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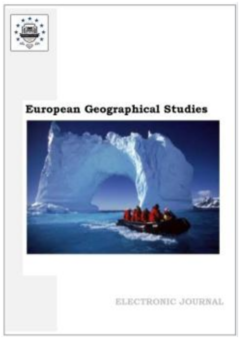

Articles

Dangerous Weather Phenomena in Tbilisi and Associated Climate Risks

Elizbar Sh. Elizbarashvili [a, *], Mariya E. Elizbarashvili [b], Shalva E. Elizbarashvili [a]

[a] Georgian Technical University, Institute of Hydrometeorology, Georgia
[b] Ivane Javakhishvili Tbilisi State University, Georgia

Abstract

The probabilities of the occurrence of individual hazardous weather phenomena and their complexes in the city of Tbilisi were studied: hot days, strong winds, heavy winds, fog, hail, blizzard. The most common of the phenomena under consideration are hot days. Even in spring and autumn their probability is quite high, and in summer it reaches 0.83. During the cold season, there is a high probability of fog. Strong winds occur at all times of the year. Their probability is not very high, but is characterized by a significant coefficient of aggressiveness. Hail is especially aggressive and occurs in the warm season. The likelihood of a snowstorm developing is negligible.

Possible social and economic risks associated with these phenomena have been identified. Both social and economic risks are greatest from fog and strong winds. In winter, the economic risk from fog per incident can be more than 3.6 million US dollars, in the fall - more than 2.3 million US dollars. The social risk from strong winds is greatest in spring, although the risk is also significant in other seasons. The economic risk from strong winds in spring exceeds $2.6 million, and in winter exceeds $2 million. These phenomena occur several times throughout the year, so the economic risk can range from several to tens of millions of US dollars per year.

Keywords: dangerous phenomenon, probability, vulnerability, social and economic risk.

1. Introduction

Tbilisi is the capital of Georgia, the most important industrial, social and cultural center of the Caucasus, occupying a strategic position at the crossroads between Europe and Asia, which gives it the status of an important transit center for transnational energy and trade projects. The city is located in the Tbilisi Basin, stretching in a narrow strip for almost 30 km in the valley of the Kura River and along the mountain slopes adjacent on three sides. The height above sea level ranges from 380-770 meters. The area of the city is 726 sq. km. The population is 1,154,314 people (estimated for 2020). The climate is humid subtropical, with long hot summers, short warm springs and mild, but relatively dry winters.

Further development of the city requires a comprehensive account of its climatic features, especially dangerous weather phenomena, which often caused significant material damage to the

* Corresponding author
E-mail addresses: eelizbar@hotmail.com (E.Sh. Elizbarashvili),
mariam.elizbarashvili@tsu.ge (M.E. Elizbarashvili), shalvaeliz@gmail.com (Sh.E. Elizbarashvili)

population (Elizbarashvili et al., 2013; Elizbarashvili et al., 2012; Elizbarashvili, Elizbarashvili, 2012; Varazanashvili et al., 2012). One of the authors of this article was an eyewitness to the catastrophic rainfall observed on June 7, 1972 in Tbilisi, when more than 100 mm of precipitation fell in a short period of time (245 minutes) (Elizbarashvili et al., 2020; Elizbarashvili et al., 2019). The downpour caused significant material damage to industrial enterprises, communications, transport, utilities and municipal services, the population of the city. More than 200 individual houses were destroyed, in which more than 1000 families lived, factories were stopped, there were human casualties. According to the catalog compiled by us at the Institute of Hydrometeorology of Georgia, material damage from strong winds on November 16-17, 1961 amounted to USD 2 million, and on March 4, 1973, damage from a hurricane wind in the Tbilisi-Bolnisi region amounted to USD 5 million. The intense heat and drought caused damage to the city of Tbilisi and its regions in April-May 1997, 20 million, in May 2000 – 150 million, and in June 2001 – 10 million US dollars, etc. To mitigate the expected negative consequences of hazardous phenomena and unfavorable weather conditions, the associated potential risks should be assessed and compared with the value of the permissible risk and then decisions on adaptation should be made (Kobysheva et al., 2015). This article presents the results of a study of the most typical hazardous weather phenomena and assesses the climatic risks they create in the city of Tbilisi, the most important industrial, social and cultural center of the Caucasus.

2. Materials and methods

Climate risk is a combination of the likelihood and consequences of a hazardous or adverse event occurring. Risk is defined as the product of the probability of a particular meteorological hazard by the conditional probability of the vulnerability of the recipient who may be exposed to this hazard (Kobysheva et al., 2015):

$$R = pU \qquad (1)$$

where: p is the probability of an event; U – the consequences of an event or the vulnerability of an object exposed to a hazardous phenomenon, which is determined by the formula:

$$U = (s / S) \cdot m \cdot t \cdot K \qquad (2)$$

s is the average area of influence of this phenomenon (sq. km),

S - the area of the administrative region (sq. Km),

m is the population of the administrative region (people),

t is the time of action of a dangerous meteorological phenomenon or unfavorable weather conditions (days);

K is the coefficient of aggressiveness of the phenomenon.

Vulnerability depends on the geography and the degree of development of the affected area. The more developed the economy, the more damage occurs when dangerous phenomena pass through it. Climate risk is usually called social risk, i.e. the risk of social damage to the territory under consideration, since it determines the size of the population affected by this phenomenon.

The general formula of social risk or the likelihood of injury to a particular recipient is as follows (Kobysheva et al., 2008; Kobysheva et al., 2015):

$$Rc = p\,(s / S) \cdot m \cdot t \cdot K \qquad (3)$$

The basis of the economic risk management mechanism is the definition of economic damage caused by a hazardous event. The cumulative damage in a given area is called economic risk. Economic risk is the product of the probability of a meteorological hazard by the amount of damage; expressed in monetary units (Kobysheva et al., 2008; Kobysheva et al., 2015):

$$Re = ARc \qquad (4)$$

where A is the share of gross domestic product per day per inhabitant of a given administrative region. The article discusses the weather phenomena that create emergency situations in the city:

- Hot days (SU25 when the maximum air temperature exceeds 25° C).
- Strong wind (W, when the wind speed is not less than 15m / s).
- Heavy precipitation (R30, when the daily precipitation is at least 30 mm).
- Fog (F).
- Hail (Ha).
- Blizzard (B).

The materials of observations of the Tbilisi Hydrometeorological Observatory for the period 1961–2020 were used. All calculations were performed in accordance with the methods developed under the guidance of Kobysheva (Kobysheva et al., 2008; Kobysheva et al., 2015). The aggressiveness coefficients of the phenomena are determined in accordance with (Kobysheva et al., 2015), and the areas of influence of this phenomenon are taken from our previous studies (Elizbarashvili et al., 2013; Elizbarashvili et al., 2012; Elizbarashvili, Elizbarashvili, 2012; Elizbarashvili et al., 2020; Varazanashvili et al., 2012). Since meteorological phenomena are seasonal in nature, the calculations were performed separately for each season. In a number of cases, in the conditions of Georgia, the recipient is often affected by a complex of hazardous processes or their combination, which creates a complex risk. According to the main provisions of the theory of probability, the probability of acomplex of independent events x and y can be calculated using the probability multiplicationtheorem (Elizbarashvili et al., 2020):

$$p(xy)=p(x)p(y), \tag{5}$$

where p (x) is the probability of an event x, p (y) is the probability of an event y.

3. Discussion

Table 1 shows the daily probabilities of some dangerous weather phenomena in Tbilisi and the corresponding aggressiveness coefficients.

Table 1. Daily probabilities of some dangerous weather phenomena and the aggressiveness coefficients of the phenomenon

Weather phenomenon	Season				K
	Winter	Spring	Summer	Autumn	
SU25	0	0.24	0.83	0.38	0.02
W	0.06	0.08	0.04	0.04	1
R30	0	0.02	0.02	0.01	0.03
F	0.22	0.02	0	0.13	0.5
Ha	0	0.01	0.01	0	3
B	0.002	0	0	0	0.08

It follows from Table 1 that hot days are the most common of the considered phenomena. Even in spring and autumn, their probability is quite high, and in summer it reaches 0.83. There is a high probability of fog during the cold season. Strong winds are recorded in all seasons. Their probability is not very high, however, it is characterized by a significant coefficient of aggressiveness. Hail is especially aggressive; it occurs during the warm season. The likelihood of a blizzard is insignificant.

Table 2 presents data on social and economic risks from hazardous weather phenomena, calculated according to formulas (3) and (4). When calculating the economic risk, the gross domestic product (GDP) was taken as USD 30 (in 2019 prices).

Table 2. Social (Rs people) and economic (Re US dollars in 2019 prices) risks from one phenomenon

Weather phenomenon	Season							
	Winter		Spring		Summer		Autumn	
	Rc	Re	Rc	Re	Rc	Re	Rc	Re
SU25	0	0	5347	160410	18492	554760	8466	253980
W	66840	2005200	89120	2673600	44560	1336800	44560	1336800
R30	0	0	668	20040	668	20040	334	10020
F	122540	3676200	11140	334200	0	0	77980	2339400
Ha	0	0	322	9660	322	9660	0	0
B	1.2	36	0	0	0	0	0	0

Social risk indicates the number of people affected at a certain level, it characterizes the severity of the consequences (catastrophic) of the implementation of hazards. Table 2 shows that the distribution of social risks is seasonal. Fog and strong winds pose the greatest risks to the city as a whole. In particular, the greatest risk from fog is expected mainly in the autumn-winter period, in spring it decreases, and in summer it is absent. The social risk from strong winds is greatest in spring, although the risk is also significant for other seasons. The economic risk is also greatest from fog and strong winds. For example, in winter, the economic risk from fog in one case can be more than $ 3.6 million, in autumn – more than $ 2.3 million. The economic risk from strong winds in spring exceeds $ 2.6 million and in winter exceeds $ 2 million. Figure 1 shows the daily probabilities of the joint realization of some dangerous meteorological phenomena in the city by the seasons of the year, calculated by the formula (5).

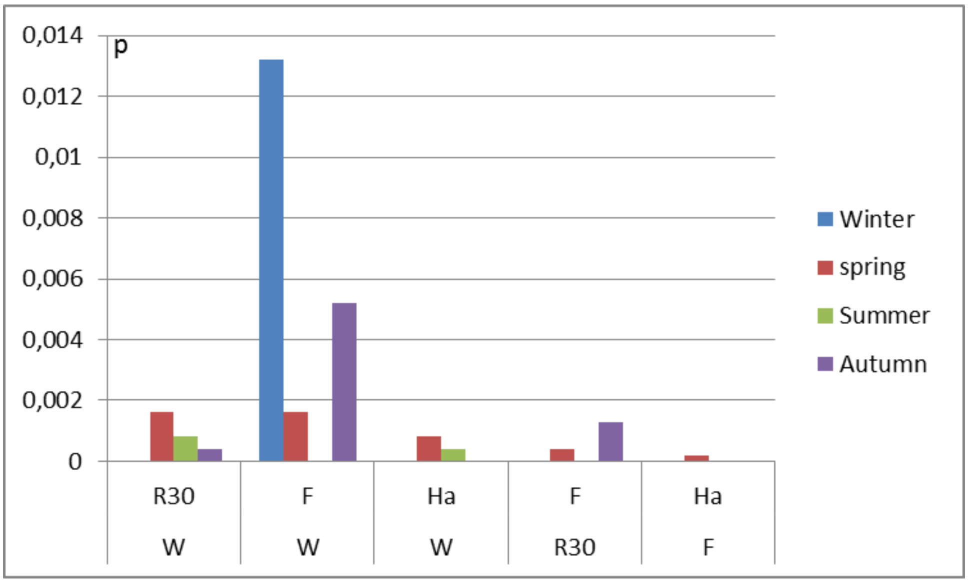

Fig. 1. Probability of joint realization of some dangerous weather phenomena

It follows from Figure 1 that the probability of joint realization of some dangerous weather phenomena is very low, however, a fog-strong wind (F-W) complex stands out, the probability of which significantly exceeds the probability of other complexes, especially in the autumn-winter season.

Accordingly, social and economic risks are significant in the implementation of this complex of phenomena, reaching more than 22 thousand people and about 700 thousand US dollars in winter, respectively (Table 3).

Table 3. Social (Rs people) and economic (Re US dollars in prices of 2019) risks from a complex of phenomena

Complex of weather phenomena	Season							
	Winter		Spring		Summer		Autumn	
	Rc	Re	Rc	Re	Rc	Re	Rc	Re
R30 - W	0	0	1840	55200	920	27600	460	13800
F - W	22770	683100	2760	82800	0	0	920	27600
Ha - W	0	0	3680	110400	1840	55200	0	0
F - R30	0	0	230	6900	0	0	805	24150
Ha - F	0	0	805	24150	0	0	0	0

From Table 3 it follows that certain risks are also created during the implementation of other complexes.

4. Conclusion

1. The most common of the phenomena considered are hot days. Even in spring and autumn their probability is quite high, and in summer it reaches 0.83. There is a high probability of fog during the cold season. Strong winds occur in all seasons. Their probability is not very high, but is characterized by a significant coefficient of aggressiveness. Hail is especially aggressive and occurs during the warm season. The likelihood of a snowstorm developing is insignificant.

2. The distribution of social risks is seasonal. The greatest risk for the city as a whole is fog and strong winds. In particular, the greatest risk from fog is expected mainly in the autumn-winter period; it decreases in the spring and is absent in the summer. The social risk from strong winds is greatest in the spring, although in other seasons the risk is also significant.

3. Economic risk is also greatest from fog and strong winds. For example, in winter the economic risk from fog per incident can be more than 3.6 million US dollars, in the fall - more than 2.3 million US dollars. The economic risk from strong winds in spring exceeds $2.6 million, and in winter exceeds $2 million.

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