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Method of analysis and forecast of the risk of threats to the area of the Pomeranian Voivodeship resulting from climate change

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ABSTRACT

The issue of climate change is one of the key political, social and economic aspects of the modern world. Many theories, controversies and misunderstandings have arisen around this problem, which gave the impression that this is irrelevant from the economic and social points of view. However, a number of worrying climatic phenomena indicate that this issue cannot be underestimated. In particular, it is difficult to argue with the events that are already taking place and indicate that the current climate change may pose a threat to both human health and life, as well as the functioning of the economy, or the environment itself. The obstacles and dynamic nature of climate change require crisis management structures to carry out in-depth risk analyses. The article is a proposal and introduction to the subject of risk analysis at the county level, taking into account the sensitivity and adaptive potential of the presented region.

KEYWORDS

extreme events, extreme weather events, logistics, crisis management

Introduction

Climate change has become one of the most pressing global challenges of our time, affecting ecosystems, economies, and communities worldwide. The Intergovernmental Panel on Climate Change (IPCC) has highlighted the urgency of addressing climate change impacts through mitigation and adaptation strategies in their latest report (Intergovernmental Panel on Climate Change, 2021). Recent studies have shown that the frequency and intensity of extreme weather events, such as heatwaves, storms, and floods, have increased as a direct consequence of global warming (Seneviratne, Zhang, 2021). These phenomena pose significant threats to public safety, infrastructure, and biodiversity, particularly in vulnerable regions, such as the Pomeranian Voivodeship in Poland. It is characterised by its diverse geography, including coastal areas, urban centres, and rural landscapes, each uniquely susceptible to the impacts of climate change. Rising sea levels and coastal erosion threaten the region's coastal zones, while increased precipitation and storm intensity pose risks to urban infrastructure (United Nations Office for Disaster Risk Reduction, 2020). Moreover, changes in temperature and precipitation patterns are impacting agriculture and water resources, challenging local communities and economies. Addressing these difficulties requires comprehensive risk assessment and management strategies that account for the region's adaptive capacity and vulnerabilities. This paper aims to explore innovative methods of analysing and forecasting climate-related risks at the county level, providing insights into potential adaptation strategies. By integrating the latest scientific research and regional data, this study seeks to enhance the resilience of the Pomeranian Voivodeship to the multifaceted impacts of climate change.

1. Scope and nature of threats to public security of the Pomeranian Voivodeship resulting from climate change

Climate is commonly understood as a set of multivariate features of interactions in a system that includes the atmosphere, hydrosphere, and land surface. Its characteristics in a given area are determined on the basis of long-term observations of various averaged (variable) components, most often temperature, precipitation and wind, on a monthly, annual or long-term basis (e.g. 30 years) (Stefan et al., 1996). Climate is therefore determined on the basis of long-term weather statistics for a given region, and its variability depends on three basic processes: heat circulation, water

circulation, and air circulation. In the geographical domain, apart from separate processes, the climate is also influenced by the system of land and oceans and altitude (Lindzen, 1994).

The climate changes observed for several decades manifest themselves as an element affecting interrelated systems (hydrosphere, biosphere or anthroposphere), leading to the effects observed today – global temperature increases, precipitation extremes, changes in turbidity and pressure systems. Negative effects of climate change are also reported in Central and Eastern Europe, which are particularly visible in relation to observations from the mid-twentieth century (Wheeler, von Braun, 2013).

The location and relief of Poland are important in shaping the weather, including the extreme weather phenomena that are particularly dangerous for cities. The belt layout of the main regions promotes free zonal circulation, which is why abrasions of oceanic and continental air masses are often observed over the territory of our country. The southern part of the country is characterised by a varied, local landscape that shapes the weather conditions; the northern part of Poland is a coastal zone, where the impact of the Baltic Sea is also visible. This means that there are significant weather differences all over Poland.

A Report of the United Nations Intergovernmental Panel on Climate Change states that in the twenty-first century, every year since 2001 has been one of the warmest years globally since 1880. In Poland, also in this period, high average annual air temperature values exceeding 9°C were recorded (2016 – 9.2°C, 2015 – 9.6°C, 2014 – 9.7°C).

The average annual area air temperature in the years 1951-2016 for Poland was 8.1°C (excluding mountain areas). Based on the analysis of air temperature trends since 1951, it can be indicated that only a slight cooling occurred in the 1960s and '70s, while the upward trend in the observed temperature has been maintained since the late '70s (Wypych et al., 2018).

The most common threats in Polish cities include heat, frost, intense rainfall and storms, urban floods, floods, sea floods, landslides, drought, gales, and sea level rise. Heat waves, i.e. periods of at least three days with a maximum temperature above 30°C, most often occur in western and central Poland and least often in the coastal region. Sequences of such days appeared as early as in the 1990s. Between 2000-2020 such phenomena were not recorded. The longest string of hot days, spanning 17 days, occurred in 1994 (Kundzewicz, Matczak, 2012; Coumou, Rahmstorf, 2012).

Precipitation is characterised by great variation in time and space. The average annual rainfall recorded in Poland from 1951 to 2020 was

633 mm. The lowest values are found in central Poland, in central Poland's lowlands, and in Polesie (548 mm). There was a change in the structure of the precipitation of the summer season, consisting of a significant increase in the number of days with intense daily precipitation of >30 mm and >50 mm, significantly in the southern part of the country. The frequency of days featuring precipitation of ≥30 mm has been increasing outside the coast and north by the non-Eastern border regions of Poland by more than three days per decade, and by ≥50 mm in southern Poland (mainly in the Beskidy region), central Poland and in northern parts of the country by two days per decade (Kubiak-Wójcicka, Machula, 2020).

Modern thermal and precipitation conditions in Poland cause changes in the water balance. Potential and actual evaporation increases, and consequently water resources shrink. The main causes are shorter retention of snow cover and its reduced thickness. The degree of soil moisture at the beginning of the growing season also decreases, which poses a threat because Polish water resources are not sizable (Sójka et al., 2020).

The observed increase in the average annual air temperature is conducive to increasing the intensity and frequency of weather phenomena, which are largely unfavourable for humans and the environment. Sometimes they reach an extreme dimension. It should be expected that as warming progresses, extreme phenomena such as heat waves, frost waves, intense rainfall, floods, and gales – which are sudden phenomena of high intensity and bring financial losses and even fatalities – will increase in the future. Long-term phenomena such as drought, shrinking water resources, and soil and coastal erosion will also increase. Sea levels will also rise.

In Poland, one can expect an intensification of floods in both lowland and mountain river basins, as well as long-term droughts associated with water shortages. Among the thermal phenomena that are unfavourable and burdensome for the environment and society, one should point out the appearance of severe heat waves, especially since the 1990s.

Destructive winds taking the form of cyclones, in which the wind speed periodically exceeds 30-35 m/s, have been recorded more than 15 times in our country since 2005. The regions most exposed to such wind speeds are the central and eastern parts of the Słowiński Coast from Koszalin to Rozewie and Hel, and a wide, latitudinal belt in the north to the Suwałki region, the Silesian Beskids region, the Żywiec Beskids, the Silesian Foothills and Podhale, and the Dynowski Foothills, as well as the central part of Poland, including Mazovia and the eastern part of Wielkopolska (Zeidler, 1997).

Winds in the form of tornadoes occur in the area of the Małopolska and Lublin highlands, reaching a wide belt in the South-West and North-East regions through the area of the Kutno Plain and Mazovia, to Podlasie and the Masurian Lake District. Between 1979 and 2017, they appeared 173 times. The effects of climate change are particularly visible in urban areas, where the nature and intensity of buildings increase climate risks or cause new phenomena that are specific to cities. In all cities, the urban heat island phenomenon is observed. It consists of a significant increase in temperature in the city in relation to the surrounding peripheral areas. This is due to many factors, but one of the most important are the properties of the materials covering the ground, which absorb more sunlight than they reflect, as well as the small share of biologically active surface. In the case of large cities, the intensity of the phenomenon may adversely affect the thermal comfort of residents.

Air circulation also depends on the buildings in the city. Maintaining the right proportions between built-up areas and urban green areas promotes thermal contrasts that cause local air circulation, which contributes to mitigating the effects of heat and reduces the concentration of air pollutants. In cities, however, there are disturbances in air circulation, which are conducive to the persistence of pollution in it, and in special weather conditions also the formation of smog (Masson et al., 2020).

2. Risk of threat to the Pomeranian Voivodeship resulting from climate change

The presented proposal to use hazard risk analysis is a comprehensive approach that also takes into account the adaptation potential of a given county.

The following are presented in: Table 1 – Analysis of risk, effects and level of threat as a result of the occurrence of selected negative phenomena in the conditions of climate change, Table 2 – Correlation of the analysis of risk, effects and level of threat as a result of the occurrence of selected negative phenomena in the conditions of climate change, Table 3 – Analysis of risk of threats to areas/areas sensitive to climate change, and Table 4 – Forecast of sensitivity of individual counties to climate change. Only the comparison of this data will make it possible to objectively identify the level of risk in the Pomeranian Voivodeship region resulting from climate change.

Table 1. Analysis of risk, effects and level of threat as a result of the occurrence of selected negative phenomena in the conditions of climate change

Negative phenomena	Possibilities of occurrence of the phenomenon			Scope and nature of the effects			Overall level of harmfulness		
	H	M	L	H	M	L	H	M	L
Fires	X	–	–	–	X	–	5	–	–
Flood	X	–	–	X	–	–	–	3	–
High temperatures	X	–	–	X	–	–	6	–	–
Low temperatures	–	X	–	–	X	–	–	–	2
Spring frosts	–	X	–	–	X	–	–	–	2
Heavy rainfall	X	–	–	X	–	–	5	–	–
Heavy snowfall	–	X	–	–	–	X	–	–	2
Intense storms	X	–	–	X	–	–	6	–	–
Strong winds	X	–	–	X	–	–	6	–	–
Prolonged droughts	X	–	–	X	–	–	5	–	–
Pest infestation	–	X	–	–	X	–	–	4	–
Restrictions in the supply of electricity	–	X	–	–	X	–	–	4	–
Water supply restrictions	–	X	–	–	X	–	–	3	–
Disruption of the food supply system	–	X	–	–	X	–	–	3	–
Destruction of crops	X	–	–	X	–	–	5	–	–
Large-scale environmental degradation/destruction	X	–	–	–	–	X	6	–	2
Epidemics	X	–	–	X	–	–	5	–	–
Epizootics	X	–	–	–	X	–	–	4	–
Epiphytotic	X	–	–	–	X	–	–	4	–
Industrial disasters	–	X	–	–	X	–	–	4	–

Abbreviations used: H – high level, M – medium level, L – low level.
In assessing the overall risk level, the following methodology was adopted:
1) to assess the possibilities and the extent and nature of the effects of negative phenomena, the following values were assigned: 3 – high; 2 – medium; 1 – low. Maximum number of points – 6 (2 indicators · max. 3 points);
2) for individual assessments of the overall threat level, the following criteria were adopted: high – 5-6 points; medium – 3-4 points; low – 1-2 points.

Source: own elaboration based on expert assessments.

An assessment of the possibilities and scope and nature of the effects of negative phenomena was performed based on data from Table 1, under the conditions of climate change of the above opinions. The highest values obtained by the following threats to security in the Pomeranian Voivodeship, which are confirmed by the analysis of source documents presented in the work, are as follows:

- droughts and fires resulting from rising temperatures;
- freezing of crops as a result of cold waves in the form of late frosts;
- destruction of building infrastructure through an increase in the frequency of cyclones;
- difficult access to drinking water as a result of floods caused by violent rainfall;
- local, sudden urban floods.

Warmer winters come at a significant cost, and these costs will increase as this season becomes even warmer in the coming decades. Mild winter temperatures can affect the deterioration of crops as a result of an increase in the number of pests. In addition, they contribute to droughts through disruptions to water supplies in places that are dependent on the slow melting of snow cover.

Flooding is more likely due to more extreme weather patterns caused by long-term global climate change. Extreme flooding can be triggered by heavy rainfall and its longer duration. Thus, climate change correlates with severity, and periods of drought will alternate with flooding. This situation is dangerous, in particular for the Tri-City region (Gdynia, Sopot and Gdańsk), district cities and the entire Pomeranian Voivodeship, whose sewage systems are not adapted to receive water from rapid rainfall.

Flooding may occur throughout the entire Pomeranian Voivodeship, although low-lying areas with poor drainage are particularly vulnerable. Flooding in the form of 'urban flooding', which threatens the local ability to drain rainwater from the densely populated area of the Tri-City, should be considered particularly threatening. This happens when runoff rain is diverted from roads, parking lots, buildings and other impermeable surfaces to storm sewers. Floods will continue to be concentrated in floodplain, low-lying (coastal regions) and highly urbanised areas of the Pomeranian Voivodeship. As global warming increases the likelihood of more extreme weather events, the risk will expand beyond the currently known high-risk areas. More extreme floods should be expected for cities and towns of the Pomeranian Voivodeship.

Table 2. Correlation of the analysis of risk, effects and level of threat as a result of the occurrence of selected negative phenomena in the conditions of climate change

Negative phenomena	Level of risk of threats for particular areas/domains																													
	Water management			Environment			Forestry			Energy			Coastal zone			Agriculture			Transport			Spatial management			Construction			Health		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Fires	–	–	X	X	–	–	X	–	–	X	–	–	–	X	–	X	–	–	–	X	–	X	–	–	X	–	–	X	–	–
Flood	X	–	X	X	–	–	–	X	–	X	–	–	X	–	–	–	X	–	–	X	–	X	–	–	X	–	–	X	–	–
High temperatures	–	X	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–
Low temperatures	–	X	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–	–	X	–	–	X	–	–	X	–	–	X	–
Spring frosts	–	X	–	–	X	–	–	X	–	–	X	–	–	–	–	X	–	–	–	–	X	–	–	X	–	–	X	–	X	–
Heavy rainfall	X	–	–	X	–	–	X	–	–	–	X	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–
Heavy snowfall	X	–	–	–	X	–	–	X	–	X	–	–	–	X	–	–	X	–	–	X	–	X	–	–	X	–	–	–	X	–
Intense storms	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–
Strong winds	–	X	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–	X	–	–
Prolonged droughts	–	–	–	X	–	–	X	–	–	–	–	X	X	–	–	X	–	–	–	–	X	X	–	–	X	–	–	–	X	–
Pest infestation	–	–	–	–	X	–	X	–	–	–	–	X	–	X	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–
Restrictions in the supply of electricity	–	X	–	–	X	–	–	–	X	X	–	–	–	X	–	–	–	X	–	–	X	–	X	–	–	X	–	–	X	–

Negative phenomena	Level of risk of threats for particular areas/domains																														
	Water management			Environment			Forestry			Energy			Coastal zone			Agriculture			Transport			Spatial management			Construction			Health		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Water supply restrictions	X	–	–	X	–	–	X	–	–	–	X	–	–	X	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–
Disruption of the food supply system	–	X	–	–	X	–	–	–	X	–	X	–	–	X	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–
Destruction of crops	X	–	–	X	–	–	X	–	–	–	–	X	–	X	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–
Large-scale environmental degradation/destruction	–	X	–	X	–	–	X	–	–	–	–	X	–	X	–	–	X	–	–	–	X	–	X	–	–	X	–	–	X	–
Epidemics	–	X	–	X	–	–	–	–	X	–	–	X	–	X	–	–	X	–	X	–	–	–	X	–	–	X	–	X	–	–
Epizootics	–	X	–	X	–	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–	–	X	–	–	X	–	X	–	–
Epiphytotic	–	X	–	X	–	–	X	–	–	–	–	X	–	X	–	–	X	–	X	–	–	–	X	–	–	X	–	X	–	–
Industrial disasters	–	X	–	–	X	–	–	–	X	X	–	–	–	X	–	–	–	X	–	X	–	–	X	–	–	X	–	–	X	–

Abbreviations used: H – high level, M – medium level, L – low level.

Source: own elaboration based on expert assessments.

Both public administration units and the community of the Pomeranian Voivodeship must be prepared to face more extreme weather events, as the climate is changing at an accelerating pace. Climate science must be taken into account when building, adapting and protecting our homes and local water resources, for example by building drainage systems and storing water in home tanks. This type of rainwater reserves can be used during periods of drought. Nature-based climate solutions, such as reforestation and land reclamation, should be considered, as they can both reduce the impact of extreme weather events and absorb CO_2.

The compiled table below shows the correlation of the analysis of risk, effects and level of threat as a result of the occurrence of selected negative phenomena in the conditions of climate change, according to experts' opinions, taking into account the criteria of the possibility of occurrence of selected negative phenomena, via its included catalogue of threats listed in crisis management plans.

As can be seen from the above analysis of source materials, it is indicated that the most sensitive areas to climate change in the Pomeranian Voivodeship are:

– public health;
– water management;
– transport;
– biodiversity.

At a high level, the risks from climate change in the public health sector are primarily related to the occurrence of extremely low or high air temperatures and precipitation. On the other hand, the source documents do not record threats resulting from the increase in the incidence of new diseases carried by distinct species not yet occurring in the Pomeranian Voivodeship, and whose invasiveness is increasing, which concerns, for example, a new species of tick that causes haemorrhagic fever.

In the transport sector, the rail subsystem, the road subsystem and urban public transport are at high risk and refer to climatic phenomena associated with the occurrence of local flooding (urban flooding), as well as an increase in air temperature and strong winds.

In the water management sector, the high-level risk concerns periods without rainfall in combination with high temperatures. This refers to water supply subsystems. At the same time, there is no plan that takes into account the risk of water contamination as a result of flash urban flooding, which may cause backflow of contaminated water.

Undoubtedly, the sensitivity to climate change index is important from the point of view of risk assessment. For this purpose, in Table 3, an assessment was performed that was divided into counties in the Pomeranian Voivodeship.

By analysing Table 3, it is clear in which sectors the sensitivity is the highest. In addition, the table made it possible to isolate which county is most vulnerable to the effects of climate change. The overall level of sensitivity of the county to climate change to a high degree is 4 counties, which is 20% of the entire voivodeship. The situation is worrying because as many as 15 counties, which constitute 75%, are in medium danger with a growing tendency close to the high level.

Thanks to a thorough risk analysis, it became possible to prepare a forecast of the potential adaptation of counties to climate change.

The forecast shown in Table 4 indicates the adaptability of individual counties to climate change. The review clearly shows that only 15% of counties have high-level capacity. On the other hand, as many as 14 counties, which accounts for 65% of them, are at a medium level with a tendency towards low potential. It is worrying that 4 counties, constituting 20%, have a potential rated at a low level.

Summary

The effects of climate change, in particular the increase in temperature, frequency and severity of extreme events, have been worsening over the last few decades and have therefore become a concern for governments and the international community. On 1 April 2009, the European Commission published a white paper titled Adapting to climate change: A European framework for action (European Commission, 2009) which defined the scope of European Union action, including the preparation of the Union's strategy on adaptation to climate change, which was finally published by the Commission in April 2013 (European Commission, 2013). The white paper is strategic in nature and guides the preparation for a more effective response to the impacts of climate change at the level of the European Union and Member States that have developed their national strategies. Among others, in Poland, a document titled the Polish National Strategy for Adaptation to Climate Change by 2020 with the perspective by 2030 (Ministerstwo Środowiska, 2013) was developed and approve for implementation in 2013 under the aegis of the Polish Ministry of the Environment.

Table 3. Analysis of risk of threats to areas/areas sensitive to climate change

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	**Level of sensitivity**	**Bytów**	**Chojnicki**	**Człuchowski**	**Gdańsk**	**Kartuzy**	**Kościerski**	**Kwidzyń**	**Lębork**	**Malbork**	**Nowodworski**	**Puck**	**Słupsk**	**Starogard**	**Sztum**	**Tczewski**	**Wejherowski**	**Gdańsk**	**Gdynia**	**Słupsk**	**Spot**	**L**	**%**
Water management	high	–	–	–	3	–	–	–	–	–	–	3	–	–	–	–	–	3	3	–	3	**15**	**25**
	medium	2	–	–	–	–	–	2	–	2	2	–	2	2	2	2	2	–	–	2	–	**20**	**50**
	low	–	1	1	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	**5**	**25**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Environment	high	–	–	–	3	–	–	–	–	–	–	3	–	–	–	–	–	3	3	–	3	**15**	**25**
	medium	2	2	2	–	–	–	2	–	2	2	–	2	2	2	2	2	–	–	2	–	**24**	**60**
	low	–	–	–	–	1	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	**3**	**15**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Forestry	high	3	–	–	–	3	3	3	–	–	–	–	–	–	–	–	–	–	–	–	–	**12**	**20**
	medium	–	2	2	–	–	–	–	2	2	–	–	2	–	–	–	–	–	–	–	–	**10**	**25**
	low	–	–	–	1	–	–	–	–	–	1	1	–	1	1	1	1	1	1	1	1	**11**	**55**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Energy	high	–	–	–	3	–	–	–	–	–	–	–	3	–	–	–	–	3	3	3	3	**18**	**30**
	medium	2	2	2	–	2	2	2	2	2	2	2	–	2	2	2	2	–	–	–	–	**28**	**70**
	low	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	Level of sensitivity	Bytów	Chojnicki	Człuchowski	Gdańsk	Kartuzy	Kościerski	Kwidzyń	Lębork	Malbork	Nowodworski	Puck	Słupsk	Starogard	Sztum	Tczewski	Wejherowski	Gdańsk	Gdynia	Słupsk	Spot	L	%
Coastal zone	high	–	–	–	3	–	–	–	–	–	–	3	–	–	–	–	–	3	3	–	3	**15**	**25**
	medium	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	low	–	–	–	–	–	1	–	1	–	1	–	1	1	–	–	–	–	–	1	–	**6**	**30**
	none	0	0	0	–	0	–	0	–	0	–	–	–	–	0	0	0	–	–	–	–	**9**	**45**
Agriculture	high	3	3	3	–	–	–	–	–	–	–	–	–	–	3	3	–	–	–	–	–	**15**	**25**
	medium	–	–	–	–	–	2	2	2	2	2	2	2	2	–	–	2	–	–	–	–	**18**	**45**
	low	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	1	1	1	1	**6**	**30**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Transport	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	3	–	3	**9**	**15**
	medium	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	–	–	2	–	**34**	**85**
	low	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Spatial management	high	–	–	–	3	–	–	–	–	–	3	3	–	–	–	–	–	3	3	–	3	**18**	**30**
	medium	2	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2	–	**6**	**15**
	low	–	1	1	–	1	1	–	1	1	–	–	1	1	1	1	1	–	–	–	–	**11**	**55**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	**Level of sensitivity**	**Bytów**	**Chojnicki**	**Człuchowski**	**Gdańsk**	**Kartuzy**	**Kościerski**	**Kwidzyń**	**Lębork**	**Malbork**	**Nowodworski**	**Puck**	**Słupsk**	**Starogard**	**Sztum**	**Tczewski**	**Wejherowski**	**Gdańsk**	**Gdynia**	**Słupsk**	**Spot**	**L**	**%**
Construction	high	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	3	3	3	3	**15**	**25**
	medium	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	**2**	**5**
	low	1	1	1	1	1	1	1	1	1	–	–	1	1	1	1	1	–	–	–	–	**14**	**70**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Health	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	3	3	3	3	**15**	**25**
	medium	–	–	–	2	–	–	–	2	2	2	2	2	2	2	2	–	–	–	–	–	**18**	**45**
	low	1	1	1	–	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	**6**	**30**
	none	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Overall level of sensitivity of the county to climate change	**high**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**24**	**–**	**–**	**–**	**–**	**–**	**26**	**26**	**–**	**26**	**4**	**20**
	medium	**18**	**15**	**15**	**22**	**–**	**16**	**17**	**15**	**16**	**19**	**–**	**18**	**16**	**16**	**16**	**16**	**–**	**–**	**20**	**–**	**15**	**75**
	low	**–**	**–**	**–**	**–**	**13**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**1**	**5**
	very low	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**0**	**0**

To assess the overall level of sensitivity of the county to climate change, the following methodology was adopted:

1) to assess the level of sensitivity of a particular area to climate change, the following values were assigned: 3 – high level of sensitivity; 2 – medium level of sensitivity; 1 – low level of sensitivity; 0 – no sensitivity. Maximum number of points – 30 (10 areas · 3 points);
2) for individual assessments of the overall level of sensitivity, the following criteria were adopted: high – 23-30 points; average – 15-22 points; low – 7-14 points; very low – 6 points and lower.

Source: own elaboration based on an analysis of climate change adaptation plans (regarding town districts) and other source materials.

Table 4. Forecast of sensitivity of individual counties to climate change

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	Adaptive potential	Bytów	Chojnicki	Człuchowski	Gdańsk	Kartuzy	Kościerski	Kwidzyń	Lębork	Malbork	Nowodworski	Puck	Słupsk	Starogard	Sztum	Tczewski	Wejherowski	Gdańsk	Gdynia	Słupsk	Spot	L	%
Financial possibilities	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	3	–	3	**3**	**15**
	medium	–	–	–	2	–	–	2	2	2	2	–	2	–	–	–	2	–	–	–	–	**7**	**35**
	low	1	1	1	–	1	1	–	–	–	–	1	–	1	1	1	–	–	–	1	–	**10**	**50**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Social capital	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	3	–	3	**3**	**15**
	medium	–	–	–	2	–	–	–	2	2	2	2	2	–	–	–	2	–	–	2	–	**8**	**40**
	low	1	1	1	–	1	1	1	–	–	–	–	–	1	1	1	–	–	–	–	–	**9**	**45**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Preparation of services	high	–	–	–	3	–	–	3	–	3	3	–	–	3	–	–	3	3	–	–	–	**7**	**35**
	medium	2	–	2	–	2	–	–	2	–	–	2	2	–	2	–	–	–	2	2	2	**10**	**50**
	low	–	1	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	**3**	**15**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Information and alert mechanisms	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	medium	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	**20**	**100**
	low	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	**Adaptive potential**	**Bytów**	**Chojnicki**	**Człuchowski**	**Gdańsk**	**Kartuzy**	**Kościerski**	**Kwidzyń**	**Lębork**	**Malbork**	**Nowodworski**	**Puck**	**Słupsk**	**Starogard**	**Sztum**	**Tczewski**	**Wejherowski**	**Gdańsk**	**Gdynia**	**Słupsk**	**Spot**	**L**	**%**
Network and equipment of health and education institutions	high	–	–	–	3	–	3	–	3	3	–	–	–	–	–	–	–	3	–	–	–	**5**	**25**
	medium	2	–	2	–	2	–	2	–	–	2	–	2	2	2	–	2	–	2	2	–	**11**	**55**
	low	–	1	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	1	**4**	**20**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Organisation of cooperation with neighbouring counties	high	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
	medium	2	–	2	2	–	–	–	2	–	2	2	2	–	2	2	–	–	–	–	–	**9**	**45**
	low	–	1	–	–	1	1	1	–	1	–	–	–	1	–	–	1	1	1	1	1	**11**	**55**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Systemicity of protecting and shaping ecosystems	high	–	–	–	3	3	3	–	–	–	–	3	–	–	–	–	–	–	–	–	–	**4**	**20**
	medium	2	–	2	–	–	–	2	–	2	–	–	2	2	–	–	–	2	2	–	2	**9**	**45**
	low	–	1	–	–	–	–	–	1	–	1	–	–	–	1	1	1	–	–	1	–	**7**	**35**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**
Existing innovation facilities	high	–	–	–	3	–	–	3	–	–	–	–	–	–	–	–	–	3	3	–	–	**4**	**20**
	medium	2	–	–	–	2	2	–	2	–	2	–	–	2	–	–	2	–	–	2	–	**8**	**40**
	low	–	1	1	–	–	–	–	–	1	–	1	1	–	1	1	–	–	–	–	1	**8**	**40**
	lack	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**0**	**0**

Specification		Counties and cities with county rights in Pomeranian Voivodeship																				Totals	
Area/Field	Adaptive potential	Bytów	Chojnicki	Człuchowski	Gdańsk	Kartuzy	Kościerski	Kwidzyń	Lębork	Malbork	Nowodworski	Puck	Słupsk	Starogard	Sztum	Tczewski	Wejherowski	Gdańsk	Gdynia	Słupsk	Spot	L	%
Overall level of adaptation potential of the county	Number of points	14	9	13	20	14	14	16	16	16	13	14	15	14	12	10	15	20	18	12	15		
	high	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–	3	15
	medium	X	–	X	–	X	X	X	X	X	X	X	X	X	–	–	X	–	X	–	X	14	65
	low	–	X	–	–	–	–	–	–	–	–	–	–	–	X	X	–	–	–	X	–	4	20
	very low	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0

To assess the overall level of the county's adaptation potential to climate change, the following methodology was adopted:
1) to assess the level of adaptation potential in individual areas/domains, the following values were assigned: 3 – high level of potential; 2 – medium level of potential; 1 – low level of potential; 0 – lack of potential. Maximum number of points – 24 (8 areas × 3 points);
2) for individual assessments of the general adaptation level of the county, the following criteria were adopted: high – 19-24 points; average – 13-18 points; low – 7-12 points; Very low level of potential – 6 points and lower.

Source: own elaboration based on an analysis of climate change adaptation plans (regarding counties) and other source materials.

Important elements of the above strategies are objectives related to improving civil protection systems. However, those require detailing and indicating the directions and scope of changes.

The research shows one particularly important conclusion. There is a need to take systemic actions that will prepare effective tools to protect the population against the effects of climate change, and mainly the threats resulting from it. These activities should be implemented in three areas: legislative, organisational, and economic. It can be concluded that this is the correctly conducted risk analysis that takes into account all the determinants, which are the reason of the increase in the level of threats. Today's challenges must take into account the adaptive potential and sensitivity of a given county to these threats. Such comprehensive analyses can only be a result of properly performed risk analyses.

The above considerations are a contribution to the analysis of research of the entire general security system, taking into account all threats caused by climate change.

References

Coumou, D., Rahmstorf, S. (2012). A decade of weather extremes. *Nature Climate Change*, *2*, 491-496. https://doi.org/10.1038/nclimate1452

European Commission. (2009). *White paper. Adapting to climate change: Towards a European framework for action*, COM(2009) 147. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM%3A2009%3A0147%3AFIN%3AEN%3APDF

European Commission. (2013). *Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. An EU Strategy on adaptation to climate change*, COM(2013) 216. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0216:FIN:EN:PDF

Intergovernmental Panel on Climate Change. (2021). *Climate Change 2021. The Physical Science Basis*. https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

Kubiak-Wójcicka, K., Machula, S. (2020). Influence of climate changes on the state of water resources in Poland and their usage. *Geosciences*, *10*(8), 1-21.

Kundzewicz, Z.W., Matczak, P. (2012). Climate change regional review: Poland. *Wiley Interdisciplinary Reviews: Climate Change*, *3*(4), 297-311.

Lindzen, R.S. (1994). Climate dynamics and global change. *Annual Review of Fluid Mechanics*, *26*(1), 353-378.

Masson, V., Lemonsu, A., Hidalgo, J., Voogt, J. (2020). Urban climates and climate change. *Annual Review of Environment and Resources*, *45*, 411-444.

Ministerstwo Środowiska. (2013). *Strategiczny plan adaptacji dla sektorów i obszarów wrażliwych na zmiany klimatu do roku 2020, z perspektywą do roku 2030*. https://

bip.mos.gov.pl/fileadmin/user_upload/bip/strategie_plany_programy/Strategiczny_plan_adaptacji_2020.pdf

Seneviratne, S.I., Zhang, X. (2021). Weather and Climate Extreme Events in a Changing Climate. In Intergovernmental Panel on Climate Change, *Climate Change 2021. The Physical Science Basis*. https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

Sojka, M., Kozłowski, M., Kęsicka, B., Wróżyński, R., Stasik, R., Napierała, M., Jaskuła, J., Liberacki, D. (2020). The effect of climate change on controlled drainage effectiveness in the context of groundwater dynamics, surface, and drainage outflows. Central-western Poland case study. *Agronomy*, *10*(5), 1-21.

Stefan, H.G., Hondzo, M., Fang, X., Eaton, J.G., McCormick, J.H. (1996). Simulated long term temperature and dissolved oxygen characteristics of lakes in the north-central United States and associated fish habitat limits. *Limnology and Oceanography*, *41*(5), 1124-1135.

United Nations Office for Disaster Risk Reduction. (2020). *Disaster Risk Reduction and Climate Change Adaptation: Pathways for policy coherence in Sub-Saharan Africa*. https://www.undrr.org/media/47688/download?startDownload=20240813

Wheeler, T., von Braun, J. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.

Wypych, A., Ustrnul, Z., Schmatz, D.R. (2018). Long-term variability of air temperature and precipitation conditions in the Polish Carpathians. *Journal of Mountain Science*, *15*(2), 237-253.

Zeidler, R.B. (1997). Climate change vulnerability and response strategies for the coastal zone of Poland. *Climatic Change*, *36*, 151-173.

Metoda analizy i prognozy ryzyka wystąpienia zagrożeń dla obszaru województwa pomorskiego wynikających ze zmian klimatu

STRESZCZENIE Kwestia zmian klimatu jest jednym z kluczowych aspektów politycznych, społecznych i gospodarczych współczesnego świata. Wokół tego tematu powstało wiele teorii, kontrowersji i nieporozumień, które sprawiają wrażenie, że jest on nieistotny z punktu widzenia gospodarki i społeczeństwa. Szereg niepokojących zjawisk klimatycznych wskazuje jednak, że problemu tego nie można bagatelizować. W szczególności trudno polemizować ze zdarzeniami, które już mają miejsce i wskazują, że obecne zmiany klimatyczne mogą stanowić zagrożenie zarówno dla zdrowia i życia ludzi, jak i funkcjonowania gospodarki, czy też dla samego środowiska naturalnego. Problematyka i dynamika zmian klimatycznych wymaga od struktur zarządzania kryzysowego przeprowadzenia dogłębnej analizy ryzyka. Artykuł jest propozycją i wprowadzeniem do tematyki analizy ryzyka na poziomie powiatu, z uwzględnieniem wrażliwości i potencjału adaptacyjnego prezentowanego regionu.

SŁOWA KLUCZOWE ekstremalne wydarzenia, ekstremalne zjawiska pogodowe, logistyka, zarządzanie kryzysowe

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Author contributions

The author contributed to the interpretation of results and writing of the paper. The author read and approved the final manuscript.

Ethical statement

The research complies with all national and international ethical requirements.