



## Climatic risks created by dangerous weather phenomenon in Kvemo Kartli

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### ABSTRACT

Kvemo Kartli is directly adjacent to the capital of Georgia and supplies it with essential agricultural products. Hazardous weather conditions typical for the region negatively affect all sectors of the region's economy and the country as a whole. Therefore, to mitigate the expected negative consequences in the region, based on the observations of 8 meteorological stations, the probabilities of typical hazardous weather phenomena and the possible social and economic risks associated with these phenomena were studied with unfavorable weather conditions. It was found that for the region as a whole, the most significant social and economic risks are represented by fog and strong wind.

**Key words:** dangerous phenomenon, probability, vulnerability, social and economic risk.

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### Introduction

Today's global warming is accompanied by growing damage worldwide from hazardous weather and climate events. About 90% of the most severe economic losses are caused not by such natural phenomena as volcanic eruptions, tsunamis, and earthquakes but by hydrometeorological phenomena: floods, strong winds, torrential rains, hail, droughts [1,2]. Thus, we can talk about climatic risk if dangerous or unfavorable meteorological phenomena are observed in a given area and a particular object (risk recipient) is under their probable influence.

Hazardous phenomena are the leading cause of accidents and disasters associated with meteorological factors. In order to develop measures to neutralize and mitigate the action of

hazardous phenomena, it is necessary to quantify the possibility of their occurrence in different geographic conditions and the associated losses. That will make it possible to determine the risk, which quantitatively expresses the effect of a hazardous phenomenon in a probabilistic form [3].

This article presents the results of a study of some dangerous weather phenomena and assesses the climatic risks they create in the Kvemo Kartli region (Georgia). The study region was not chosen by chance; the capital of Georgia is directly adjacent to it from the north, which the region supplies with agricultural products. The administrative region includes 1 city of regional subordination and 6 municipalities. The region's population is multinational and amounts to 432,300 people, and its area is 6,528 sq. Km (Table 1).

**Table 1.** Area and population of municipalities

Municipality	square, km <sup>2</sup>	population grade 2018 people	Centre
Tsalka municipality	1051	19 302	Tsalka
Tetritskaro municipality	1174	21 889	Tetri-Tskaro
Ruštavi city	60	127 839	-
Marneuli municipality	935	106 454	Marneuli
Dmanisi municipality	1199	20 216	Dmanisi
Gardabani municipality	1304	81 280	Gardabani
Bolnisi municipality	804	55 284	Bolnisi
Total	6528	432 264	Ruštavi

Typical for the region, such dangerous weather conditions as fog, strong wind, hail, heavy rainfall, and snowstorms negatively affect all sectors of the region's economy, causing significant material damage and even human casualties. For example, according to official data, material damage from a strong wind observed on March 4, 1973 in the Tbilisi-Bolnisi region amounted to 5 million US dollars. A strong wind on October 26, 1962 caused damage to the Tetri-Tskaro district of \$ 400,000, and on January 24, 1963, Dmanisi district caused damage to \$ 200,000. On March 5, 1966, heavy fog caused US \$ 10,000 in damage to the region.

In order to mitigate the expected negative consequences of hazardous phenomena and unfavorable weather conditions, it is necessary to assess the associated potential risks, compare them with the value of the acceptable risk and then make decisions on adaptation [4].

## 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 specific meteorological hazard by the conditional probability of the vulnerability of the recipient who may be exposed to this hazard [4]:

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

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

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

**s** — average impact area of this phenomenon (sq. km),

**S** — administrative area (sq. km),

**m** — population of the administrative region (people),

**t** — time of action of a dangerous meteorological phenomenon or unfavorable weather conditions (day);

**K** — 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.

It is customary to call climatic risk social, 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 for social risk or the likelihood of injury for a particular recipient is as follows [4,5]:

$$Rc=p(s/S) (si/S) \cdot m \cdot t \cdot K \quad (3)$$

where **si** - recipient area, sq. km.

The basis of the economic risk management mechanism is determining the 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 [4,5]:

$$Re=ARc=p(s/S) (si/S) \cdot m \cdot t \cdot K \cdot A \quad (4)$$

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 emergencies in the region:

- Abundant precipitation (**R30**, when the daily precipitation is at least 30 mm).
- Hail (**Ha**).
- Fog (**F**).
- Strong wind (**W**, when the wind speed is not less than 15m / s).

• Blizzard (**B**).

The materials of observations of 8 meteorological stations in the region were used (Table 2).

Table 2. *Used material*

Station	Height above sea level m	Used material, yy
Tsalka	1457	1961-2019
Tetri-Tskaro	1140	1961-2006
<b>Bolnisi</b>	534	1961-2019
<b>Gardabani</b>	300	1961-2006
<b>Dmanisi</b>	1256	1961-2006
<b>Marneuli</b>	432	1961-2019
<b>Manglisi</b> (Tetrtskaro municipality)	1191	1961-2006
<b>Rustavi</b>	374	1961-2015

To restore the available individual missing data in the observation series, we used the approach we repeatedly tested [6]: correlation matrices were compiled for all stations and, based on their statistical analysis, and taking into account the physical and geographical conditions of the station location, groups of highly correlated stations were identified, which for the studied phenomenon were significant at the level of 95% or more. Further, the missing data was determined by applying the

method of corresponding relations.

All calculations were performed following the methods developed under the guidance of NV Kobysheva [4,5]. The aggressiveness coefficients of the phenomena are taken in accordance with [4], and the areas of influence of this phenomenon are taken from our previous studies [7-12] (table 3). Since meteorological phenomena are seasonal, the calculations were performed separately for each season.

**Table 3.** *The coefficient of aggressiveness (K) and the average area of influence (s) of the phenomenon*

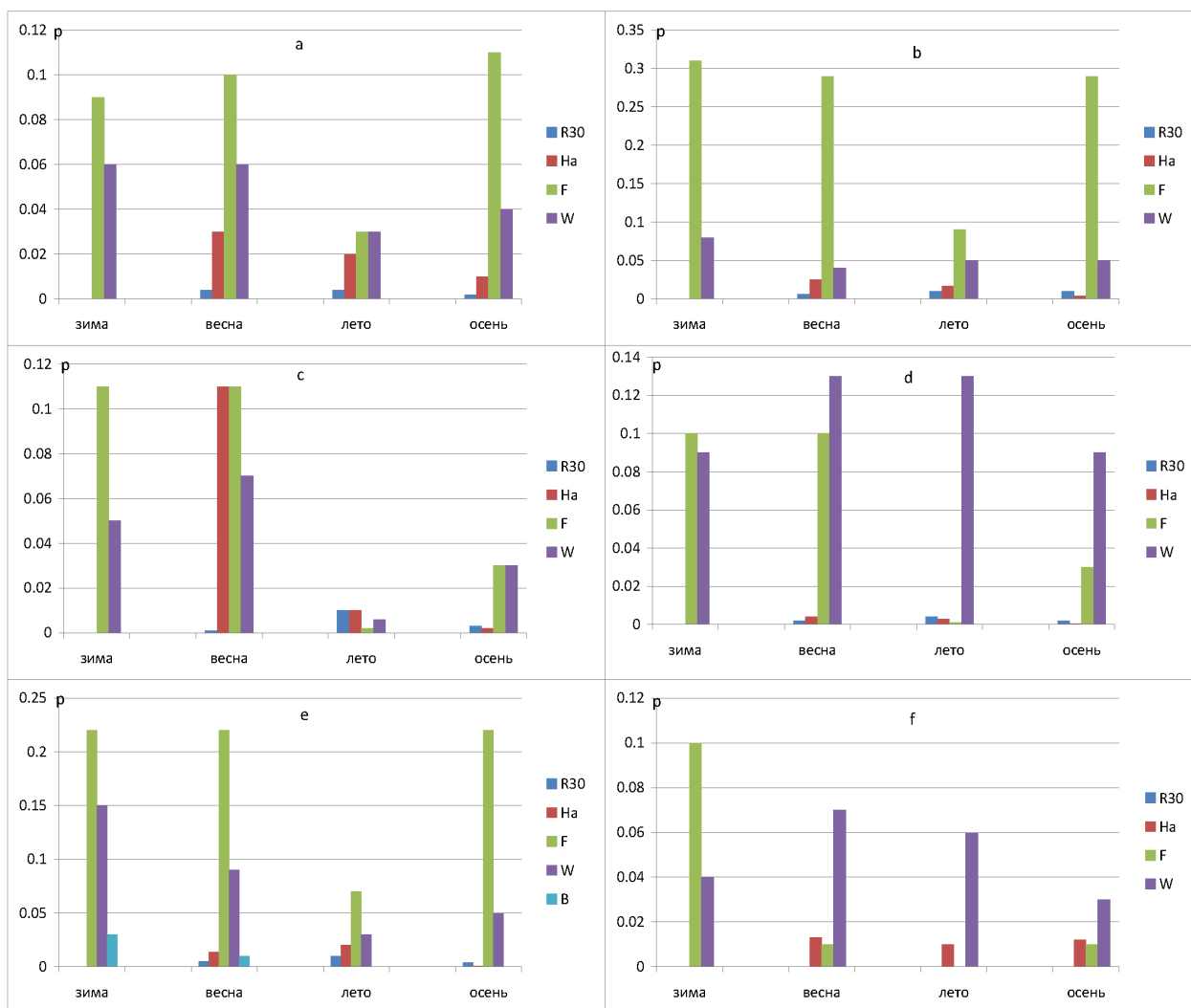
Characteristic	Meteorological phenomenon				
	<b>R30</b>	<b>Ha</b>	<b>F</b>	<b>W</b>	<b>B</b>
K	0.03	3	0.5	1.0	0.8
s sq. km	3000	7	6000	4000	5

**The discussion of the results**

Figure 1 shows the daily probabilities of some dangerous meteorological phenomena in individual municipalities of the region by seasons.

It follows from Fig. 1 that fog is the most frequent of the considered phenomena in the region. It is observed in all areas in all seasons,

relatively rare in summer. The probability of fog in Tetri Tskaro is about 0.3; in Dmanisi, it exceeds 0.2, and in the rest of the region, it exceeds 0.1. Strong winds are also often noted, especially in Gardabani and Dmanisi, and hail is most dangerous in Bolnisi, where its probability in spring exceeds 0.1, i.e., drops out every 10 days. Blizzards are observed in Dmanisi in almost all seasons. Heavy rainfall is rare.



**Fig. 1** Probability of some dangerous meteorological phenomena by municipalities: a-Tsalka, b-Tetri-Tskaroi, c-Bolnisi, d-Gardaban, e-Dmanisi, f-Marneuli

Table 4 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 assumed to be \$ 26 (in 2015 prices).

**Table 4.** Social (*Rs people*) and economic (*Re US dollars in 2015 prices*) risks from one phenomenon by municipalities of the region

Administrative region	Phenomenon	Season							
		Winter		spring		Summer		Autumn	
		Rc	Re	Rc	Re	Rc	Re	Rc	Re
Tsalka	<b>R30</b>	0	0	4	104	4	104	2	52
	<b>Ha</b>	0	0	6	156	4	104	2	52
	<b>F</b>	2881	74906	3201	83226	960	24960	3521	91546
	<b>W</b>	2547	66222	2547	66222	1273	33098	1998	51948

Tetri-Tskaroiskiy	<b>R30</b>	1	26	6	156	11	286	11	286
	<b>Ha</b>	0	0	6	156	4	104	1	26
	<b>F</b>	11086	288236	10371	269646	3218	83668	10371	269646
	<b>W</b>	3794	98644	1897	49322	2371	61646	2371	61646
Bolnisi	<b>R30</b>	0	0	1	26 52	7	182	2	52
	<b>Ha</b>	0	0	2	70018	2	52	1	26
	<b>F</b>	2693	70018	2693		49	1274	735	19110
	<b>W</b>	1623	42198	2272	59072	194	5044	974	25324
Gardabani (including the city of Rustavi)	<b>R30</b>	0	0	2	52	5	130	2	52
	<b>Ha</b>	0	0	1	26	1	26	1	26
	<b>F</b>	3972	103272	3972	103272	40	1040	1191	30966
	<b>W</b>	4740	123240	6847	178022	6847	178022	4740	123240
Dmanisky	<b>R30</b>	0	0	6	156	12	312	5	130
	<b>Ha</b>	0	0	4	104	5	130	1	26
	<b>F</b>	8035	208910	8035	208910	2556	66456	8035	208910
	<b>W</b>	725	18850	4359	113334	1453	37778	2421	62946
	<b>B</b>	2	52	1	26	0	0	0	0
Marneulsky	<b>R30</b>	0	0	2	52	6	130	2	52
	<b>Ha</b>	0	0	2	52	2	52	2	52
	<b>F</b>	2848	74048	285	7410	0	0	285	7410
	<b>W</b>	1510	39260	2644	68744	2266	58916	1133	29458

Social risk indicates the number of people affected at a certain level, and it characterizes the severity of the consequences (catastrophic) of the implementation of hazards.

It follows from Table 4 that fog and strong winds pose the most significant risk for the region as a whole. In terms of the impact of these phenomena, the Tetri-Tskaro and Dmanisi districts are the most sensitive. In the latter area, a blizzard also poses a risk. In addition, it follows from Table 4 that the distribution of social risks is seasonal. In particular, the greatest risk from fog is expected mainly in the autumn-winter or spring period; in summer, it decreases slightly or is absent altogether. Depending on the physical and geographical conditions, the social risk from strong wind is most remarkable in winter or spring.

The economic risk is also most significant from fog and strong winds. For example, in the Tetri-Tskaro region in winter, the economic risk from the fog in one case may amount to more than 288 thousand US dollars. The economic risk from strong winds in the Dmanisi region exceeds USD 208 thousand, and in the Gardabani region, it exceeds USD 178 thousand. These phenomena are observed in the region several times during the year, so the economic risk can range from several to tens of millions of US dollars per year.

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