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REGIONAL VARIATION IN THE VULNERABILITY OF SOCIOECONOMIC SYSTEMS TO CLIMATE CHANGE. A CASE STUDY OF POLAND[1]

Summary

Purpose – The aim of the study was to identify the differences in the vulnerability of Polish voivodships to climate change, which may pose a threat to the sustainable development of particular regions.

Research method – To achieve the purpose of the research, for each voivodship, a Synthetic Measure of Socioeconomic Vulnerability to Climate Change (SMSEVCC) was calculated. The SMSEVCC was applied in the linear ordering of objects characterized by several diagnostic variables, which were later replaced by one diagnostic value.

Results – The implementation of sustainable development in Poland is strongly determined by climate change and the associated extreme weather phenomena. The risk varies regionally and depends on the natural vulnerability of a given area that results from environmental conditions and the level of socioeconomic development.

Originality /value / implications / recommendations – The paper presents a comprehensive analysis, evaluation of socioeconomic vulnerability of voivodeships in Poland to climate change. Progress in the implementation of sustainable development requires strengthening adaptation measures to climate change, which should be adapted to the specifics of individual regions. An important element of actions for sustainable development should be the increased importance of the economic insurance system.

Keywords: climate change, vulnerability, sustainable development, insurance, Poland

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1. Introduction

The growing frequency and intensity of extreme weather events provoked a rapid development of quantitative and empirical research to illuminate key linkages in the coupling of complex natural and human systems, uncovering notable effects of climate on societies and economies. These effects vary across countries and sectors, but the climate and how it is changing undoubtedly impacts people's lives in many ways, including their activities, their welfare, and their wellbeing [Popovsky, Mundy, 2012]. Climate is defined as the weather averaged over a long period (typically averaged over 30 years). The most commonly measured meteorological variables are temperature, precipitation, humidity, atmospheric pressure, and wind. The difference between weather and climate is the measure of time. Weather refers to atmospheric conditions over a short period, while climate is how the atmosphere "behaves" over relatively long periods [Shepherd et al., 2005]. While the relationship between climate change and weather hazards is complex, available research methods make it possible to determine whether extreme events in a particular region, such as rain above a certain amount or temperatures above a certain threshold, have become more or less likely compared to the world without climate change. It cannot be said that a single event is due to climate change because random extremes occur naturally. However, by comparing the extremes with historical measurements and computer models of a climate unchanged by greenhouse gas emissions, scientists have shown that global warming has already strongly influenced the emergence of dangerous weather events [Birkmann, von Teichman, 2010].

Data on weather fluctuations are used to identify relationships between climate change and both economic performance and human health and safety [e.g., Streets, Glantz, 2000; McMichael et al., 2003; Robine et al., 2007; Dell et al., 2012; Bittner et al., 2015]. Climatic factors affect not only economically relevant outcomes such as production and economic growth, the situation in agriculture, forestry, fisheries, and livestock farming, but also health, demographics, migrations, or conflicts [Mora et al., 2018]. A careful understanding of the effects of the impact may be essential to the rational design of contemporary economic policies and institutions, including insurance [e.g., King, 2004; Renaud, Perez, 2010; Kunreuther, Michel-Kerjan, 2011].

Poland is facing large-scale climate-related risks occurring at an accelerating rate. Recent climate studies indicate Poland should also expect more extreme weather-related events in the future. Scientists are of the opinion that climate change is influencing rainfall patterns in Europe and will result in more frequent heavy rainfall and flash floods, combined with a trend towards longer dry phases [Faust, Rauch, 2020]. This is also confirmed in Poland. Between 1946 and 2020, there were over 600 floods of various scales, causes, courses, and losses. The most frequent were rainfall floods (approx. 60 percent of the total) but *meltwater floods, snowmelt and rainfall floods, ice-jam floods, and storm floods* also caused heavy losses in many regions. In total, there are at least 790 sections of river beds predestined for the formation of ice or grease blockages [Bartnik, Jokiel, 2012]. Heavy and prolonged rains and floods contribute to the formation of landslides.

In Poland, the urban population constitutes 60.3 percent of the total population. This places Poland above the world average, but below the European average of 73.9 percent. The UN forecast indicates that by 2050, urbanization will increase, and in Poland, it will reach approx. 70 percent [*The World's Cities*, 2018]. A significant proportion of the assets of the economy, private and public property, and human capital is concentrated in cities. Considering that the very limited share of biologically active surfaces and the small amount of retained water are conducive to flash flooding, the potential losses can be serious [Bryndal, 2015].

Heatwaves have been the main cause of death from natural disasters in Europe over the past 70 years. This is confirmed by numerous research results from various countries. Hot extremes of air temperature are increasing in length and frequency, and in Western Europe, heatwaves have doubled in length since the end of the nineteenth century [Della-Marta et al., 2007]. The average increase in air temperature in Poland in the 20th century was 0.9℃ [Kożuchowski, 2011], and further growth is expected. The number of days with a maximum daily air temperature exceeding 30ºC will increase several times, and temperatures above 35ºC may occur almost every summer. Data collected by weather stations show that since 1971, annual average air temperatures have increased in all voivodeships, with 2020 being the hottest [*Concise Statistical Yearbook of Poland*, 2021]. Another study found that the heatwaves that occurred in 1992, 1994, 2006, and 2010 contributed to an increase in the number of deaths, especially of people over 65 years of age and suffering from cardiovascular diseases [Kuchcik, Błażejczyk, 2005; Kuchcik, Degórski, 2009; Błażejczyk et al., 2013; Graczyk, Kundzewicz, 2014; Graczyk et al., 2017]. In some of the cities included in the study, the number of deaths during the hottest days was more than three times higher than the average death rate during the reference period. In the examined cities, there was the highest increase in the risk of mortality during heat waves, which were both intense and long-lasting. The results indicate that the increase in mortality during a heatwave is already a serious threat in Poland in the current climate, and an increase in the risk should be expected as the country warms [Kuchcik, 2013; Graczyk et al., 2019].

The total annual atmospheric precipitation in the same period also increased, but the size of the changes varies more regionally than the temperature increase that took place throughout the country, including mountain regions [*Concise Statistical Yearbook of Poland*, 2021]. However, at the same time, droughts are becoming an increasingly acute threat. They develop in stages, ranging from atmospheric drought, through soil and hydrological drought, to hydrogeological drought. The formation of drought is favored not only by the lack of rainfall but also high temperatures, strong winds, and high sunshine. In Poland, droughts are mostly observed in the summer (in July). The highest probability of drought occurs in central Poland [Diakowska et al., 2018]. For the period 1951–2006, there is a strong link between hot weather occurrence and precipitation (dryness). This link is significant when periods of low precipitation and a hot event occurrence overlap. It means that a month with a higher-than-average number of hot days simultaneously has precipitation below average [Wibig, 2012]. Thus, the resulting losses from the reduction of productivity in agriculture and forestry, etc., which are caused by heat stress in the changing economic and climatic conditions, are also growing.

Whirlwinds (tornadoes) are another threat of an increasing frequency and intensity of destruction in Poland. In the past, whirlwinds happened every few years. However, in recent years, they have occurred annually, sometimes many times. For example, on May 21, 2019, there were as many as six whirlwinds. There is even talk of a "Polish tornado alley" running through the Śląskie, Malopolskie, Opolskie, Swietokrzyskie, Lodzkie, and Mazowieckie provinces. These regions are most at risk of whirlwinds in terms of intensity and damage caused. Whirlwinds usually accompany the violent formation of a storm, the supercell, which provides it with the necessary energy in the form of warm air, rich in moisture. Since the beginning of the 21st century, over 350 phenomena of this type have been observed in Poland, 61 of which were in the form of water whirls, characteristic of the Baltic Sea coast [www 1].

In Poland, as in the whole of Central Europe, an increase in the frequency of hailstorms is also expected. The size of the change depends on the climate change scenario. According to the results of a study carried out by Munich Re in collaboration with the European Severe Storms Laboratory, in a moderate scenario, one can expect a 30–40 percent increase in the number of such events almost everywhere in Europe. In the "business as usual scenario", when climate change is not halted, severe hailstorms may occur almost twice as often in large parts of Central and Eastern Europe, as well as in Italy, southern France, and the Adriatic coast. A hailstone with a diameter of more than 2 cm does not cause serious damage to buildings, but it does destroy crops. In line with research results, even in a moderate scenario, Europe will generally experience a 10–20 percent increase in this type of hailstorm. If global warming continues, the risk of hail could rise by 80 percent, especially in Eastern Europe, including Poland, Italy, and parts of Germany [Rädler, Faust, 2020]. The record-breaking hail ball that fell in June 2021 in Poland was 13,5 cm in diameter [www 2].

Although global warming will also involve certain limited economic benefits for Poland, e.g., lower expenditure on heating, the possibility to grow new plants, or a longer vegetation period, the threats seem to outweigh any potential benefits [Lange et al., 2018]. Prolonged periods without rainfall, which result in a loss of water from soil, rivers, and reservoirs, significantly affect the country's energy security, especially the generation of electricity from power plants with an open cooling system and hydropower plants. A too-low water level reduces cooling efficiency or, in extreme cases, prevents the use of water from rivers or reservoirs for this purpose. Moreover, low water levels limit or even prevent the generation of electricity from hydropower plants. Between 2005 and 2015, weather factors and problems with distribution accounted for as much as 75 percent of the causes of disruptions in energy supplies in Poland. Eighteen percent of these disruptions were due to a lack of available resources (e.g., the water shortage in August 2015).

Policies for sustainable development affect the climate and policies for climate protection affect sustainable development. Ideally, these interrelationships enhance the positive attributes of development. However, it should be taken into account that climate protection already requires significant expenses, which may slow down the GDP growth. This should result in benefits for society and the economy in the long run. Today, it is difficult to come up with clear conclusions on how the costs and benefits will be distributed. The linkages between climate and sustainable development are presented in Table 1.

TABLE 1.

Two-way linkages between climate and sustainable development

Sustainable development policies	→ • Alternative development paths • New sectoral environmental and economic policies • Institutional and technological changes • Organizational and technical innovations	**Climate change**
Sustainable development	• Climate change mitigation • Avoided damages and losses • Additional benefits / costs • Institutional and technological changes • Technological change • Organizational and technical innovations ←	**Climate change policies**

Source: own elaboration based on: [Swart et al., 2003].

The study aimed to identify the differences in the vulnerability of Polish voivodships to climate change, which may pose a threat to the sustainable development of particular regions. Vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity [Watson et al., 2001].

2. Materials and methods

To identify the differences in the vulnerability of Polish voivodships to climate change, demographic, social, economic, and environmental indicators were considered. The most recent data (2018–2020) published by Polish Statistics [www 3] in Local Databank, and the results of specialist research and expert opinions were used. A Synthetic Measure of Socioeconomic Vulnerability on Climate Change (SMSEVCC) was calculated for each voivodship. The SMSEVCC was applied in the linear ordering of objects characterized by several diagnostic variables, which are later replaced by one diagnostic value. The procedure of constructing the SMSEVCC based on Hellwig's method (1968) was carried out in several steps.

Step 1. Selection of variables to construct the SMSEVCC. The initial choice of variables for analysis was justified as follows in table 2.

TABLE 2.

The initial choice of variables for analysis

Index	Index description	Measurement unit	Type of index
X1	The population aged 0–14 and over 70	Percent	stimulant
X2	Population density	Number of people per km^2	stimulant
X3	Population density in built-up and urbanized areas	Number of people per km^2	stimulant
X4	Employment in agriculture	Percent	stimulant
X5	Beneficiaries of social assistance at domicile	Number of people per 10 thousand of citizens	stimulant
X6	Average gross salary	PLN	destimulant
X7	Average GDP per capita	PLN	destimulant
X8	Gross value of fixed assets in the national economy per capita	PLN	stimulant
X9	Total public roads per 100 km^2	km	destimulant
X10	Number of working doctors per 10,000 inhabitants	Number	destimulant
X11	The number of inhabitants per bed in a general hospital	Number	destimulant
X12	Average expenditure on the regulation of rivers and mountain streams in 2014–2018	Thousand PLN	stimulant
X13	Forest cover	Percent	destimulant
X14	Confirmed landslide threat	0/1	stimulant
X15	Recurring significant floods in the 21st century	0/1	stimulant

Source: own elaboration.

Step 2. Checking whether the selected indicators have appropriately high volatility. The coefficient of variation calculated based on the standard deviation for the variables X1, X6, and X11 did not exceed the threshold value (0.2), which resulted in their elimination from further analysis.

Step 3. Assessment of the correlation of diagnostic variables. For this purpose, a parametric method was used. As a result, a cluster was determined in which the central feature is X7, and the satellite feature is X8. The remaining variables, X2, X3, X4, X5, X9, X10, X12, X13, X14, and X15, are isolated features. Ultimately, 11 diagnostic indexes were used to build the ranking of voivodships. The list of indexes finally used in the model includes:

X2 – Population density describes the number of people per square km (stimulant). Densely populated areas can generate more victims and losses of extreme weather events and vector-borne diseases spreading through global warming. Additionally, such areas are a challenge when evacuation is needed [*Area and population*, 2019].

X3 – Population density in built-up and urbanized areas describes the number of people per square km in these areas (stimulant). Built-up and urbanized areas are particularly prone to climate change and are at risk of greater losses in the event of natural disasters [*Area and population*, 2019].

X4 – Employment in agriculture as a percentage of people employed in agriculture in total employment (stimulant). The agricultural sector includes agriculture, forestry, hunting, and fishing, which are very vulnerable to climate change and extreme weather phenomena like spring frosts, storms, hailstorms, floods, droughts, and fires. They directly affect the size of the producer's income and the wages of seasonal workers, and they have an impact on the GDP of particular voivodships. Employment in agriculture reflects the importance of the sector for society and the economy in particular regions [*Statistical yearbook*, 2019].

X5 – Beneficiaries of social assistance per 10,000 population (stimulant). The variable includes all members of households with at least one social assistance beneficiary and homeless people who, in the survey year, received any benefit provided by social welfare centers at least once. The reason for this approach is that when considering applications for social assistance, the material situation of all household members of the person submitting the application is analyzed, and the income per capita in the household is calculated. The variable shows the burden of individual voivodeships that need to provide help to people who are helpless in life or suffering from poverty. This group is highly exposed to the negative effects of extreme weather phenomena, especially extreme cold and heat [*Statistical yearbook*, 2019].

X7 – Average GDP per capita (destimulant). The variable shows the economic strength of the region, which determines the ability to help people, to recover from losses, and to adapt to climate change, e.g., by restoring infrastructure and building appropriate protection facilities [*Statistical yearbook*, 2019].

X9 – Total public roads per 100 square km (destimulant). The access to public roads affects the possibility and time to reach people in specific places by ambulances or the fire brigade, and thus the possibility of helping victims of weather events [*Statistical yearbook*, 2019].

X10 – The number of working doctors per 10,000 inhabitants (destimulant). The access to medics affects the availability of professional medical assistance. The higher the number of doctors, the better it is for the region's inhabitants because they can get professional help faster in the event of, e.g., strokes, heart attacks, or vector-borne diseases spreading through global warming (e.g., ticks, mosquitoes) [*Statistical yearbook*, 2019].

X12 – Average expenditure on the regulation of rivers and mountain streams in 2014–2018 (stimulant). Regulating rivers and mountain streams that contribute to the acceleration of runoff and drainage of the surrounding areas is counterproductive in areas at risk of drought. During heavy rainfall and thaw, it increases the risk of local floods and inundation, which paradoxically stimulates the construction of further flood embankments, disrupting the functioning of natural ecosystems. The arithmetic mean over the five years was taken into account, as expenditure is not regularly incurred [Nawrocki, Nieznański, 2020; Wiśniewska, 2020].

X13 – Forest cover (destimulant). It affects not only capturing and retaining carbon dioxide, but it is also a natural buffer against soil erosion and landslides. It plays a significant role in flooding mitigation [*Statistical yearbook*, 2019].

X14 – Confirmed landslides (stimulant). A zero-one variable was used, where 1 was implicated in the voivodeships at risk of landslides. In this case, data published by the Ministry of Climate were used [*Gdzie występują*…, 2019].

X15 – Territories with recurring significant floods (stimulant). Territories were indicated based on the Françou-Rodier flood index (K). The index is calculated from the maximum flow rate and the catchment area. It is a unitless quantity. The higher it is, the greater the catchment/river susceptibility to flooding. In Poland, the K index does not exceed the value of 5.0, but only for about 10 percent of rivers is it more than 3.5 [Bartnik, Jokiel, 2012, data from the map p. 237]. A zero-one variable was used, where 1 was implicated in the voivodeships at risk of flood with K >4.

Step 4. Division of variables into stimulants (X2, X3, X4, X5, X12, X14, X15) and destimulants (X7, X9, X10, X13) and normalization of diagnostic features for indicator comparability. Variables were normalized using the classical standardization [Panek, 2009]:

$$z_{ij} = \frac{x_{ij} - \overline{x_j}}{s_j},$$

where:

$\overline{x_j}$ – arithmetic mean of the next feature,

S_j – standard deviation of another feature,

z_{ij} – standardized value.

Step 5. Hierarchy of objects by Hellwig's method [Hellwig, 1968]. The method used in the analysis prioritizes objects by comparing them to the designated development pattern. The coordinates of the reference object (z_{0j}) are the maximum values of the standardized variables (z_{ij}).

z_{0j} = max z_{ij} (when the feature is a stimulant).

Objects are prioritized based on the distance from the pattern. For this purpose, the Euclidean metric was used [Panek, 2009]:

$$d_{i0} = \sqrt{\sum_{j=1}^{m} (z_{ij} - z_{0j})^2}, \text{ j=1,2, …,m; i=1, 2, …, n,}$$

where:

z_{ij} – standardized value of diagnostic variables,

z_{0j}= maxz_{ij} (for stimulants).

In Hellwig's method, objects are ordered based on the value of a synthetic measure (indicator) of development:

$$s_i = 1 - \frac{d_{i0}}{d_0},$$

where:

$$d_0 = \overline{d_0} + 2S_0$$

wherein:

$$\overline{d_0} = n^{-1} \sum_{i=1}^{n} d_{i0},$$

$$S_0 = \sqrt{n^{-1} \sum_{i=1}^{n} (d_{i0} - \bar{d})^2}$$

The measure s_i has values from the interval [0; 1]. The closer the object is to the pattern, the higher the values. Higher values indicate a higher level of a complex phenomenon; in this case, a higher socioeconomic sensitivity to threats related to climate change.

Step 6. Assigning objects to classes. Objects are assigned to specific classes based on the limits of the s_i measurement intervals determined using the arithmetic mean $\bar{s}$ and standard deviation S_s as follows [Nowak, 1990]:

Class I: $s_i \geq \bar{s} + S_s$

Class II: $\bar{s} + S_s > s_i \geq \bar{s}$

Class III: $\bar{s} > s_i \geq \bar{s} - S_s$

Class IV: $s_i < \bar{s} - S_s$.

3. Results

The values of the synthetic measure of the vulnerability of particular Polish voivodeships to climate change (SMSEVCC) were specified based on the set of indicators presented in Table 2. Higher values of the index correspond to higher vulnerability to climate change, which poses a threat to the region's sustainable development. The final ranking is shown in Table 3.

TABLE 3.
Ordering of voivodeships in terms of vulnerability to climate change

	Voivodeship	SMSEVCC	Class
1	Podkarpackie	0.293841	**1**
2	Swietokrzyskie	0.280225	**1**
3	Dolnoslaskie	0.218103	**2**
4	Malopolskie	0.208431	**2**
5	Kujawsko-Pomorskie	0.184318	**2**
6	Lubelskie	0.155644	**2**
7	Lodzkie	0.149006	**3**
8	Opolskie	0.146777	**3**
9	Warminsko-Mazurskie	0.145335	**3**
10	Wielkopolskie	0.130632	**3**
11	Slaskie	0.123034	**3**
12	Podlaskie	0.121572	**3**
13	Pomorskie	0.121142	**3**
14	Zachodniopomorskie	0.089675	**3**
15	Mazowieckie	0.016043	**4**
16	Lubuskie	0.013806	**4**

Source: own calculation.

In terms of their vulnerability to climate change, Polish voivodeships can be divided into four groups. The number of voivodeships in subsequent groups is as follows: group I – 'very high vulnerability to climate change' – two voivodeships (Podkarpackie and Swietokrzyskie); group II – 'high vulnerability to climate change' – four voivodeships (Dolnoslaskie, Malopolskie, Kujawsko-Pomorskie, and Lubelskie); group III – 'low vulnerability to climate change' – eight voivodeships (Lodzkie, Opolskie, Warminsko-Mazurskie, Wielkopolskie, Slaskie, Podlaskie, Pomorskie, and Zachodniopomorskie), and group IV – 'very low vulnerability to climate change' – two voivodeships (Mazowieckie and Lubuskie).

The analysis of the SMSEVCC values allows the following conclusions to be drawn regarding the regional variation in vulnerability to climate change. The situation of voivodeships is strongly spatially diversified. The top-ranking position is occupied by Podkarpackie, with Swietokrzyskie as the runner up. In both regions, unfavorable natural conditions (risk of floods and landslides) meet a low level of economic and social development (in terms of GDP per capita and access to medical care) and very high employment in agriculture (30 percent). In Swietokrzyskie, low forest cover also raises the vulnerability to climate change. Mazowieckie and Lubuskie are at the opposite end of the ranking. In Mazowieckie, relatively unfavorable natural conditions (risk of floods) are compensated for by the high level of socioeconomic development in terms of GDP per capita, the number of working doctors per 10,000 inhabitants, and the low importance of agriculture measured by employment in this sector, which remains below the average for the country (11.4 percent compared to 17 percent). The lowest-ranked position, occupied by Lubuskie, can be explained by low population density generally and in built-up areas, low employment in agriculture (10.4 percent), and the highest forest cover in the country (49 percent).

4. Discussion

The discussion will combine the results of the SMSEVCC analysis with observations related to the climate change and extreme weather events in Poland. In Poland, the area of agricultural land is approximately 18 million ha, which constitutes 60.3 percent of the total area of the country [*Statistical yearbook…,* 2020]. It is necessary to emphasize the still high importance of the agricultural sector in Poland. It provides employment to nearly 10 percent of total employment and 3 percent of GDP, while in the EU, these values are 4.3 percent and 1.6 percent, respectively. However, the situation varies regionally. The large fragmentation of farms and their poor economic condition remain a problem, especially in the east of the country. Weather extremes will cause a number of adverse changes in the Polish environment. An increase in temperature in spring and autumn will extend the growing season. However, biomass production by plants will be reduced, mainly due to the insufficient amount of water and the high temperature. Warm, snowless winters interrupted by rapid temperature drops, without snow cover providing protection for plants, will cause considerable losses in agriculture and gardening. Similarly, the earlier beginning of the vegetation season will involve a higher probability of damage caused by spring frost. In addition, changing temperature extremes in Central and Eastern Europe might reduce the amount of rainfall in summer, increasing the risk of drought and forest fires, and increasing the occurrence of strong winds and the development of pathogens [Kundzewicz, 2013; *SOER*, 2015].

Due to frost and hail in 2017, the harvest from Polish orchards was 30 percent lower than average, but because of a lack of insurance, only PLN 45 million was paid by insurers to farmers. According to data from the Ministry of Agriculture and Rural Development, at the end of September 2018, direct losses in agriculture caused by the 2018 drought amounted to PLN 3.6 billion with an additional PLN 1 billion of losses as the impact on other sectors. Unfortunately, only a small part of the affected area was insured [*Climate of risk*, 2019]. Pursuant to the Act of July 7, 2005, on the insurance of agricultural crops and livestock [Journal of Laws of 2019, item 477], farmers are obliged to take out an insurance policy for at least 50 percent of the area of agricultural crops for which direct payments are granted. Compulsory insurance in agriculture includes insurance of farmers' civil liability due to farm ownership, the insurance of buildings belonging to the farm against fire and other random events, the insurance of agricultural crops, and third party liability insurance of motor vehicle owners. Each farmer who obtained direct payments within the meaning of the provisions on payments under the direct support scheme (i.e., subsidies) is obliged to conclude an insurance contract for at least 50 percent of the crop area against the risk of damage caused by flood, drought, hail, and the negative effects of winter or spring frost. Additionally, each farmer is obliged to conclude an insurance contract for buildings included in the farm. On the basis of this contract, the insurer undertakes to pay compensation in the event of damage caused by random events in the form of fire, hurricane, flood, flooding, torrential rain, hail, snowfall, lightning strike, explosion, landslide, crump, avalanche or falling aircraft. Although every year the government subsidizes the insurance for farmers, only a small part of arable land is covered by this type of protection. In 2020, the government transferred a total of PLN 500 million for subsidies to agricultural crops and livestock insurance, which means that PLN 350 million was transferred from the state budget, while PLN 150 million was obtained from managing the agricultural property of the state treasury [www 4]. In 2021 the total transfer amounted to 900 million. Farmers who do not conclude a compulsory insurance contract will be required to pay a fee for failing to meet the obligation, which will be the PLN equivalent of €2 per hectare, determined using the average exchange rate announced by the National Bank of Poland.

In Poland, the lack of social awareness about the effects of natural disasters remains a serious problem. Although Poles have half as many assets as residents of the euro area, a significant increase in earnings and capital accumulated after the transition to the market economy in 1989 was observed. The average household has €61,700 in assets, while the average per family from the euro area has €109,200 [*Household Wealth and Debt in Poland*, 2015]. The development of infrastructure and the enrichment of society means that the value of assets at risk, both private as well as state and municipal, is increasing. Unfortunately, the scope of private insurance is still low, and people expect help from the state. In Poland, only 60 percent of private real estate is covered by insurance. For example, a total of 24,000 families suffered during the 2010 flood, and the estimated losses amounted to more than PLN 12 billion, of which less than 13 percent of losses had insurance coverage. The same flood demonstrated the scale of the problem of landslides in the Carpathians. Approximately 1,300 landslides occurred at that time in Malopolskie, where 81 private residential and farm buildings, two road bridges, a school building, and 250 m of a county road were damaged. The estimated direct property losses amounted to PLN 25.9 million [*Climate of risk*, 2019]. Currently, it is estimated that the number of landslides in the Carpathians could be in the range of 50,000–60,000. In the Carpathians, the "landslide indicator", which expresses the size of the area covered and threatened by landslides in relation to the total area, is estimated at 30–40 percent [*Gdzie występują…*, 2019].

It is becoming increasingly obvious that heatwaves are a growing threat to human health and the normal functioning of the Polish economy [Kuchcik, Błażejczyk, 2005]. A serious threat to sustainable development also comes from the energy sector, which has difficulties in ensuring energy supplies during strong winds, snowstorms, and heatwaves. The situation compounds the unfavorable demographic changes (i.e., the aging population) that are taking place in Poland. Advanced age is considered to be one of the most serious health risk factors during heatwaves. In 1990, the population aged 65+ accounted for 10.2 percent of the total population, while in 2012, it was already 14.2 percent. Predictions indicate that by 2025 it could reach 21.5 percent, i.e., more than twice as much, in relative terms, as in 1990 [*Population projection 2014-2050*, 2014].

5. Conclusions

It is evident, that the pace and character of development influence adaptive capacity and that adaptive capacity influences the pace and character of development. It follows that development paths, and the choices that define them, will affect the severity of climate impacts, not only through changes in exposure and vulnerability but also through changes in the capacities of systems to adapt. This includes local-scale disaster risk reduction and resource management, and broader social dimensions including governance, and societal engagement. Summarizing the research results, the implementation of sustainable development in Poland is strongly determined by climate change and the associated extreme weather phenomena. The risk varies regionally and depends on the natural vulnerability of a given area that results from environmental conditions and the level of socioeconomic development. Voivodeships with a large share of agricultural land and repeated floods and landslides are particularly exposed. Economic entities in voivodeships with a high share of the agricultural sector are, unfortunately, usually also more sensitive to weather risk, as it affects entire production chains. The risk of losses rises not only due to the increase in property values, which was the expected consequence of the progress that took place in Poland during the systemic transformation that began in 1989. Another factor is the concentration of assets in hazard-prone areas.

Actions should be implemented in two ways, through disaster risk management, and disaster risk reduction. The first one is the systematic management of administrative decisions, organizations, operational skills, and abilities to implement policies, strategies, and capacities of society and individuals to cope with the impacts of climate-related hazards. The second one includes the development and application of policies, strategies, and practices designed to minimize socioeconomic vulnerability and the impacts of climate-related disasters through a combination of technical measures to reduce physical hazards and enhance social and economic capacity to adapt. In order to meet the challenges resulting from global warming, it is necessary to change the organizational structures responsible for crisis management aimed at dealing with sudden events such as hurricanes or floods. Climate change also requires a long-term approach, taking into account events such as prolonged droughts and heatwaves, or the constant rise of sea levels. There are, effectively, two broad approaches to disaster risk reduction, and adaptation to climate change. The first one is the top-down approach which is based on institutional responses, allocation of funding, and agreed procedures and practice. The second one, the bottom-up approach to disaster risk reduction is based on enhancing the capacity of local communities to prepare for disasters and to adapt to changing natural environment. Climate change can be incorporated into this approach through awareness-raising and the transmission of knowledge about risk management and the role of insurance to local communities. Progress in implementing sustainable development requires strengthening adaptation measures to climate change. Thus, an important element is the improvement of the quality of spatial planning. Another important issue is ensuring energy security through the wider use of distributed sources with a large share of renewables. The situation of individual economic entities may be enhanced by the use of the insurance system. Taking into account potential damages and losses resulting from the impact of weather extremes, the cooperation of the state, and local authorities with the insurance sector seems to be indispensable. Global warming and weather extremes, which cause a number of adverse changes in the Polish environment, also affect people's health. Therefore, it is recommended that the availability of medical care be improved. At present, it is highly diversified regionally and is weakest in regions without strong urban centers.

The diversified vulnerability of Polish voivodships to climate change should be the starting point for the development of adaptation strategies tailored to the local specificity. It is especially about the development of a policy focused on the practical use of ecosystem services in the field of carbon capture and storage, mitigation of flood risks, and reduction of the nuisance of urban heat islands. The scientific recognition of the importance of the LULUCF sector and the formulation of political recommendations for land management also need to be strengthened. At the same time, the resilience of socioeconomic systems should be enhanced by education policy.

The results of the research can be applied practically and used by policymakers to enhance the resistance of Polish regions to climate change and ensure their sustainable development.

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