. This area is not rich in lakes, although we can see a few lakes (Maruashvili, 1954; Maruashvili, 1968; Maruashvili et al., 1971).

There are 4 protected areas in Adjara, and each one is characterized by individual and endemic varieties. Adjara is also rich in coastal and mountain resorts. Mountainous Adjara is especially fascinating, where sea and plain landscape mix. Tourist places are almost all over the spring and offer an unforgettable sight to the tourists. For example, Tago village is connected to Khulo district only by cable car (Georgian Travel Guide, n.d.) (Fig. 3).

Therefore, many different factors cause catastrophic events in the study area. Hence, the subject of our research is hydrological natural events in the Adjara region: floods and debris flow.

Data collection

Data were collected from the works and research of the Institute of Hydrometeorology. The material collected over the years formed the basis of numerous previous studies and articles. Data analysis was also done with the cooperation of the Environmental Protection Agency of Georgia. Important data are discussed in V. Tsomaia and S. Gorgijanidze's monograph on debris flow, where according to practical materials, expeditionary and annual studies, floods are determined throughout Georgia. which provides important information on the factors of occurrence of floods. Current flood information is available from a few information sources.

The facts

Figure 3. Tourist facility in the village of Tago (1000 m) (photo by G. Jincharadze)

As we mentioned above, Adjara is characterized by an abundance of atmospheric precipitation. Against the background of climate change, it is important to know the negative consequences caused by their frequency. The frequency of natural hydrological events also depends on them, which creates a lot of problems for the region. During heavy rains, coastal flooding is frequent, which actively damages the surrounding area. In addition, the infrastructure and tourist facilities located on the coast are damaged. The years 2002, 2005, 2007, 2012, 2022 and 2023 stand out, when storms and coastal flooding occurred several times during the year. The level of the Black Sea has risen significantly.

Figure 4. Batumi, New Boulevard. February 17, 2017. (YouTube, n.d.)

Adjara has risen by 22-25 cm during the last century, the result of which is that during the intrusion of the sea, the marine erosion has intensified along the coastline. And then brackish water causes bank erosion. If this includes agricultural fields and beaches, they are already severely eroded, easily flooded and destroyed by seawater. In addition, the power of storms is increased, seasonality also changes the characteristics of floods. Which is confirmed by many photo materials (Fig. 4).

The activation of landslides, which occurs almost every year, is also dangerous, as a result many residential buildings are damaged or destroyed, agricultural fields are damaged. Sometimes this process is accompanied by the blocking of riverbeds, which causes water stagnation. As a result, it is possible to breach a naturally dammed lake, which is accompanied by strong floods. A sharp increase in the level of the rivers in the entire valley is common, and the consequences of floods are always negatively reflected both in the mountainous Adjara and in the downstream of the rivers. Due to heavy rains, landslides often occur in valleys, and floods and debris flows occur on rivers. Such cases are frequent, for example, in 2005, the flood occurred on the Safristskali River, which damaged the surrounding road, destroyed bridges and disabled highways (Fig. 5). Such an event was repeated in 2021 and again damaged the surrounding areas and roads (Fig. 6).

Figure 5. River Safristskali valley 2005 (photo by S. Gorgijanidze)

In 2007, because of a landslide in the village of Feria, the river was blocked, but for a short time. Unfortunately, the necessary works were not carried out immediately and the breakthrough of the dammed water caused a flood. Houses and infrastructure in the river valley were damaged.

Also, in 2016, there was a flood on the Akavreti river, which completely washed away the infrastructure of the restaurant "David" in the village of Oktomberi. The raging river in the Uchambi administrative unit took away the Kvafti bridge and cut off four villages from the central road: Tsablana, Samoleti, Moprineti, Laklaketi. The water also washed away the iron bridges of Gomikri, Okhorti and Tsiskvilighele in the village of Kviriauli. In the village of Kviriauli, the homestead of 10 families located on the shore of Uchambistskali was flooded.

Figure 6. River Safristskali valley 2021, (https://geologymaps.ge)

A similar process took place in 1989 at river Skhalta. A flooded lake appeared. It was the result of blocking the valley by a landslide that came as a result of intense rains. (Fig. 7).

River On the left slope of Skhalta, the Salgoman mountain was hit by a landslide. The landslide came in two waves. During the first wave, the village of Tsablana, where 4 families lived, was completely buried. At the same time, the landslide engulfed the river Skhalta valley. It was followed by a second wave, during which the passengers who came to the rescue were killed. The second landslide further strengthened the submerged area of the river, buried the road that ran on the opposite slope. River above the dam. He buried the road that ran on the opposite (right) slope. The total volume of the crushed mass was 1.3 mln. m^3, the width along the river Skhalta - 450 m, the thickness to the crest of the dam is 45 m. Above the collapsed dam, the Skhalta River dammed up and a dammed up lake was formed. (Fig. 8) (Tsomaia et al., 2009).

Figure 7. Skhalta Dammed Lake and Skhalta River (1989 photo by V. Tsomaia)

If there was no place for its breakthrough and the related catastrophic flood, the channel was made. As a result, the flooded water went down, and a dangerous debris flow was avoided.

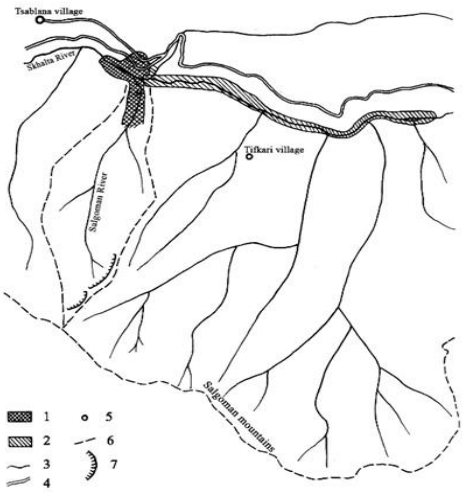

Figure 8. The rock-avalanched area of the Skhalta river and the flooded lake in the village of Tsablana (April 14, 1989). (1. A hollowed-out area; 2-a flooded lake; 3-a river; 4-a road; 5-a village; 6-a path; 7- rocky shores). (Tsomaia et al., 2009)

In the period of 2022 and 2023, such natural events took place several times, which caused significant damage to Batumi and its surroundings. The beginning of 2024 turned out to be tragic. On February 6, the avalanche took the life of one person who saved his family and could not get out of the avalanche cone himself. It is worth noting that during snowless winters, avalanches came here for years. Expedition groups are currently going to study avalanches with the participation of the author (Gorgijanidze et al., 2023a). The degree of avalanche hazard in Adjara is marked by particularly strong, less strong, medium and weak zones and the corresponding map is made. For 32 Avalanches of Khulo-Mlashe, Batumi-Akhaltsikhe Road, a schematic map of avalanche hazard, as well as for 161 avalanches of mountainous regions of Adjara and 32 avalanches, which converge on the automobile road, are

computed morphometric and dynamic Indicators. (Salukvadze, 2020, Gorgijanidze et al., 2023b) The given schematic map shows the places of active avalanches in Adjara. (Fig. 9).

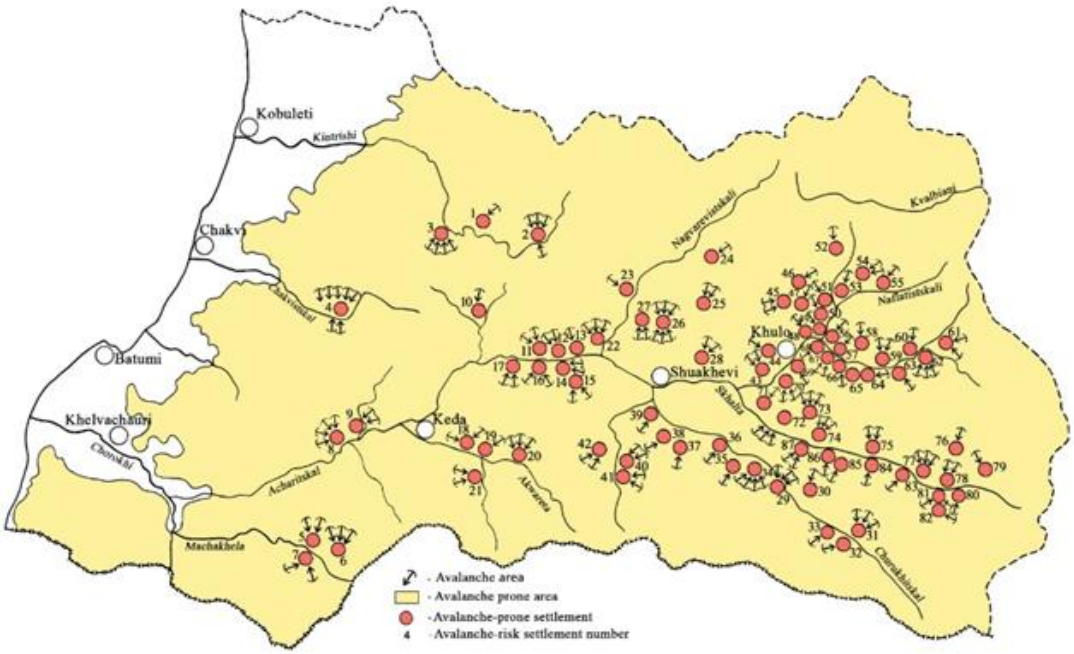

Figure 9. Avalanche settlements in the Adjara region (Salukvadze, 2020)

Methods

It should be noted that certain mechanisms and methodology have been developed by a group of authors, which consider the ways to prevent floods caused by the breakthrough of lakes dammed by river intrusion. It gives a certain forecast of what might happen to this or that blocked river. The methodology includes several stages.

1. First, the height of the impoundment dam (h) is measured, and the length (L) and width (B) of the embankment on the crest of the embankment dam are calculated for the height of the dam using a topographic map. Based on the received data, the volume of the impounded lake volume is determined (W) by the formula:

$$W = \frac{l \cdot B \cdot h}{k} \qquad (1)$$

where k is the coefficient to be calculated, it is considered equal to 3.

2. The expected length of flooding on the flooded area is determined, which begins with the overflow of water from the banks of the river;

3. The water consumption of the river and its tributaries above the catchment will be measured using known methods in hydrology. If we indicate the total water consumption of the river and its tributaries ΣQ, then the duration of filling the boiler (T) will be:

$$T = \frac{W}{\sum Q} \qquad (2)$$

In this case, T is calculated in seconds, then converted to minutes, hours or days in the usual way.

4. As a result of the mass of water accumulated in the boiler, the dam can be breached. During dam failure, a trapezoidal shaped riverbed (like the well-known sluice in hydrometry) is produced. Therefore, the maximum flow of water is calculated by the well-known formula in hydraulics:

$$Q_m = 1{,}9B \cdot h_1^{\frac{2}{3}} \quad (3)$$

5. The maximum flow of water in the downstream reaches of the river undergoes a transformation due to the expansion of its water. In this regard, the use of the isochronous theory describing the flow gives us better results, according to which:

$$Q_{mn} = \frac{1}{l + l_n} \cdot Q_m \quad (4)$$

where Q_m - is the maximum flow of flood water at the breakthrough location; (Tsomaia, 1985).

The maximum flow of water in the downstream reaches of the river transforms due to the expansion of its water. In this regard, the use of the isochronous theory describing the flow gives us a better result, according to which we will understand the magnitudes of the water expansion. These data provide the basis to further determine the duration of water filling of the dammed lake in the research areas and hydrographic parameters: maximum and average flood discharge, total duration, total volume of dammed water, and assessment of the stability of the dam. The main factor here is the water, which has a place to lie on the bottom of the mass that has been crushed as much as possible. (Tsomaia et al., 2009)

Results and Discussion

Methodology, statistical data and many theoretical materials reveal that the Adjara region is distinguished by its beauty and attractiveness, although it faces the threat of hydrological natural events almost every year. That is why this area is always being researched and studied, which allows to avoid these events. It should be noted that many prevention methods are improving at the modern stage. An early warning system has been developed which can completely or partially avert an impending threat to the region.

Avoiding floods is therefore one of the priorities in this region. In the conditions of abundant rainfall, the main thing is the correct management of the natural event, which will cause relatively less damage and, most importantly, will minimize casualties among the population. This is an important issue for the sustainable development of tourism in the Adjara region.

It should be noted here that in the background of climatic warming there are also objects that are threatened primarily by environmental degradation rather than natural hazards. Such are the lakes in the Ghorjomi valley formed by landslide blockage. Their breakthrough came with a small loss. Then 4 swampy lakes appeared in the area, three of which are on the way to swamps. However, this area is one of the attractive areas for tourists in mountainous Adjara. The existing lakes, which are hidden in the dense forest massifs, are the popular destinations for hikers. They are in danger of disappearing in the face of today's climate change, which is an ecological disaster.

Based on all the above, it is necessary and aimed to always observe hydrological natural events, which occur in the Adjara region almost every year. Knowledge of their mechanisms and statistical analysis of frequencies will allow us to properly manage catastrophic processes. Such a forecast will lead to positive results in the future depending on the seasons of the year. They carried out all the works that represent the riverbank stabilization, as well as the construction of protective dams, laying of canals and many other protective measures. This will avoid the casualties and losses in the region. Incorrect utilization of agricultural land, water erosion and other ecological problems should also be considered. Finally, it will have a positive impact on the sustainable development of tourism potential and tourism in the administrative unit of Adjara. This is most important for the economic stability of our country.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

All authors provided critical feedback and helped shape the research, analysis and manuscript.

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