Effects of Global Climate Change and Improvement of Adaptation Especially in the Public Service Area

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EFFECTS OF GLOBAL CLIMATE CHANGE AND IMPROVEMENT OF ADAPTATION ESPECIALLY IN THE PUBLIC SERVICE AREA

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Unexplained "Global Warming Hiatus" (2002–2013): Symptoms and Reasons with Respect to Adaptation and Mitigation

1. Introduction

The media reflected one statement by the recent IPCC WGI Report (2013): "It is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together."

On the other hand, strong discussions took place behind the scenes, since no increase of surface air temperature is seen since ca. 2002 or 1998 (a strong El Nino year). The 2013 IPCC Report, page 3 of Summary for Policy Makers states in this respect: "In addition to robust multi-decadal warming, global mean surface temperature exhibits substantial decadal and interannual variability. Due to natural variability, trends based on short records are very sensitive to the beginning and end dates and do not in general reflect long-term climate trends."

The author of the present paper is sure that this pausing is a more serious event, modifying our correct foci of adaptation, but not requiring changes in mitigation, according to our view. The paused warming since ca. 2002 is not fully reflected by the IPCC WGI (2013) Report. The aim of our study is to collect and discuss the key arguments of the issue, tackling three aspects: the symptoms and reasons of pausing, as well as the implications for adaptation and mitigation possibilities. The paper concludes in recommendations, addressing challenges in science, adaptation and mitigation.

This chapter is built up as follows. Section 2 introduces symptoms and likely reasons of the pause in atmospheric warming. The symptoms are presented in the various domains of the Climate System. Consequences of the stagnation in the atmospheric temperatures concerning adaptation are shown in Section 3, together with some illustrations on the extremes of our present climate. Section 4 comprehends the need, the degree and the technical possibilities of adaptation, including various forms of green energy, which remains an urgent goal despite the short hiatus period. Section 5 surveys the recent literature published in the period after the IPCC WGI (2013) comprehension of the climate change issue including the Global Warming Hiatus. Finally, Section 6 provides the conclusions of this chapter.

2. Symptoms and Causes of the Pause in Warming

2.1. The symptoms

Let us start with the atmosphere (Figure 1). It is seen that in the last 10–15 years the previous steep warming does not continue (upper left panel). The start of this pausing is questionable, since the year 1998 was a strong El Nino year, but the next years were cooler, still reminiscent of the steeper trends of previous decades. Air humidity is driven by thermal conditions. Both evapotranspiration and the maximum vapour content strongly depend on temperature. As the lower left part of Figure 1 indicates, stagnation of specific humidity is also unequivocal in the recent decade. Unfortunately, the lower troposphere and the lower stratosphere (right panels of Figure 1) also exhibit unequivocal signs of a pause in changes (in the lower stratosphere, it means a pause in cooling).

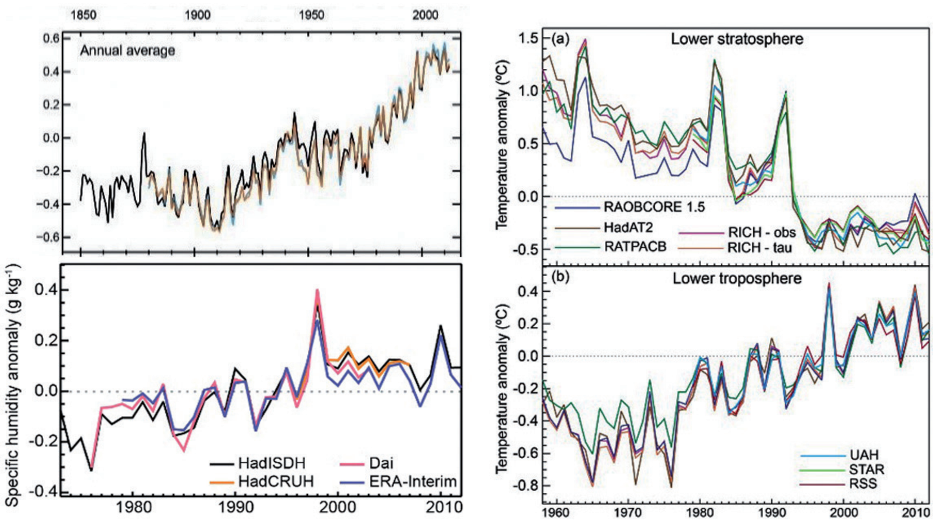

Figure 1.

Observed annual and decadal global mean surface temperature anomalies relative to 1961–1990 from different global data sets 1850 to 2012 (IPCC WGI 2013: Fig. SPM.1) Global annual average anomalies in land surface specific humidity from four different sources. Anomalies are relative to the years 1979–2003. (Left pair of the panels.)

Global annual temperature anomalies of the lower stratosphere (a) and lower troposphere (b), relative to climatology of 1981–2010, from different data sets. (Right pair of the panels.)

Source: IPCC WGI 2013: Fig. 2.30b and 2.24

How did the other near-surface indicators of thermal conditions behave in the recent 1–1.5 decades? Figure 2 presents us some answers. In its upper left panel, one can see that both sea-surface temperature and near-surface marine air temperature clearly stopped warming in the critical period! On the other hand, melting of solid water does not exhibit a pause in the Northern Polar latitudes, neither in the snow cover extent nor in the sea ice extent. This may mean that the lack of warming, established in global averages, has regional differences.

This is supported by the right lower panel of Figure 2, showing the surprising fact that sea ice is increasing around the Antarctic for much longer time than 10–15 years, as it was expressed by the earlier IPCC Reports, too. Observed Arctic sea ice trends are well simulated.

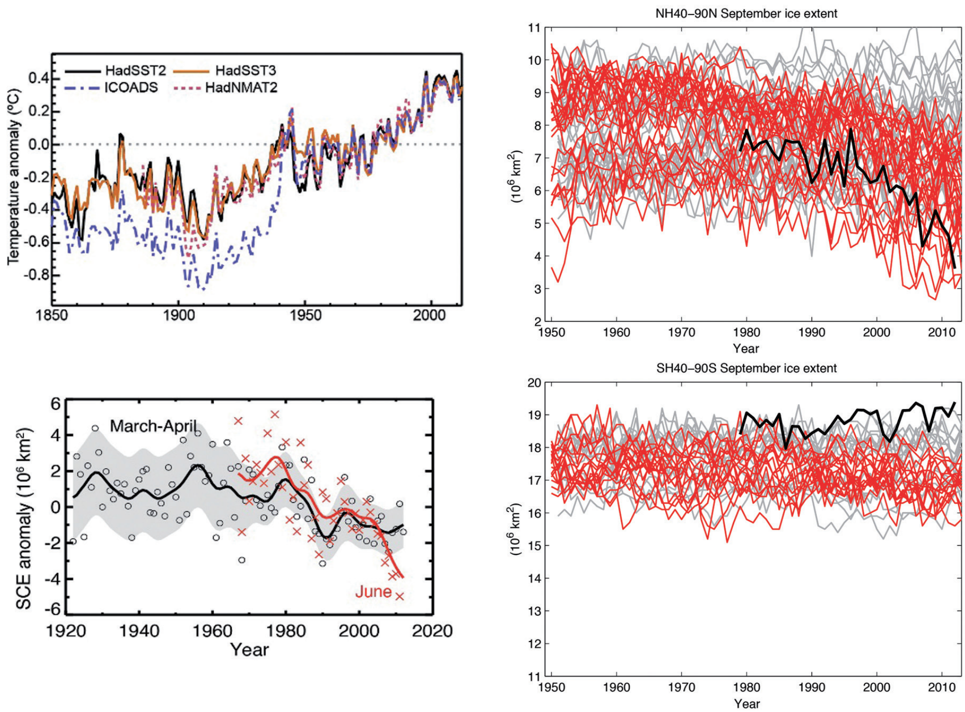

Figure 2.

Global annual average sea surface temperature (SST) and Night Marine Air Temperature (NMAT) relative to 1961–1990 from various data sets (Upper left panel.)

March–April NH filtered snow cover extent over the period of available surface data, and June SCE, from satellite data. The anomalies are compared to the 1971–2000 mean. (Lower left panel.)

September sea ice extent for Arctic (top) and Antarctic (bottom) from observations (thick black lines) and various simulations (thin grey lines). Climate models simulating sea ice in agreement with observations were considered. (Right panels.)

Source: IPCC WGI 2013: Fig. 2.16; 4.19 and 10.16

Differences in success of temperature reproduction by the climate models between the various domains of the Earth are presented in Figure 3. The fluctuating upper black lines are always the observations, to be compared with the upper smooth lines of simulations based on all known natural and anthropogenic factors. The upper shaded bands represent the uncertainty of the various model runs. (The blue bands indicating simulations by natural forcing factors are out of our interest.)

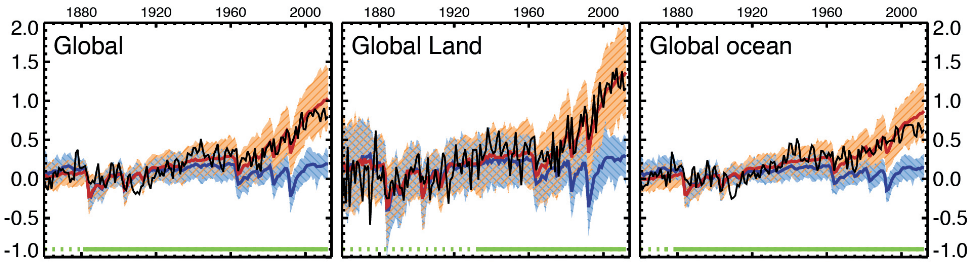

Figure 3.

Global, land, ocean and continental annual mean temperatures for CMIP5 historical data and historical simulations (multi-model means shown as thick lines with 5 to 95% ranges) and for Hadley Centre/Climatic Research Unit gridded surface temperature data set (black).

Source: IPCC WGI 2013: Fig. 10.7

The observations and simulations differ strongly in the Global and Global ocean comparisons, where the expected changes are above the observations by ca. 0.15 and 0.20°C by the end of the decade, respectively. Considering smaller scale simulations, observed decadal mean air temperature lags behind the simulation by ca. 0.4 over continents of South America and Australasia (Figure 4). These characteristics indicate that the lack of temperature behind the considered physical reasoning, i.e. model simulations is the strongest near the Southern Oceans. Over the northern continents, no lack behind the simulations can be established.

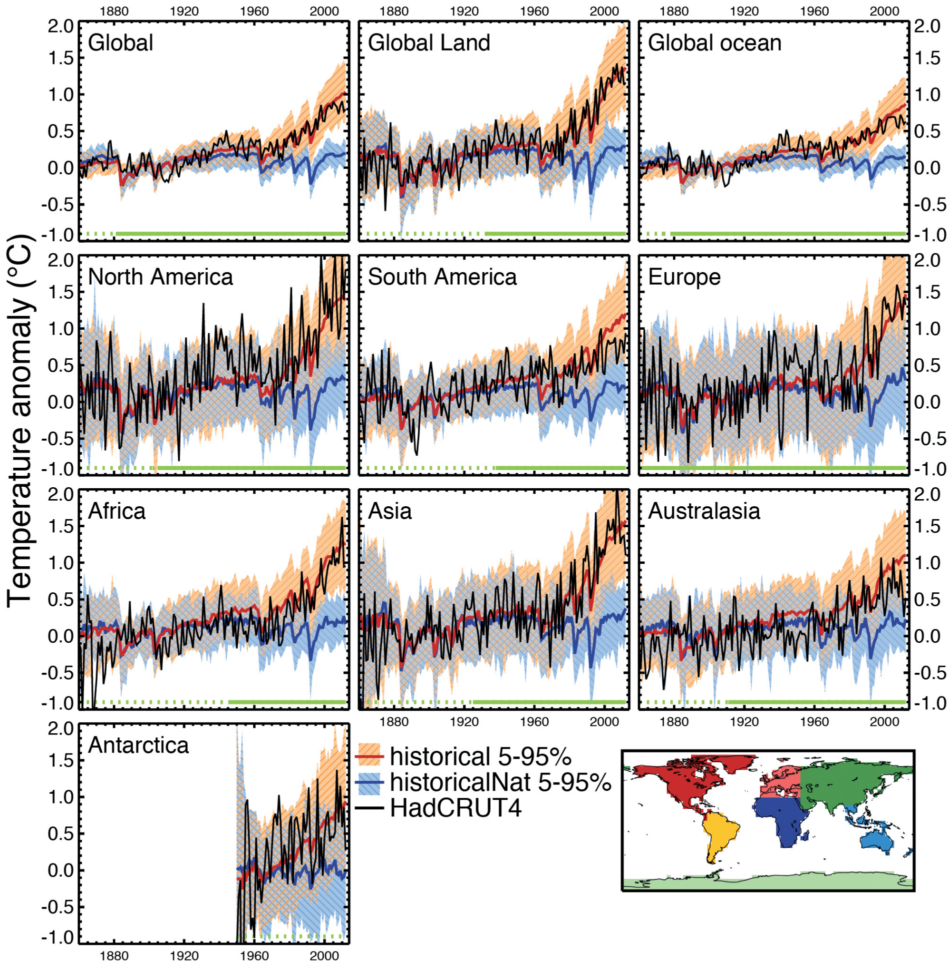

Figure 4.

Global, land, ocean and continental annual mean temperatures for CMIP5 historical data and historical simulations (multi-model means shown as thick lines with 5 to 95% ranges) and for Hadley Centre/Climatic Research Unit gridded surface temperature data set (HadCRUT4, black). Mean temperatures are shown for Antarctica and six continental regions formed by combining the sub-continental scale regions. Temperatures are shown with respect to 1880–1919 for all regions except Antarctica where temperatures are compared to 1950–2010.

Source: IPCC WGI 2013: Fig. 10.7

2.2. The likely causes

The first obvious attempt to explain the pause in warming in the last one and a half decade is to find a weakening in the natural or anthropogenic forcing factors. But, this is not the case (Figure 5). Only a slight cooling can be attributed to fluctuations in the solar irradiation or transparency of the atmosphere due to volcanic activity.

Putting together all natural and anthropogenic factors in Figure 6, one can establish that the increasing anthropogenic factor should have caused warming in the given period, since the decrease of natural components was much below the surplus from the greenhouse components. Moreover, natural forcing was stagnating during the last decade, whereas the greenhouse effect was further increasing. Hence, the reason should be somewhere else.

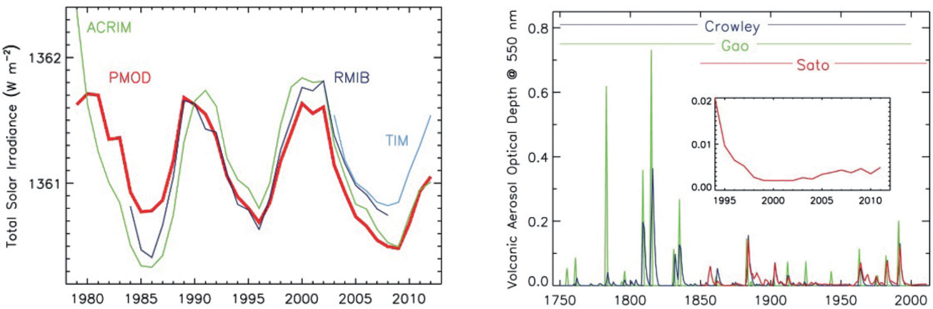

Figure 5.

Annual total solar irradiance: Data by Active Cavity Radiometer Irradiance Monitor (ACRIM), Physikalisch-Meteorologisches Observatorium Davos (PMOD) and Royal Meteorological Institute of Belgium (RMIB). The composites are standardized to the mean (2003–2012). Total Irradiance Monitor (TIM) measurements are also shown. (Left panel.)

Global mean aerosol optical depth (at 550 nm) of volcanic origin according to various estimations. Gao and Crowley are from ice core data; Sato includes data from surface and satellite observations. (Right panel.)

Source: IPCC WGI 2013: Fig. 8.10 and 8.12.

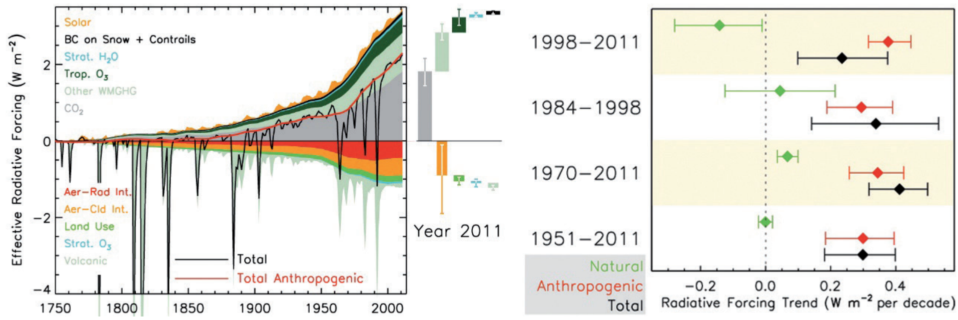

Figure 6.

Time evolution of forcing for anthropogenic and natural forcing mechanisms. The total anthropogenic forcing was 0.57 Wm–2 in 1950, 1.25 Wm–2 in 1980 and 2.29 Wm–2 in 2011. (Left panel.) Linear trend in computed anthropogenic, natural and total forcing for the given years with a 90% confidence range. (Right panel.)

Source: IPCC WGI 2013: Fig. 8.18 and 8.19

Analysing Figures 3 and 4 above, we established that Oceans of the Southern Hemisphere might be the key region in the pause in warming phenomena. Observed warming in the various sections of the oceans (Figure 7) supports this statement.

Deep ocean layers warmed almost at its every depth in 1992–2005, according to the upper left panel, but the warming of the Southern oceans was even stronger. The lower panel shows which parts of oceans exhibit the strongest warming. The right panel of this Figure is probably one of the most important drawing of the whole IPCC WGI (2013) Report, indicating that even during the pause in the warming period, the heat content of the climate system has been increasing. 95% of this warming took place in the upper and deep oceans.

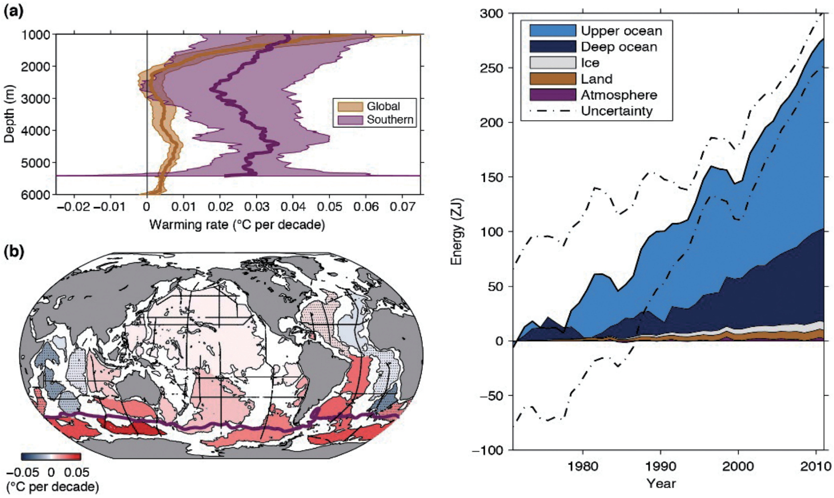

Figure 7.

(a) Area-mean warming rates (ºC/decade, thick lines) at the various depths (shading), globally and south of the Subantarctic Front, in 1992–2005. (b) Mean warming rates (ºC/decade) below 4000 m (bar) estimated for deep ocean basins (thin black), also in 1992–2005. Positions of the Subantarctic Front and the oceanographic transects, from which the warming rates are estimated (thick black) are also shown. (Left panel.)

Plot of energy accumulation in ZJ (1021 J) within all components of the Earth's climate system in 1971–2010 unless otherwise indicated. Ocean warming dominates within the upper ocean (above 700 m) contributing more to the warming than the deep ocean. Ocean estimates also dominate the total 90% confidence band of total heat content. (Right panel.)

Source: IPCC WGI 2013: Fig. 3.3 and Box 3.1, Fig. 1

Intensified heat uptake of the Southern Oceans and its cooling effect on adjacent atmospheric layers and the contribution of this process to the pause in warming even in a global average is a challenge for climate science. As the left panels of Figure 8 indicate, all models strongly overestimate the temperature changes of the last 1.5 decades, whereas in average they correctly estimate the shift of the radiation forcing during the same period.

At the same time, the right panel of Figure 8 demonstrates the effect of missing heat uptake in the majority of the ten years' long simulations in the recent decade after 2001, leading to strong overestimation of global sea surface temperature. At the same time, simulations performed for the other decades fit the observations fairly well. Hence, the lack of model performance is quite a new problem.

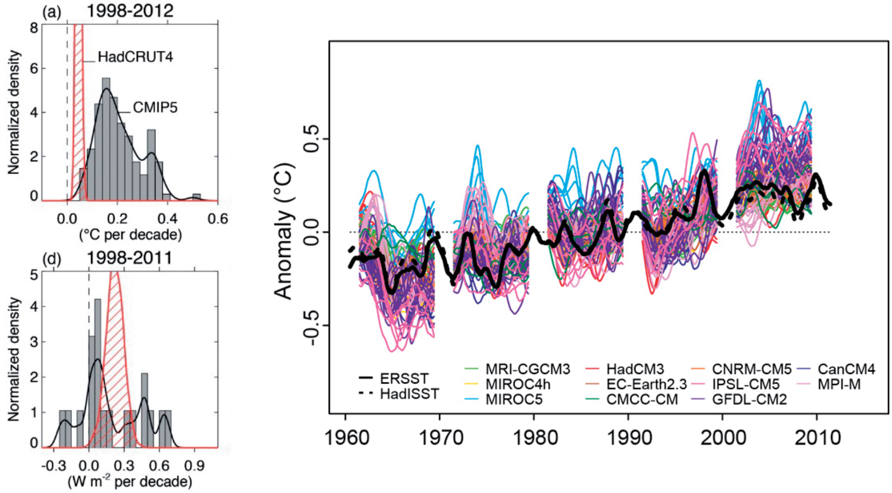

Figure 8.

Observed and simulated GMST trends in °C/decade, over the periods 1998–2012. For the observations, 100 realizations of the Hadley Centre/Climatic Research Unit surface temperature data ensemble are shown (hatched). For the models, all 114 available CMIP5 historical realizations are shown, extended with the RCP4.5 scenario from 2005 to 2012 (grey). (Upper left panel)

Trends in effective radiative forcing (Wm–2/decade) over the periods 1998–2011. The figure shows AR5 best-estimate trends (hatched) and CMIP5 (grey). Each histogram is normalized so that its area sums up to one. (Lower left panel.)

Time series of global mean sea surface temperature in the 60o S – 60o N non-polar latitudes from the anomalies of the CMIP5 multi-model initialized hind-casts. Results for each forecast system are plotted. Results for the start dates 1961–2001 are shown, while the model and observed climatologies to obtain the anomalies have been estimated using data from start dates every 5 years. The reference data (ERSST) is drawn in thick black. (Right panel.)

Source: IPCC WGI 2013: Fig. 1 and 11.2

The above Figures indicate that the Global Warming Hiatus creates challenges not only for impact, adaptation and mitigation, but also for climate sciences. Lack of proper simulation of the Hiatus by the climate models makes further development of these models rather actual.

2.3. The origin of the consensus on the anthropogenic reason of long-term global warming

Changes of climate can always be traced during Earth's history. Yet, historical changes have two common features: they were relatively slow and the processes were of natural origin in every case. In the recent century the situation has very likely been changing. Besides natural forces, human activity has been added to the climate factors. In a few decades it can change the present climate to such extent and rate that has not been experienced in the past one hundred thousand years. There is a broad agreement among the scientific reconstructions of mean air temperatures over the Northern Hemisphere. However, the key question of the issue is whether mankind is really responsible for global warming.

Figure 9 shows us the strongest argument for this statement, at least in the last 50 years. The observed series of the global mean temperature are successfully simulated by the interval of 14 global climate models reproducing the past changes under the influence of all known anthropogenic and natural climate forcing factors. When leaving out the anthropogenic ones, i.e. allowing just natural factors, like volcanic eruptions and solar activity to act, this simulation clearly departs from the facts.

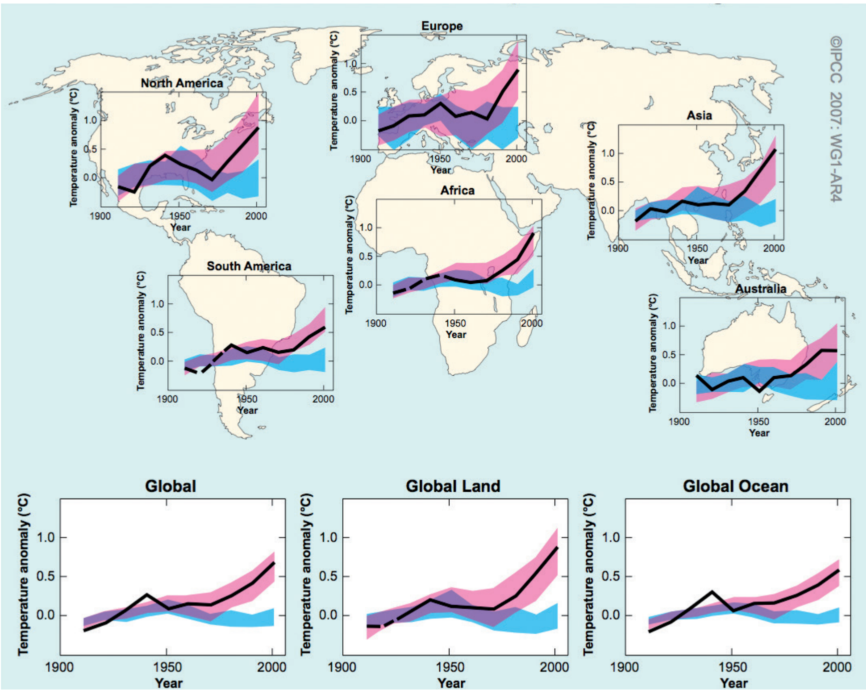

Figure 9.
Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models. Decadal averages of observations are shown for the period 1906–2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations by 14 climate models using both natural and anthropogenic factors.

Source: IPCC WGI 2007: FAQ 9.2, Figure 1

So, the warming of the recent half century could not happen without the anthropogenic factors. This statement can only be erroneous when two parallel strong mistakes occur. The first error being when scientists strongly overestimate the effects of greenhouse gases in their computations, and the second one, when the *true* reasons of the observed warming are not known at all. The probability of these two mistakes is assessed by the IPCC WGI (2013) Report as ≤5%. Until this unlikely combination becomes proven, the only smart decision is to get prepared for further warming, as it follows from the ≥95% likelihood of the anthropogenic origin.

3. Impact and Adaptation Tasks

Most of the living world's characteristics, as well as many features of the social and economic life have been developed basically in alignment with the climate of the environment. Hence, changes of climate may lead to significant impacts in the various geographical latitudes.

However, until we do not understand this recently enhanced ocean heat uptake, i.e. climate models are unable to simulate the pause in warming adequately, our all near-term climate projections may be wrong. This is illustrated by Figure 10 where climate projections starting from 2005 exhibit strong overestimation of the global mean temperature following any Representative Climate Projection (RCP) scenario, bearing in their abbreviations the expected radiative forcing in 2100 (in Wm^{-2}). Since even the longest adaptation processes need only 10–20 years to be performed, adaptation as a societal response becomes rather difficult due to the present inability of the models to perform scientifically correct near-term projections.

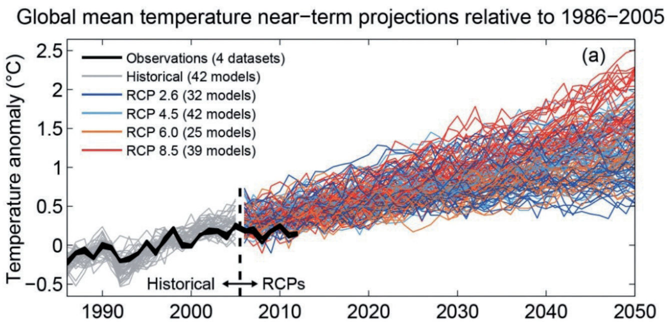

Figure 10.

Synthesis of near-term projections of global mean surface air temperature (GMST). Projections of annual mean GMST 1986–2050 (anomalies relative to 1986–2005) under all RCPs from CMIP5 models (grey and coloured lines, one ensemble member per model), with four observational estimates for the period 1986–2012 (black lines).

Source: IPCC WGI 2013: Fig. TS.14

The lack of strong tendencies in short-term future changes, however, does not mean that there is no need for adaptation. Due to the many weather extremes that still cause significant harm, the target of this should not be an expected future climate average. Increasing resilience against weather and climate extremes is important for all societies, especially in the tropical and subtropical countries, where sensible and latent energy is concentrated to a larger extent, but there are less resources in the societies to respond.

Though several adaptation steps also help in minimizing the losses by extreme events, we discuss the relation of weather risks to climate change in a wider scope, according to IPCC, SREX (2012). The *impact areas* of extreme meteorological events cover wide ranges. The disadvantageous impacts of extreme meteorological events include: floods, excess water, droughts, rainstorms, hails, heat waves, strong UV radiation, early and late frosts, snow jams, wind storms, forest and bush fires, effects of new pathogens and pests.

The IPCC, SREX (2012) assesses how *exposure* and *vulnerability* to weather and climate *hazards* determine the impacts and the disaster risk (Figure 11). It also evaluates the influence of climate variability and changes on the extremes. The Report also examines how disaster risk management and adaptation to climate change can reduce exposure and vulnerability to the extreme.

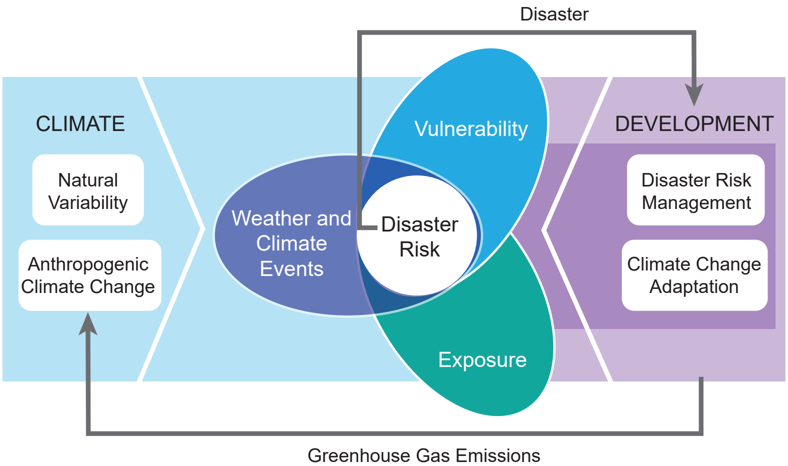

Figure 11.
Core concepts of natural and anthropogenic factors causing meteorological extremes, as well as the condition determining the risks and general ways of response by the society.

Source: IPCC SREX (2012): Fig. SPM.1

Furthermore, the Report provides a good collection of necessary measures to reduce the exposure and also the vulnerability against extreme events. Even if climate change does not convincingly influence the meteorological hazards themselves, the present frequency and the harm caused (i.e. the risks) are high enough even in the present climate to consider these possibilities and their possible synergies with adaptation to longer development of climate.

4. Mitigation

Finally, one should establish, that even if the not yet understood heat uptake timely disrupts all near-term climate forecast, it does not mean that the human influence on climate should be questioned (see above, related to Figure 7), or that the long-term warming expectations should be strongly revised. Apparently, ocean heat uptake may not be endless, since the ocean heat reservoirs become saturated at a point.

As Figure 12 demonstrates, this saturation may not be too far, since the vertical temperature gradient between the sea surface and 200 m below became ever decreasing after 1998. However, without correct modelling of the enhanced heat uptake, unfortunately one cannot state for how many years the pause in warming may continue in the future!

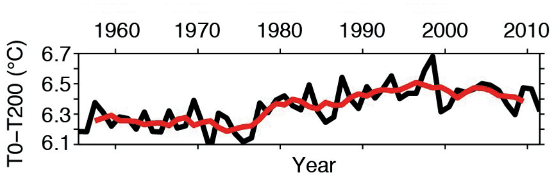

Figure 12.

Globally averaged temperature difference between the ocean surface and 200 m depth (black line: annual values, red line: 5-year running mean).

Source: IPCC WGI 2013: Fig. 3.1

Since the Framework Convention on Climate Change in 1992, the limitation strategies are scientifically established and politically encouraged even in countries with less economical potential. After the previous IPCC Report (2007), it became clear that we should establish so called tipping points, (Lenton et al. 2008) where our climate may exhibit irreversible changes (Table 1).

The melting of the West Antarctic ice sheet, the slowdown of the Atlantic thermohaline circulation and the El Nino – Southern Oscillation may turn into a new state after 3 K of global warming. The Greenland ice sheet starts melting after 1–2 K, the Arctic summer ice melts already.

15 years ago the fear from a new ice age was common following the famous Pentagon Report (Schwartz–Randall 2003) and the fiction movie *The Day after Tomorrow* in 2004.

Table 1.

The global tipping-points of climate to be avoided by reduction of greenhouse gas emission, to avoid the last three jumps.

Tipping element	Feature of system (sign of the change)	Control parameter(s)	Critical values	Global warming	Transition timescale	Key impacts
Arctic summer sea ice	Areal extent (–)	Local DTair, ocean heat transport	Unidenti-fied	+ 0.5–2 ºC	» 10 yr (rapid)	Amplified warming, ecosystem change
Greenland ice sheet	Ice volume (–)	Local DTair	+ » 3 ºC	+ 1–2 ºC	> 300 yr (slow)	Sea level + 2–7 m
West Antarctic ice sheet	Ice volume (–)	Local DTair or less DTocean	+ » 5–8 ºC	+ 3–5 ºC	> 300 yr (slow)	Sea level + 5 m
Atlantic thermo-haline circulation	Overturning (–)	Freshwater input to N Atlantic	+ 0.1–0.5 Sv	+ 3–5 ºC	» 100 yr (gradual)	Regional cooling, sea level, ITCZ shift
El Nino – Southern Oscillation	Amplitude (+)	Thermohaline depth, sharp-ness in EEP	Unidenti-fied	+ 3–6 ºC	» 100 yr (gradual)	Drought in SE Asia and elsewhere

Source: LENTON et al. 2008

However, even if the oceanic conveyor belt switched off totally, the consequence would not be a strong cooling, with significant glaciations, but an extremely contrasted temperature distribution between the continents and the ocean of the Northern Atlantic region. (WOOD et al. 2003) Hence, no scientific reason exists for considering a new ice age in connection with enhanced greenhouse effects.

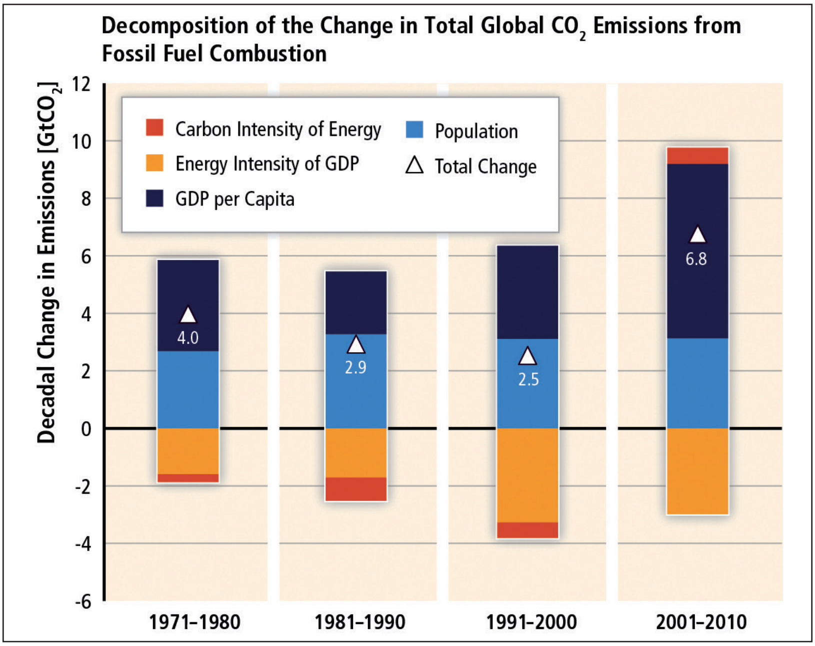

Figure 13.

Development of the four components determining the CO_2 emission. Note that, after three decades of improvement, carbon efficiency became weaker in the recent decade, i.e. unit energy production releases more CO_2, again.

Source: IPCC AR5 WGIII 2014: Fig. SPM3

Emission of carbon dioxide is a product of four components (Figure 13). They are the number of people on the Earth *(Pop);* the average wellbeing of each human *(GDP/capita);* the mean energy required creating one USD *(TPES/GDP)* and the mean CO_2 emission required to produce a unit amount of energy *(CO_2/TPES):*

$$CO_2 = Pop \times (GDP/capita) \times (TPES/GDP) \times (CO_2/TPES)$$

The values represented in Figure 13 indicate that:

- Despite the slowly decreasing speed of the global population growth, the absolute number of population increase and their contribution to the CO_2-emission is fairly constant between the decades;
- the increasing (global mean) living standard contributed to the greenhouse effect very much in the last full decade (2001–2010);
- energy efficiency has been improving even in the last decade, but the reduction in emission caused by this factor is less than in the previous decade;
- after three decades of successful improvement in the carbon-efficiency, the last full decade required more emission for consuming unit energy than a decade before.

Finally, Figure 14 indicates the importance of the possible tools to decrease greenhouse gas emission. They (from above) are renewable energy sources, nuclear energy, carbon sequestration, forest sinks and non-carbon dioxide greenhouse gases. As we can see, no single solution exists, i.e. all tools are needed to achieve stabilization!

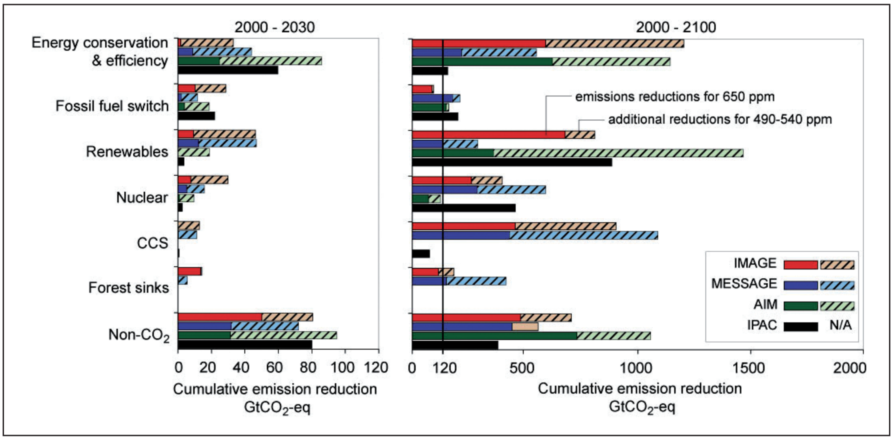

Figure 14.

Cumulative emissions reductions for alternative mitigation measures for 2000–2030 (left-hand panel) and for 2000–2100 (right-hand panel). The figure shows illustrative scenarios from four different economical models aiming the stabilization at 490–540 ppm CO_2-eq and at 650 ppm CO_2-eq, respectively. The dark bars denote reductions at the higher level and the light bars denote the lower level, respectively. CCS is carbon capture and storage from biomass. Forest sinks include reforestation.

Source: IPCC WG-III 2007: Fig 3.23

5. Post-AR5 Sources on the Global Warming Hiatus

All recent sources have the common feature that they state the start of the *hiatus* in 1998, so they include the El Nino peak (and the three cooler years afterwards), as well. As it is described in Section 2.1, these four years (1998–2001) were different from the following 12 years, since the latter period is characterised by a stagnating (or negligibly warming) trend.

The following section tries to comprehend the scientific papers that occurred after 2014, i.e. which were probably not taken account of in the last report by the IPCC WGI (2013).

The survey should start with the two comprehensive studies issued by the European Environmental Agency (EEA 2017) and U.S. Global Change Research Program (USGCRP 2017), but these studies do not add much to the Global Warming Hiatus.

The EEA (2017) does not even pay attention to the temporal temperature stagnation and the word *hiatus* is only found in one of the below quoted references. The USDCRP (2017) report documents the slower increase of tropospheric temperature observed by various satellite technologies (Table 2).

Table 2.

Global Trends in satellite-based Temperature Total Troposphere (TTT) values in 1979–2000 vs. 2000–2015. Note that the latter period contains two cold years at the beginning and two warm years at the end of the 2002–2013 period considered in the present paper. The original trends are given in Fahrenheit.

Data set	Trend (1979–2015) (°C/decade)	Trend (2000–2015) (°C/decade)
RSS V4.0	0.17	0.11
UAH V6Beta5	0.11	0.08
STAR V4.0	0.18	0.09
RSS V3.3	0.12	0.06
UAH V5.6	0.10	0.12
STAR V3.0	0.16	0.03

Source: USDCRP 2017: Appendix A, Fig A.1.

Furthermore, Chapter 1 of the USDCRP (2017) report devotes a point entitled *Was there a "Hiatus" in Global Warming?* The main statement of this point is that this period is too short to question the long term trend and that another slowly warming period occurred already in the middle of the 20th century. Please see the author's opinion below after having the arguments classified. The statement by the USDCRP (2017) is the most frequent one.

Besides the two sources above, Wikipedia (2018) can also be used as it contains a scholarly and continuously refreshing compilation, reflecting both scientific and British–American public media sources on the topic. In the following section, this study only takes account of the scientific papers, having studied all of them before including into this section.

The statements of the post IPCC WGI (2013) papers can be sorted into five different topics, allowing that one paper may contain more of the statements:

- There are errors *artefacts* (Karl et al. 2015) in the global air temperature series which amplify what seems like stagnation.
- This is just an internal fluctuation during a short period of time, not a reason to query the long-term trends. Such stagnation existed over a much longer period in the middle of the 20th century, too.
- The *hiatus* is well explained by the intense heat exchange with the oceans or in combination with known fluctuations in the external forcing factors.
- Some new external forcing factors (e.g. enhanced volcanic sulphur emission) as potential reasons were hypothesised, as new internal factors, short-term variations in the Pacific Decadal Oscillation and other circulation modes have been established.
- Since the full set of the global models show a much stronger warming than occurred during the hiatus period, there was an attempt (Risbey et al. 2014) that selected among the models according the success of simulating the ENSO phases.

Note that our survey will not include those numerous papers which further establish that the deep ocean warmed more rapidly and the sea level rose faster, since these facts are also well established by the IPCC WGI (2013) report. (This way, the third group of statements will not be complete.) At the same time, note that Steinman et al. (2015) and Xie et al. (2015) already state that the intense ocean heat uptake will finish soon.

In the first set of statements, Cahill et al. (2015) showed a statistical technique, the change point (CP) analysis, to identify the changes in the global temperature records. This analysis did not identify the present hiatus as a significant changing point. Despite the fact that the authors of this paper widened their analysis, (Rahmstorf et al. 2017) note that the method selected only the periods where the sign of the linear trends changed.

Still in the first group, two papers indicate that extremely high air temperatures occurred with increasing frequency even in the critical period over the continents. (Seneviratne et al. 2014; Sillmann et al. 2014) Karl et al. (2015) re-calculates the trends using corrected ocean water temperature data considering differences in the various observation techniques and a different geometry of the Arctic areas with more grid-points in this strongly reacting region. For the IPCC period (1998–2012), the new analysis has led to a warming that is double in strength at the global scale, 0.086° vs. 0.039°C/decade).

Concerning this correction, the author cannot provide a scientific argument. On the other hand, taken from the second set of statements, Figure 15 shows that in the recent *hiatus,* the observed series always runs below the simulation with a difference that increases in time within the slowdown period, reaching 0.2–0.3 K difference at the end (ca. 2013). In reaction to the second part of the second group, i.e. that such stagnating period also existed between ca. 1951 and 1972, one must point out the fact that in that older period the real near-surface air temperatures did not basically differ from the results of model simulations (CMIP-5).

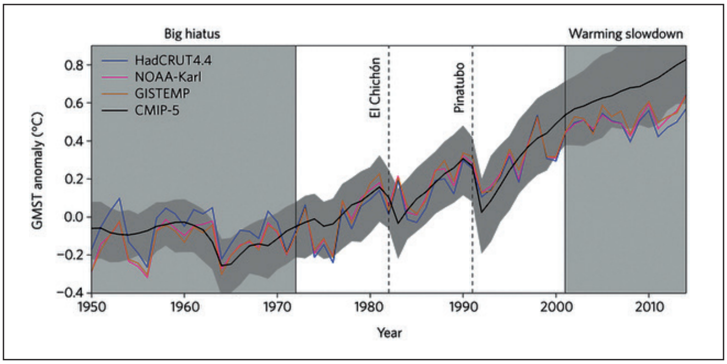

Figure 15.

Annual global mean surface temperature anomalies

Source: Fyfe at al. 2016: Fig. 1.

Concerning the third group of statements, enhanced volcanic emission has been established and forwarded as possible reason by Ridley et al (2014) and Santer et al (2014). These calculations are based on consideration of small post-Pinatubo (June 1991) volcanoes fully neglected by climate models. According to Ridley et al (2014) the global volcanic aerosol forcing since 2000 is $-0.19 \pm 0.09\ Wm^{-2}$, which is equivalent to a global cooling of 0.05 to 0.12°C. This could be a good reason of the hiatus, but the author of the present study could not find further supporting or questioning papers from the last four years.

As far as PDO oscillations are concerned, several papers highlight that (Dai et al. 2015; Trenberth 2015; Fyfe et al. 2016) this is not an external forcing factor and the final question of why it happened is still a scientific problem to answer in the future. The same doubt can be raised in response to further internal mechanisms, e.g. intensification of Pacific circulation (England 2014) and North Atlantic Oscillation (Li et al. 2013) found parallel to the reduced near surface warming of the atmosphere. This is the case even if a careful a posteriori process modelling simulates the slowdown as a result of a normal effect of a postulated 60 years' oscillation of the main atmospheric circulation modes and the long-term trend. (Yao et al. 2015)

Finally, concerning the pre-selection of the climate models according to ENSO, (Risbey et al. 2014) the author of the present study thinks that it is not a fully scientific approach either. The ENSO fluctuation is the result of a physical chain of the ocean–atmosphere interactions as the enhanced heat absorption by the oceans. Selecting those models which are successful in one side of the processes without identifying the physics behind them is not a satisfactory explanation of the hiatus in warming, especially if the coincidence of the simulations starts with the El Nino of the century which is – according to the author's view – not even a part of the real hiatus period.

6. Conclusion

The Global Warming Hiatus, started in ca. 2002 and finished in 2013, is a relatively long stagnation of the global mean air temperature, despite the increase of the greenhouse forcing. Most authors and the IPCC WGI (2013) report state that the Hiatus started in 1998. However, in the following years, the global air temperature turned back to its ENSO-free value.

As the analyses by the IPCC WGI (2013) correctly document, overall energy budget of the climate system has increased in 2002–2013 with unchanged pace, but most likely, the Southern Oceans absorbed the heat more intensively than before in the recent warming.

Considering the publications of the recent years surveyed in Section 5, there is a hope that the previously neglected smaller volcanic eruptions could really cause a substantial cooling as stated by a paper from 2014 and not supported by any other paper. The other approach of pre-selected models that are good in simulation of the ENSO is not scientifically convincing.

Without undoubted explanation of the reduced warming in 2002–2013, surprises to either direction may occur in the future, despite the broad scientific consensus on the anthropogenic reason of global warming. This makes successful adaptation to the changes very difficult, since adaptation can be performed during 1–2 decades in most respects.

At the same time, stagnation of the air temperature may not be a reason for any slowdown of climate change mitigation, since the extra heat is inside the system, and the vertical temperature gradient is already decreasing in the upper ocean, indicating that the strong heat absorption by the oceans is approaching to its end.

Since 2014, each year was warmer than 2013, so the global warming hiatus has surely finished. However, climate science cannot be stuck up. We do not know everything on climate change.

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Mikulas Monosi

Climate Changes and Their Impacts on the Population and Preparedness of Rescue Services to Help People in Need

1. Introduction

These days, climate change affects all the inhabitants of our planet Earth. Recently, increased attention has been paid to climate change, in addition to professional meteorologists and climatologists, also by the general public, resulting from various surveys. The real impacts on people by the variability of climate are often in the centre of attention, especially in periods with different weather anomalies compared to long-term averages (long-term averages are at least a 30-year period). Humankind must think about adequate preparation for these changes in climate, including adequate assistance to people in need as a consequence of climate change. (Lapin 2014)

2. Historical Trends of Global Climate Change

The trend of air temperature increase in most parts of the Earth, especially on the Northern Hemisphere and the Arctic, has overcome all the changes that have occurred over the entire period of meteorological measurements. (Stratégia 2017)

The observed rising trend of Earth surface temperature is the most noticeable sign of ongoing climate change. Global temperature has increased on average by more than 0.8°C since the industrial revolution (Figure 1), with the largest warming in the northern Polar Regions. Similarly, other indicators have changed, e.g. the water temperature in the oceans has increased into a depth of 3,000 m, the amount of water vapour in the air has also increased, the melting of permafrost has begun together with the melting of polar ice and mountain glaciers. Significant changes were also observed in total precipitations, salinity and pH indicator of seawater, but also in the air circulation of the atmosphere. (Stratégia 2017)

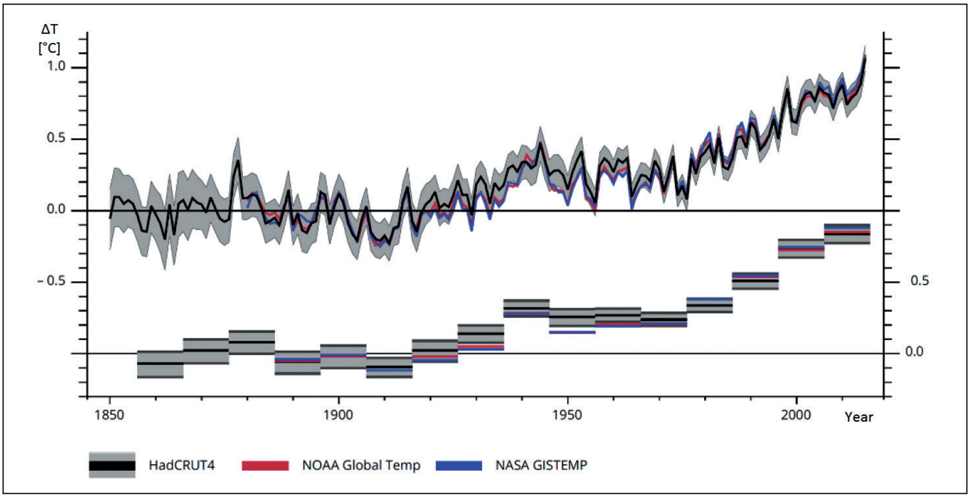


Figure 1.

Changes in the average global air temperature relative to the pre-induced period

Source: www.minzp.sk/files/odbor-politiky-zmeny-klimy/strategia-adaptacie-sr-nepriaznive-dosled-ky-zmeny-klimy-aktualizacia.pdf

The Central European region has general features of climate change. The warming is manifested in all locations and climatic areas. Trends in atmospheric precipitations are not as unambiguous, but this fact is due to their greater variability, as well as to the modification of the total sums by penetrating and convex influences.

The warming of the climate system is unquestionable, and since the 1950s, the series of observed changes has no analogues for many decades to a thousand years. The atmosphere and the ocean have warmed, the amount of snow and ice has fallen, ocean levels have risen, and greenhouse gas concentrations have increased. Each of the past three decades has been warmer near the Earth's surface than any previous decade since 1850 (Figure 1). In the Northern Hemisphere, it was probably the warmest 30-year period – between 1983 and 2012 – over the last 1,400 years. The linear trend of average global temperature has been warming by 0.85°C for the period of 1880–2012 (Figure 2).

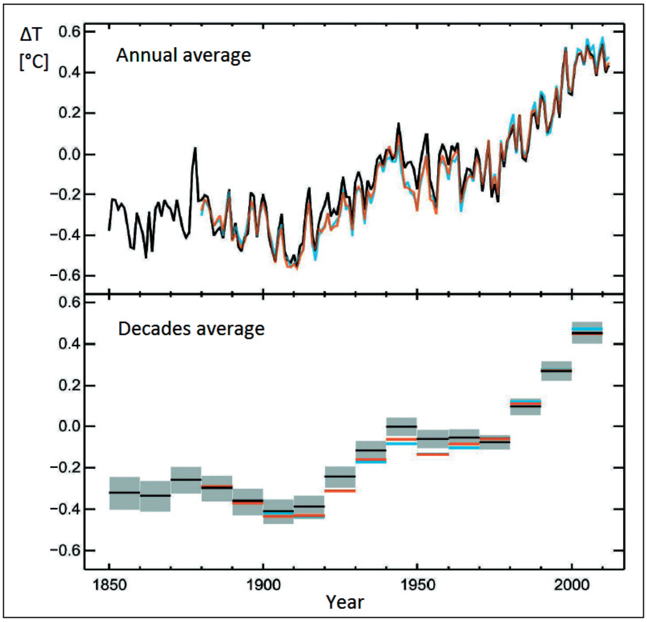


Figure 2.
Trends of global temperature changes

Source: www.minzp.sk/files/odbor-politiky-zmeny-klimy/strategia-adaptacie-sr-nepriaznive-dosledky-zmeny-klimy-aktualizacia.pdf

2.1. Causes of climate change

The climate is changing and has always changed in different time and space dimensions. The main factor determining the climate on Earth is the radiation and heat balance. Changes in individual energy flows are the impulse that can cause climate change. These impulses are caused by natural or anthropogenic factors. (Príčiny 2018)

In time values from thousands to millions of years, climate change was mainly caused by geographic and astronomical influences, their effects were exacerbated or weakened by feedback. Among these external influences, we classify changes of Earth's orbit parameters, changes in Earth's distribution of the continents and changes in solar activity. Another natural factor influencing the climate in a shorter time horizon is volcanic activity.

Anthropogenic factors mean the impact of human activity on different parts of the climate system. These are emissions of greenhouse gases, aerosols and other pollutants into the atmosphere (e.g. whether from industrial production, raw materials mining or agriculture activities), changes in surface properties (e.g. deforestation, construction etc.), interventions in the hydrological regime (e.g. construction of dams, changes in watercourses, irrigation systems), etc.

Also, assuming that all the factors determining the climate are constant, the climate still may change. We are talking about climate fluctuations (variability). This is not a change, but a variation around a certain average value with varying amplitude and period, and with varying spatial range. This variability is a consequence of the non-linear character of the climate system. An example of its manifestation is, for example, the phenomenon of El Niño or NAO. (Príčiny 2018)

3. Climate Change and Its Impacts in the Slovak Republic

The historical trend of climate change unambiguously shows us the need to prepare for its manifestations that effect humanity. The causes of climate change can also be attributed to human activities, which are not compatible with the right environment on Earth.

According to the Strategy of the Slovak Republic (SR), the historical trend suggests that climate change is real. After 1987, the air temperature average increased significantly in Central Europe, and the highest temperature records occur approximately 5 times more often than the lowest temperature records. Certain change also happened in the occurrence of atmospheric precipitation extremes. After 1975 there was a spacious deviation from the climate change, and not only regional but also the global average air temperature began to rise in a relatively rapid way.

For the period 1881–2017, in the Slovak Republic the following was observed:

- average annual air temperature increase of about 1.73°C;
- annual decrease of atmospheric precipitation averages by about 0.5% (in the south of Slovakia, the decrease was also higher than 10%, in the north and northeast the precipitation increased to 3%);
- decrease of relative air humidity (in the south of Slovakia since 1900 up to now by about 5%, in the other regions less);
- decrease of all characteristics of snow cover up to 1,000 m in almost the whole regions of the SR (its increase was recorded at a higher altitude);
- increase of potential evaporation and decrease of soil moisture – characteristics of soil and plant water evaporation, soil moisture and solar activity confirm that in particular the south of Slovakia is gradually drying up;
- changes in climate variability (especially the amount of precipitation) – examples of extremely wet and dry years are: extremely dry year 2003 and partly 2007, extremely humid years 2010 and 2016 and exceptionally dry year 2011 and partly 2012; over the last 15 years there was a significant increase in the occurrence of extreme daily and multi-day precipitation, which resulted in an increase in the risk of local floods in various areas of the Slovak Republic; on the other hand, in the period 1989–2017 much more often than before, there was local or total drought, which was caused mainly by long periods of relatively warm weather with small amounts of precipitation in any part of the vegetation period; the drought was particularly pronounced in 1990–1994, 2000, 2002, 2003 and 2007, in some regions of the west of the SR in 2015 and 2017. (Stratégia 2017)

This shows that the weather has become more extreme during the past decades (Figure 3). The statistical processing of the monthly temperature extremes indicates the fluctuations in the occurrence of extreme temperatures and precipitation in the decades since 1961 until now, but the trends of the given characteristics are relatively unambiguous.

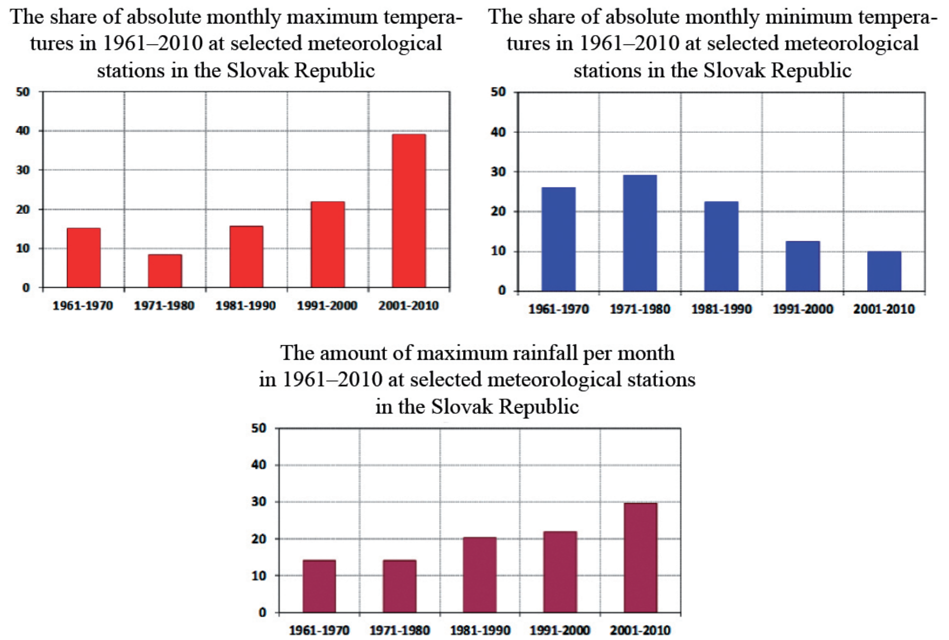


Figure 3.

The proportion of extreme temperatures and total precipitation in the individual period of 1961–2010 (SHMÚ)

Source: www.minzp.sk/files/odbor-politiky-zmeny-klimy/strategia-adaptacie-sr-nepriaznive-dosledky-zmeny-klimy-aktualizacia.pdf

3.1. The predicted trend of climate change in Slovakia

The predicted trend of climate change can be formulated as follows:

3.1.1. Air temperature

The air temperature diameters should be gradually increased by 2 to 4°C compared to the 1951–1980 average, while preserving the current yearly and inter-seasonal time variability. The daily minima should grow faster than daytime maxima of air temperature, which causes a drop in the average daily air temperature amplitude. Scenarios do not foresee any significant change in the annual air temperature, but in autumn months the temperature should be lower than the rest of the year. (Stratégia 2017)

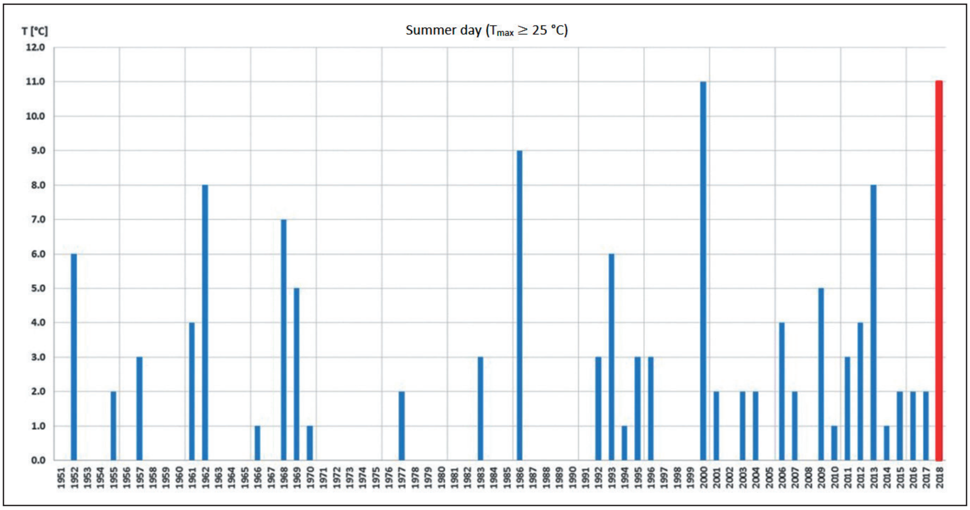


Figure 4.

The number of summer days at the Hurbanovo meteorological station in the period of 1951–2018

Source: www.shmu.sk/sk/?page=2049&id=926

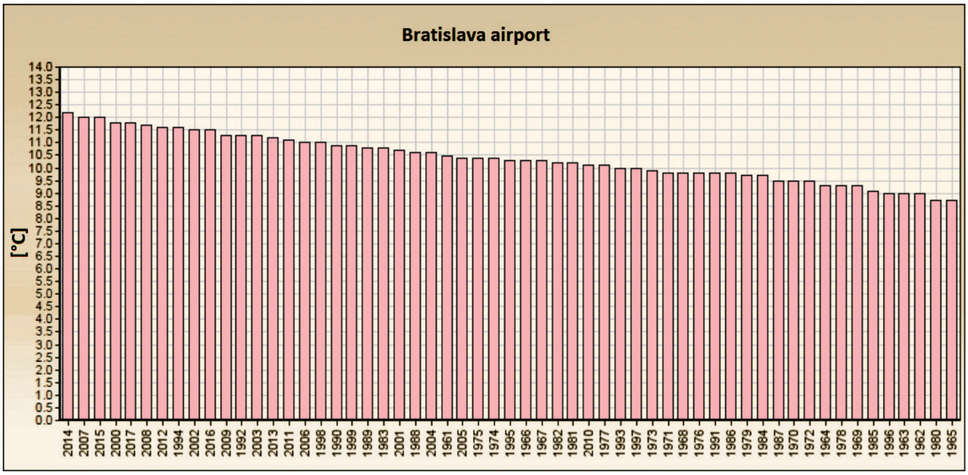


Figure 5.

Average annual air temperature in the years 1951–2017

Source: www.shmu.sk/sk/?page=1&id=klimat_operativneudaje1

3.1.2. Total precipitation

The annual precipitation totals should not change significantly, but rather a slight increase is expected (around 10%), especially in the north of Slovakia. Greater changes should occur in the annual precipitation and precipitation regime – a slight decrease in precipitation (especially in the south of Slovakia) is generally expected in the summer, and in the remainder of the year a slight to moderate increase in precipitation (especially in winter and in the north of Slovakia). (Stratégia 2017) In the warmer part of the year, the variation in precipitation is expected to increase, apparently prolonged and more frequent precipitation (dry) on the one hand, and drastically more shorter rainy periods on the other. Because warmer weather is expected in the winter, up to 900 m a. s. l., the snow cover will be irregular and there will be more frequent winter floods. The snow cover will probably be on average higher than 1,200 m a. s. l., but these positions represent in Slovakia less than 5% of the area, which cannot significantly affect the flow conditions.

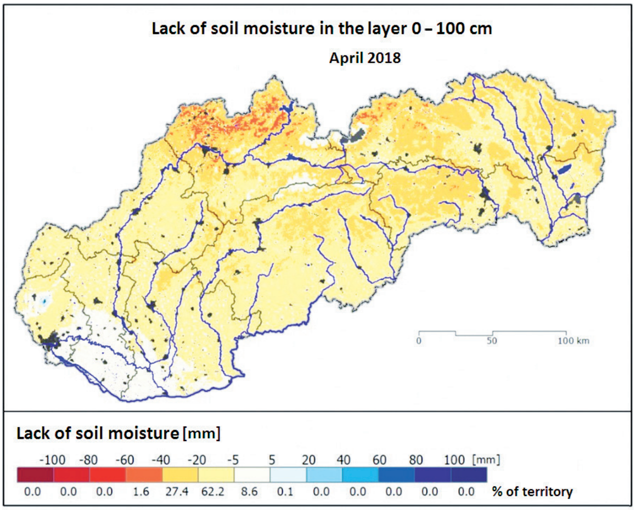


Figure 6.
Deficit of soil fertility

Source: Deficit 2018

3.1.3. Other Climate Elements and Characteristics

Due to the increase of storms in the warm part of the year, more frequent wind, storms and tornadoes are expected in connection with storms. A decrease in soil moisture in the south of Slovakia is expected and an increase potential evapotranspiration in the vegetation period of the year by about 6% per 1°C of warming, with precipitation in the vegetation period of the year not significantly increasing.

Climate change is occurring faster and has an increasing tendency. The average annual air temperature in the area of Bratislava has increased by 2°C over the last 67 years and is expected to increase further. According to the WHO estimates, between 2030 and 2050, climate change will cause about 250,000 deaths per year. It is precisely because of the extreme weather that protection will be more expensive and inaccessible in the future. The climate trend in the world raises questions about Slovakia's preparedness. (Prejavy 2018)

The Earth's surface temperature has an ascending trend, and this long-standing observation is the most significant manifestation of ongoing climate change. While the global average temperature of the ground atmosphere has risen by almost 1°C since the beginning of the 20th century, the region of Central Europe, including Slovakia, shows twice as fast warming in the same period. For example, in the region of Bratislava, the average annual air temperature has increased by almost 2°C since 1951.

3.1.4. Early start of spring

In Slovakia, we will also have to get used to a faster start of warm and dry weather in the spring season. Another expected manifestation of climate change in Slovakia will be the increase in daily maximum and minimum of air temperature. By 2050, there is a significant increase in the number of summer and tropical days, as well as the decrease in the number of frost and ice days. "The inhabitants of Slovakia must also assume that the intensity and duration of the warm-waves will increase. These waves can occur during May and will not be rare even in mid-September. It is also expected to have a higher number of days with sultry weather, in consideration of the increase of water content in the atmosphere." says Jozef Pecho.

3.1.5. Frequent storms, less snow

Because of the higher air temperature, the rate of evaporation will increase from the earth's surface, creating conditions for longer dry periods throughout Slovakia, especially in the southern half. As a result of higher air humidity, more frequent and stronger storms, as well as more intense precipitation are expected to present a more serious risk to human activities. Changes in temperature and precipitation rates in the winter will result in a decrease in the number of days with a snow cover and also in a decrease in the average height of snow cover. However, due to the increase in precipitation extremes, it is necessary to expect a higher occurrence of higher daily gains of new snow.

3.1.6. Climate change and its impact on health

Increasingly intense and faster climate change is considered to be one of the biggest environmental problems of today. These changes in air quality have a significant impact on water quality, stratospheric ozone depletion, declining biodiversity and soil degradation, as well as our health. "According to the World Health Organization (WHO) estimates between years 2030 and 2050, climate change will cause about 250,000 deaths a year due to the stress or under-nutrition that will result from drought. Climate change will also increase the cost of health care and solicitude. WHO estimates, that they will grow to 2–4 billion EUR a year by 2030." says David Balla from the Institute of Health Policy of the Slovak Ministry of Health.

3.1.7. Increase in insurance events

Insurance damage caused by meteorological phenomena on a global scale is on the rise for a long time, and the year 2017 has been a record year. Last year the volume of insurance events increased by 170% in comparison with the previous year and has become the historically most expensive year. Economic damage reached 357 billion USD and global insurance damages reached 134 billion USD.

Slovakia is particularly vulnerable to the presumptive increase of the intensity of storm events in the summer, which can result in higher damages caused by hailstones and floods. The expected increase in temperatures and droughts in Slovakia will also have an impact on agriculture and water resources. The accompanying phenomenon of this condition is now an even higher risk of fires. "The volume of insurance against fire and other property damages increased in 2017 compared to 2016 by 123%. At the Postal Insurance Company in the summer months, we regularly register increased reporting of life insurance claims." says Daniel Vida, Vice Chairman of the managing board of the Postal Insurance Company.

As a result of climate change, insurance protection is already too expensive and unavailable for some groups of physical and legal persons. "In the future, the cost of insurance will be even higher and there will be groups of people, fields and localities in Slovakia who due to the consequences of the ever increasing weather extremes, will be impossible to insure. In addition, the state by its intervention deteriorates the availability of insurance protection. An important negative impact on insurance protection is, for example, its burden with a new tax on insurance."

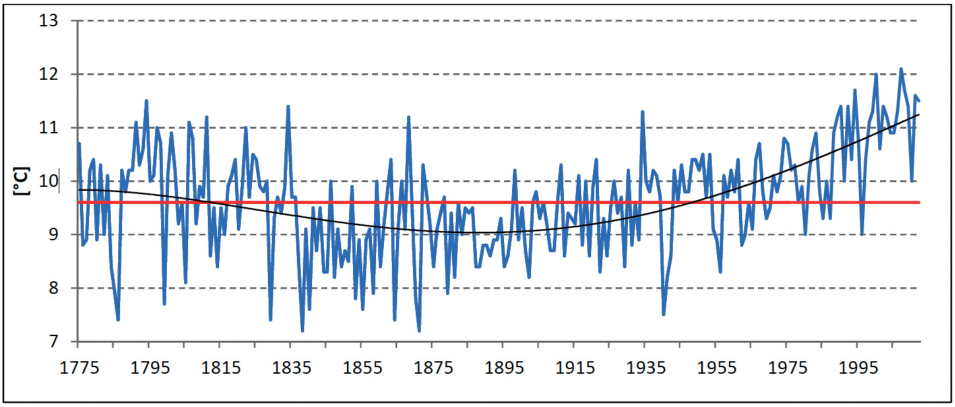
4. Manifestations and Impacts of Climate Change in the Czech Republic

In this part of the climate change assessment, we have to deal with the territory of the Czech Republic. In the introductory part of the Climate Change Adaptation Strategy, some definitions of the basic concepts have been made.

Climate change means in a climatological concept the change of climate in general. The natural and anthropogenic component of climate change cannot be separated from each other, so it is necessary to work with the resultants of both components. (Strategie 2016)

Climate is a long-term characteristic weather mode, conditioned by energy balance, atmospheric and oceanic circulation, earth surface characteristics and human activities. Therefore, not only the atmosphere, but also the processes in the other components of the climate system are involved in the creation of the Earth's climate. In a simple way, climate (or clime) is the *average weather* of several decades. To describe it, we use parameters like average air temperature, average precipitation, solar activity duration and intensity, wind speed, air humidity and other climatic variables over a longer period of at least 30 years (currently, the period of 1961 to 1990 is mostly used). However, we cannot only talk about average values, but also in the description of the climate we have to mention the variables that express its fluctuations (e.g. year-round variability, extreme values, etc.). (Príčiny 2018)

To illustrate the long-term development of the temperature and precipitation regime in the Czech Republic, observations from the Prague–Klementinum station which measures temperature since 1775 and precipitations from 1805 (Figure 7) can be used as a whole. It is to be seen that the end of the 18th century was associated with a rise in temperature that was shifted in the first half of the 19th century. Since the second half of the 19th century, temperature has gradually increased; the increase has been slowing down in the middle of the 20th century, but temperature has begun to increase significantly since the early 1980s. Seasonal processes also have very similar trends.



The legend:
red line - long-term temperature average; blue curve - annual average temperatures; black curve - 11-year continuous average.

Figure 7.
The average annual air temperature over the period 1775–2012, Prague–Klementinum

Source: UNFCC (s. a.)

4.1. Climate change and its causes in the Czech Republic

Climate change increases the probability of occurrence of extraordinary events. It is assumed that the intensity and frequency of extreme meteorological phenomena (extreme temperatures, precipitation, wind) and long-term droughts (water shortage in sources, limitation of groundwater resources), large scale floods, landslides (due to extreme rainfall) and extensive forest fires will increase. It may be expected that the frequency and intensity of the threat to the energy system resulting from these extreme meteorological phenomena will also increase. It is at the centre of interest to mitigate or prevent the threat to human life, health, the environment and heavy property damages. (Prejavy 2018)

In relation to the above-mentioned impacts of climate change, the protection of the population and the environment has great importance. Protecting the population is intended to minimize the negative impacts of possible extraordinary events and crises on the health and lives of people and their property. When there is a major frequency of climate-induced disasters in the future, it will pose increased demands for civil protection, especially for resources, crisis and rescue management, in a wider context than to public administration.

For this reason, climate change requires the adoption of precautions in the field of population protection and also the environment protection. These include, in particular, the technics and equipment of the units of the Integrated Rescue Services to process the emergencies, additional precautions in the field of crisis management preparedness and increasing the critical infrastructure resilience.

From the point of view of the Czech Republic's foreign and security policy, these potential impacts should be taken into account and further elaborated. Long-term rise in temperatures may encourage the occurrence of forest fires, which increase the risks of damages to property and the risks to human health and life, either directly or as a result of air pollution (increased release of carbon dioxide and nitrogen oxide), mainly in the urbanized area. The spread of forest fires has a significant impact on climate conditions – in case of long-term droughts, the fire spreads more rapidly, and this is also true for its spreading supported by the wind. Firefighting is particularly challenging for large volumes of water consumed, the technics capable of negotiating the terrain, overcoming the height difference by pumps and a great deal of human resources.

5. Selection of the Most Serious Events – The Impact of Climate Change

5.1. Floods

Floods in Slovakia are most common in the area of the Hornád and Slaná rivers in eastern Slovakia, Hron and Kysuca rivers in central Slovakia, the Danube and Ipeľ rivers in the south of Slovakia. The overflow of the river bed is caused by several factors. The most common cause is severe winter and consequently, heavy precipitation causing the environment to be saturated, which is no longer able to absorb surplus water, respectively glacier formation, ice barriers and subsequent drainage occur especially on water courses not treated by water bodies. The rise in water levels is also due to the melting glaciers in the Alps and global warming. The accumulation of water vapour in the atmosphere causes cloud increases and subsequent torrential rains.

All major floods on the Slovak section of the Danube River have originated mainly in the catchments of the Alps tributaries of the Bavarian and Austrian sections of the Danube. Water measurements on the Danube in Bratislava began in 1823, average daily flows and maximum annual flows are evaluated since 1876. The earliest written records of the floods on the (present) Slovakian section of the Danube date back to 1012. Further, the parameters of the great floods from 1210, 1342, 1402, 1466, 1499 may approach the floods in 1899 and 1954. The largest flood in more than 500 years in Germany, Austria and Slovakia was the flood in August 1501. Other major floods that occurred in July 1670, June 1682 and November 1787, are comparable to the recent floods that were in the years 1899, 1954 and 2002. (Analýza 2010)

Table 1.
The consequences of floods for the period 1998–2012

Year	Number of municipalities affected by the flood	Flooded area [ha]	Damage caused by floods [Bil. €]	The price for [Bil.€]		Total [Bil. €]
				Rescue work	Security work	
1998	75	3,952	33.34	3.94	1.28	38.56
2000	220	76,494	40.97	0.30	1.84	43.11
2001	379	22,993	65.08	1.90	10.7	68.05
2002	156	8,678	50.64	2.13	1.66	54.43
2003	41	744	1.43	0.19	0.14	1.76
2004	333	13,717	34.91	1.23	3.42	39.56
2005	237	9,237	24.03	2.24	2.67	28.94
2006	512	30,730	47.90	5.98	6.42	60.30
2007	60	339	2.49	0.30	0.21	3.00
2008	188	3,570	39.75	3.59	2.51	45.85
2009	165	6,867	8.41	1.59	1.30	11.30
2010	1,100	103,006	480.85	17.93	27.53	526.31
2011	87	3,076	20.01	2.00	12.58	34.59
2012	146	538	2.44	0.37	0.46	3.27

Source: www.enviroportal.sk/uploads/spravy/2012-05-4-havarie.pdf

In 2012, 146 cities and municipalities were affected, in total 269 residential buildings, 64 non-residential buildings, 353 hectares of agricultural land, 24 hectares of forest land and 161 intravilanes of municipalities and towns were flooded. (Správa 2012)

Figure 8.
Flood in Bratislava city in 2012 – the Danube River

Source: www.enviroportal.sk/uploads/spravy/2012-05-4-havarie.pdf

Written records of floods have been known since the earliest times. The worst floods in Slovakia occurred on the Danube in 1501 and are considered to be a three-thousand-year-record water level; the Danube flow then reached the limit of 14,000 $m^{3}.s^{-1}$ in Bratislava, one third more than the floods in later times. The long-term average flow of the Danube in Štúrovo city is 2,264 $m^{3.s-1}$.

Other floods with major economic and human damages have been recorded on the Danube River, e.g. in June 1965, when the catastrophe occurred due to the long-standing high status level to break the dam near the city of Patince and two days later nearby the city of Čičov. As a result, more than 54,000 people were evacuated from the affected areas, with 3,474 homes being completely destroyed. (Lapin 2014) Due to obedience and discipline, the flood did not require any sacrifice of human lives. (Stratégia 2017) Large floods were also known in the valley of the river Váh. One of the strongest took place on 26 August 1813, at least 243 people have lost their lives and heavy damages to property were recorded. Heavy floods caused a slow moving pressure on the Tatra Mountains on 28 and 29 June 1958, which caused precipitation totals exceeding 100 mm for 2 days. Water flows have exceeded their 100-year maximum. (Počet 2018) A similar situation was repeated in the Tatra Mountains in July 2008. Among the floods that threaten its floodplains are the rivers Hron, Morava, Poprad, Dunajec, Bodrog and Hornád in the confluence with Torysa.

One of the most famous floods caused by torrential rain was the flood on the Little Svinka River on July 20, 1998 when precipitation in the Bachuren Mountains amounted to 100 mm in about 1 hour. This caused a 4 m high flood wave, which hit the village in the lower part of the flow. In the village of Jarovnice, water has destroyed a number of homes and caused the death of 50 people.

5.2. Muddy avalanche

For the last couple of years, we have registered a remarkable increase in the occurrence of exceptionally high rainfall in the Slovak Republic. More often than not, we are confronted with the danger of extreme precipitation.

Among the most extreme torrential rain recorded in Slovakia is the rainfall cloud of July 12, 1957, north of Štúrovo city, where 228.5 mm of water fell in 65 minutes.

On July 21, 2014 the Slovak Hydro-meteorological Institute issued a 1st level alert for Žilina city and its surroundings. (Povodňová 2014; Liščák et al. 2014) As a result of sudden storms and heavy precipitation, a flood wave flooded many villages in northern Slovakia, including the city of Žilina, where traffic in the city was paralyzed for several hours. The underpasses have been also flooded.

Under the influence of extreme precipitation and extensive landslides a flood wave was created, which destroyed the entire upper part of the Varinka river basin and Terchová village.

Examination of the preparedness and operational capacity of the Integrated Rescue Services was to remove the consequences of a mud-stone avalanche that hit a recreation centre in the Little Fatra Mountains on July 21, 2014 in the afternoon. There was a gradual release of earth and massive rocks that, in conjunction with the dripping water, formed a massive mud-stone avalanche. The avalanche crossed the steep slopes for nearly 2 km, the lower station of the cableway, adjacent car parks and the only commute from Terchová village was hit the most. Unbelievable is the result of the destruction of Nature. Not a single person was injured and nobody died.

Mountain rescuers had to evacuate more than 120 tourists from the devastated area, who gradually concentrated in the vicinity of the ruined parking lot. More than 50 motor vehicles were destroyed in the car park, some of which were released from mud and rock deposits after two days. For a regular motorist, it was not possible to identify the original motor vehicle. The repair of the damaged ropeway in the resort was completed three months after the accident.

The only access road was totally destroyed – flushed more than 1.5 km. In order to save people from the affected area and to remove the consequences of the natural disaster, rescue forces from almost the entire Žilina region were called.

It is difficult to prepare for these disasters, but with effective measures we can reduce the impacts and perhaps the likelihood that landslides will occur, such as afforestation instead of headless deforestation.

Figure 9.

Catastrophic mudslide

Source: MONOŠI 2015

Figure 10.

Mudslide in the Little Fatra Mountains on 21st July, 2014

Source: www.shmu.sk/File/Hydrologia/Publikacna_cinnost/2015/2015_MPaPRaHD_Liova_kol_Prirodna_katastrofa_vo_Vratnej_doline.pdf

All sections of the civil defence and the Mountain Rescue Service were involved in the rescue operations.

5.2.1. The Czech Republic

The flood in the Czech Republic in 2002 was one of the most important events of its kind in the history of the Czech Republic. Together with the floods in the Morava region in 1997, it is one of the most calamitous natural disasters of modern Czech history. It was the biggest flood since the devastating Great Flood of 1845. (Povodeň 2002)

The flood in numbers: 17 people died, 134 animals lost their lives in the Prague Zoo, a state of emergency was declared in 6 counties, 753 affected villages, 225,000 evacuees, 73.3 billion CZK loss, of which over 6 billion CZK from the Prague metro, the highest water flow on the Vltava river in Prague 5300 m³/s.

Figure 11.

Flood in Prague

Source: https://cs.wikipedia.org/wiki/Povode%C5%88_v_%C4%8Cesku_(2002)#/media/File:CharlesBridge-2002floods.JPG

Figure 12.

Bridge over the river Písek

Source: https://cs.wikipedia.org/wiki/Povode%C5%88_v_%C4%8Cesku_(2002)#/media/File:Pisek_povoden.jpg

5.3. Wind calamity

The climate change is also reflected in an increase in the number and intensity of wind shocks. Meteorologists and rescue services are witnessing ever-increasing incidents, with increasing devastating effects on buildings and stands. Most common wind shocks occur during the summer months when the pressure queue passes. Exceptionally, however, they also occur in spring or autumn months, when rapid warming ensues after a significant warming. The result is a significant water flow, often associated with torrential storms.

The most widespread wind shock in the last hundred years hit the territory of the High Tatra Mountains on November 19, 2004. *Tatranská Bora* reached wind speeds of up to 230 $km.h^{-1}$ at the upper border of the forest and caused the devastation of the forest cover on an area of 12,600 hectares. Fallen trees created a nearly continuous barrier of 3 to 5 km wide and its length reached up to 30 km. Falling trees killed only one person and two people were killed in a passenger car.

The total volume of wood that was destroyed in less than 3 hours was estimated at 2.5 million $m.^3$ For the unblocking of road, rail and energy infrastructure, almost 950 professional firefighters were deployed over the next 13 days, saving and transporting nearly 100 people from the affected area. Rescue works were complicated in the early hours by a strong wind and in the following days, heavy frost and heavy snowfall. In the worst sections of the transport infrastructure, wood was laid up to a height of 6 m. Rescue units removed wood from public roads in a total length of 101 km. Subsequently, it was necessary to remove the spikes of trees captured on 170 objects – residential houses, family houses, recreational buildings, hotels, service objects, etc. More than 260 freight and transport vehicles, more than 200 motor saws were used. The total cost of the rescue and restoration work exceeded 10 million EUR. (All the related data were presented by Ing. Marián Lopúch OR HaZZ Poprad).

Knowledge learned from the elimination of the consequences of wind calamity:

- insufficient space capacities of territorial HaZZ for temporary accommodation and boarding of members of other intervention units;
- insufficient technical equipment for setting up a mobile command post;
- insufficient provision of individual intervention sections by means of connecting and communication means;
- problematic supply of intervention areas by food, hot drinks and fuel.

These shortcomings have been greatly eliminated in the coming years by strengthening the material, technical and personal equipment of the Fire Brigade of HaZZ, which in the long run creates the necessary mobile accommodation facilities with complete security – feeding, hygiene, rest and medical treatment of minor injuries.

In the following years, the firefighters and rescuers also had to deal with the consequences of the wind calamity, because it was impossible to remove the wood from such a large area. After drying it has enormously increased the risk of calamity fire in the summer months. In July 2005, the aforementioned fire broke out and spread to an area of 250 hectares.

The second largest wind calamity affected mainly the Orava region and the Slovak Rudohorie Mountain on 14–15 May 2014. Wide beech forests were destroyed. Major damages to property were recorded in almost all of Slovakia. In the following month, June 12, 2014, the plants were destroyed in the protected areas of the Western Tatras and the Choč Mountains. Remote localities – Prosiecka and Kvačianska dolina were rendered inaccessible.

During the removal of the debris of wind calamities in areas with a higher degree of protection (e.g. national parks), forest-protecting and ecological civic associations play an important role in preventing the forestry from removing damaged trees. The result are often negative phenomena – the spreading of woodworms and the subsequent dying of undamaged trees in the vicinity of the disaster. Subsequently, there is soil erosion and weakening of the soil cover in the forests. In case of torrential rain, they cause extensive flooding of the released soil, thereby increasing the risk of wetlands and avalanches. The consequences of such interventions are evident at present throughout the High Tatra Mountains. Negative consequences are evident already in the forests on the other side of the High Tatra Mountains in Poland.

A positive example from the past is the liquidation of the consequences of a massive calamity in the Horehronie region, when on July 8, 1996, the wind calamity destroyed nearly 2,400 hectares of forest cover. For the next few days almost 200 forest mechanics and trucks were concentrated in the area. 22 cableways were built in inaccessible terrain. Approximately 80 trailing horses were attached to the tree trunks on the forest paths. 80% of the fallen trunks were harvested over the next 12 months. Subsequently, areas planted with new forest cultures were paid. The forest is restored today, it is healthy and is not affected by a critical amount of underwater insects. There was no major fire in the area of the calamity.

5.4. Fires in the natural environment

The total area of the Slovak Republic is 49,037 km.^{2} The territory of the Slovak Republic is quite rugged. Except for the four lowlands, the most extensive of which is the Danube Lowland in southern Slovakia and the East Slovakia Lowland, the country consists of mountains. The most famous mountains are the High Tatras, the Low Tatras, the Little Fatra, the Great Fatra, the Slovak Paradise and the Slovak Rudohorie Mountain.

In Slovakia, 9 national parks provide large-scale nature protection, with the largest and oldest Tatran National Park. Altogether, 1,082 small-scale protected areas, 382 sites of European significance and 38 protected bird areas are registered in Slovakia.

Slovakia has developed agriculture using 19,350 km^2 of agricultural land (39.5% of the surface area). Up to 44.3% of the territory of the Slovak Republic (2.17 million hectares) is afforested. 60% of the forests consist of deciduous trees and 40% conifers; 60 to 100-year-old trees prevail. Among the trees, beech is the most represented, with a share of over one third of all trees, then spruce and oak. 60% of forest land plots are managed by state organizations. In terms of the number of fires in fire statistics, there are annual fires occurring in the natural environment.

Forest fires are a frequent phenomenon in a dry spring season. According to the above-mentioned statistics, the firefighting activities of the firefighting units for the period 2000–2015 show that fires in the natural environment represent about 30% of all interventions. The occurrence of fires in the natural environment is significantly influenced by climatic factors, especially long-lasting hot and dry weather.

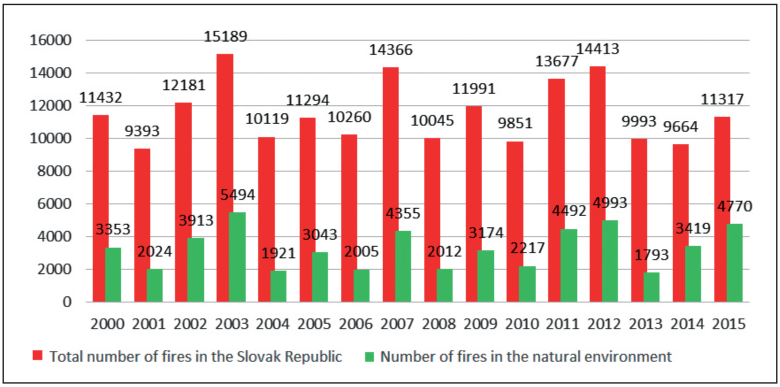


Figure 13.

Number of intervention to fires and fires in the natural environment in the period 2000–2015

Source: Lanďák 2012

Table 2.

Parameters and causes of major forest fires in the Slovak Republic in the period of 2000–2007

Territory	Slovak Paradise 2000	High Tatras 2005	Slovak Paradise 2007	Old Mountains 2007
Area of the affected territory [ha]	67	250	18.5	120
Participation in extinguishing	2,981 people	354 people	650 people	154 people
Extinguishing – duration [days]	11	10	15	10
Cause of fire	human factor	human factor	lightning strike	human factor
Damages [€]	12,154,00	564,297	3,700,00	228,042

Source: Lanďák 2012

The elimination of these fires is difficult in terms of the number of incendiary firefighters and inaccessibility by mobile technology (especially forest fires).

6. Strategy for Adaptation to Climate Change in the Slovak Republic and in the Czech Republic

The effects of climate change in the Slovak Republic and the Czech Republic over the last period clearly confirm the need to prepare for its consequences. Manifestations of climate change are indicated in individual cases of floods, forest fires and landslides in the Slovak Republic and the Czech Republic. First of all, it is about the safety of the population and the preparedness of the fire and rescue services to help people in need.

The Neighbouring States of the Slovak Republic and the Czech Republic, on the basis of the recommendation of the European Commission for Climate Change, prepared a *Strategy for Adaptation of the Slovak Republic to the Adverse Effects of Climate Change* and *Strategy for Adaptation to Climate Change in the Czech Republic.*

The Strategies of the Slovak Republic and the Czech Republic addressed the issue of climate change from a global, continental and national point of view. They have solved the impact of climate change on individual areas of human activity. At the end of the strategy, they set out the different tasks to meet the climate change adaptation strategy objectives. (Srategie 2016)

6.1. Strategy for Adaptation to Climate Change in the Slovak Republic

The main objective of the *Strategy for Adaptation of the Slovak Republic to the Adverse Effects of Climate Change* is to improve the preparedness of the Slovak Republic to face the adverse consequences of climate change, to provide the widest information on the current adaptation processes in the Slovak Republic, and to analyse the institutional scope and coordination mechanism to ensure the effective implementation of adaptation measures at all levels and in all areas, as well as raising overall awareness of this issue. (Srategie 2016)

Based on an analysis of the situation at international, European and national level, the inter-ministerial debate and stakeholder consultation, the following sub-objectives and adaptation frameworks have been identified that contribute directly or indirectly to the main objective of the national adaptation strategy:

1. To ensure the active creation of a national adaptation policy

   Scope measures:
   - Periodically evaluate the state of the adaptation policy and update all guidance documents in line with the learned knowledge.
   - Improve the institutional scope and the coordination mechanism for adaptation at national level. Add or adapt the legislative framework to support the adaptation process. Incorporate current knowledge of science and research into the development of adaptation policy. Effective implementation of adaptation measures and monitoring the effectiveness of these measures in practice.
   - Ensure sustainability of funding for the implementation of priority adaptation measures from international grant programs and public resources by 2020, looking for public and private resources beyond 2020.
   - Prepare a set of indicators for monitoring, evaluation and review of adaptation measures.
   - Develop a system of action plans for a national adaptation strategy that would strengthen the implementation of key adaptation measures in the areas concerned and contribute to better reflecting the adaptation measures in the sectoral policies of the affected sectors. Key adaptation measures will be identified in the process of preparing action plans.

6.2. Strategy for Adaptation to Climate Change in the Czech Republic

The objective of adapting to climate change is to reduce the vulnerability of the system (natural and socio-economic) in a timely manner and to increase their resilience to their impact without jeopardising the quality of the environment and the economic and social potential of the development company. Adaptation is a set of measures that have been developed progressively, gradually and in the long run, as well as the actual process of their implementation over time.

Adaptation to the effects of climate change includes preventive measures, measures to increase system resilience, preparatory measures, response to adverse events and activities that restore the system's function. (Srategie 2016)

Scope Measures of Climate Change in the Czech Republic: (Srategie 2016)

- Identify the priority areas (sectors) that are most affected by climate change (nature and landscape, air, agriculture, industry, health, safety, population protection and crisis management, etc.).
- Structure information with the risks and predicted impacts of climate change in these areas, define the general principles of adaptation measures, identify priorities, draw attention to sectoral linkages and link with individual measures, and set out guidelines and examples of appropriate adaptation measures.
- Analyse the current state of the legislation in the given context and propose the necessary legislative changes.
- The strategy also provides a scope assessment of the financial difficulty of implementing the proposed adaptation measures, an analysis of the impact on the business environment and the quantification of costs in case of inaction, followed by the presentation of current and prospective economic instruments and the possibilities of their use.

The adaptation strategies for climate change in the Slovak Republic and the Czech Republic correctly describe the individual activities that are necessary to reduce the danger and threats to human life. It is necessary to stick strictly to the right direction of adaptation to climate change. It is very important to inform the public about how to reduce the effects of climate change and how to prepare for the sudden change of weather in case of extraordinary manifestations.

7. Preparedness of Slovak Fire Units to Deal with the Consequences of Emergencies Due to Climate Change

The preparedness of the Slovak Republic for climate change comes from the individual experiences of the Slovak population with nature. The individual consequences of climate change are described in more detail in the second part of the chapter where it is stated that the preparation for individual extraordinary manifestations of climate change is necessary. On the other hand, some emergencies have convinced us that it is not possible to prepare quintessentially for all kinds of situations and throughout the whole country of the Slovak Republic.

7.1. Preparedness of fire and rescue services of the Ministry of the Interior of the Slovak Republic for climate change

In this section, we would like to describe in more detail the preparedness of the Fire and Rescue Services for floods and forest fires, which lately have affected individual regions of the SR more. These extraordinary events had to be resolved, and so projects were prepared to protect the population from the dangerous effects of climate change.

One of the important projects to protect the population from floods was called *Active Flood Protection Measures* (hereinafter referred to as AFPM). (Aktívne 2015)

By the decision of March 23, 2015, the European Commission approved a financial contribution from the Cohesion Fund for a project entitled *Active Flood Protection Measures* for the Ministry of the Interior of the Slovak Republic. The project is part of the Operational Program of Environment within Priority Axis 2: Flood Protection and its total budget amounts to 159,719,101 EUR.

The individual activities and their deployment were designed on the basis of a detailed analysis of flood risks and interventions in the Slovak Republic in recent years. This analysis is based on national analyses relating to flood risk assessment, as well as an in-depth comparative analysis of the available and necessary technical intervention equipment of professional intervention units, such as the Fire and Rescue Services of the Ministry of the Interior of the Slovak Republic, Voluntary Fire Brigades and the Slovak Water Management Company.

In order to mitigate the negative consequences of floods throughout Slovakia, the project will support rescue units at four horizontal levels:

- local level
- regional level
- national level
- European level

Assistance in the form of special flood protection will be distributed to the Fire and Rescue Services, to the Slovak Water Management Company and to 771 municipalities. At the local level, first aid intervention packages during floods will strengthen the technical equipment of the volunteer Fire Brigade to make it easier to deal with extraordinary events and emergencies.

The project also includes training and instructions of intervention capacities for the manipulating and usage of the equipment, and the education will be implemented in the regions according to the respective municipalities.

7.2. Local level – Cities and municipalities

To facilitate self-governments and manage emergencies at local level in case of a flood, first-aid intervention packages are available. The flood protection technics for the intervention of voluntary fire brigades will be distributed to 771 most vulnerable municipalities. The key to the choice of municipalities to which assistance is addressed was the factor of flood risk, as well as a detailed analysis of the database of firefighters' and rescuers' interventions.

Special technics will enable local governments to respond quickly to the crisis situation in case of a flood and at the same time to obtain a certain degree of self-sufficiency. Technical means is part of a trailer, making it easy to move from one place to the other. These packages will be stored directly in vulnerable communities, reducing the response time to an extraordinary event and reducing the extent of damage caused by floods.

7.3. Regional level – Self-governing regions

Helping to place the flood situation under control and mitigate their consequences in the regions is the task of intervention packages designated for each of the eight self-governing regions. This will significantly increase the safety and protection of the population in high-risk areas.

Eight regional intervention packages are designed to improve preparedness and reaction time of the units of the Fire and Rescue Services in order to protect the people and their property. Four other packages of equipment will help the Slovak Water Management Company in managing the flood risk system.

A total of twelve packages of technical intervention equipment will be available at the regional level, which significantly shortens reaction times and increases the quality of intervention in the affected area.

The packages of technical intervention equipment for self-governing regions include pumping systems, vehicles for evacuating victims and carrying rescue workers in inaccessible terrain, and containers for long-term intervention.

7.4. National level – National flood protection modules

To strengthen the preparedness of the country for floods, we have national flood protection modules made up of qualified fire and rescue units with modern equipment. Expert teams equipped with special and high-capacity devices will be able to intervene quickly in extreme situations throughout Slovakia and abroad.

Two specialized flood protection modules will be created:

- the national flood protection module using boats
- the national water purification module

Specialized intervention equipment can fulfil the needs of the entire territory of Slovakia. The equipment includes mobile fuel tanks and water purifiers, vehicles, oil product separators, boats, transmitters, rescue equipment for aircraft and water rescuers, and a large-capacity generator for electric power.

7.5. European level – European civil protection modules

A part of the flood protection equipment will serve to create specialized modules that will be part of the European Union Civil Protection Mechanism. Thanks to these equipment, Slovakia will be committed to its partners and will contribute to a Europe-wide civil protection system in accordance with the European Union (hereinafter referred to as the EU) policies. European civil protection modules will be registered under the European-wide system called CCISE – Common Communication and Information System during Emergencies. Two European civil protection modules will be created:

- The EU civil protection module specializing in high-capacity pumping in affected areas.
- The EU civil protection module designed to deal with floods includes flood barriers, universal loaders, container for a long-term intervention equipped with device for heating and food outgoing, and for personal hygiene, platform containers, multi-purpose vehicles for transportation of rescuers and material in inaccessible terrain and for dams with unpaved surfaces.

The module is a mobile team composed of one group or several groups of members of the Fire and Rescue Services (hereinafter referred to as a *member*) with the requisite professional competence and material-technical equipment, that are self-sufficient and independent in fulfilling the tasks and rescue works of the fire units in the defined area (floods, fires, etc.).

The logistics unit is a mobile team composed of one group or several groups of members with the requisite professional competence and material-technical equipment, which in particular ensure the self-sufficiency of the modules in performing the tasks.

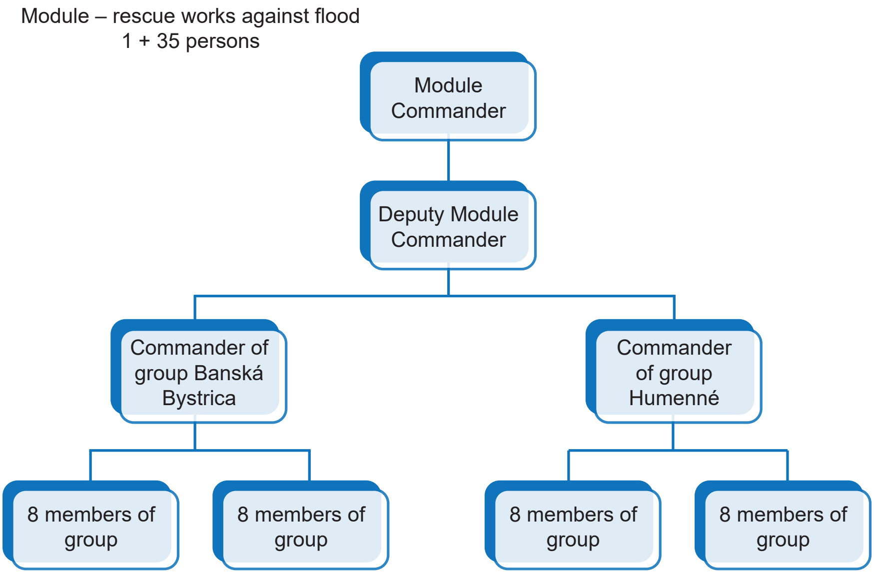


Figure 14.
Organizational structure of the module – rescue works against floods

Source: Modul 2014

7.6. Fire in the natural environment and preparedness of fire units for intervention

Fires in the natural environment are one of the negative manifestations of climate change. In general, it can be said that the cause of most of these fires are the people who unintentionally cause them. On the basis of forest fires in Slovakia in the year 2000, when six people fell victim to the fire, it was necessary to radically address this situation. After this tragic event, new technics and technical means for extinguishing natural fires were purchased. Air fire extinguishing modules were also created, later renamed to ground fire extinguishing modules.

7.7. Ground fire extinguishing module

This module was established on the basis of national needs for forest fire extinguishing in difficult and inaccessible mountain terrain. (Apo 2017)

The ground fire extinguishing module was later guided by the organizational regulation of the President of the Fire and Rescue Services of the Ministry of the Interior (Order of the President of HaZZ MV SR No. 24/2014).

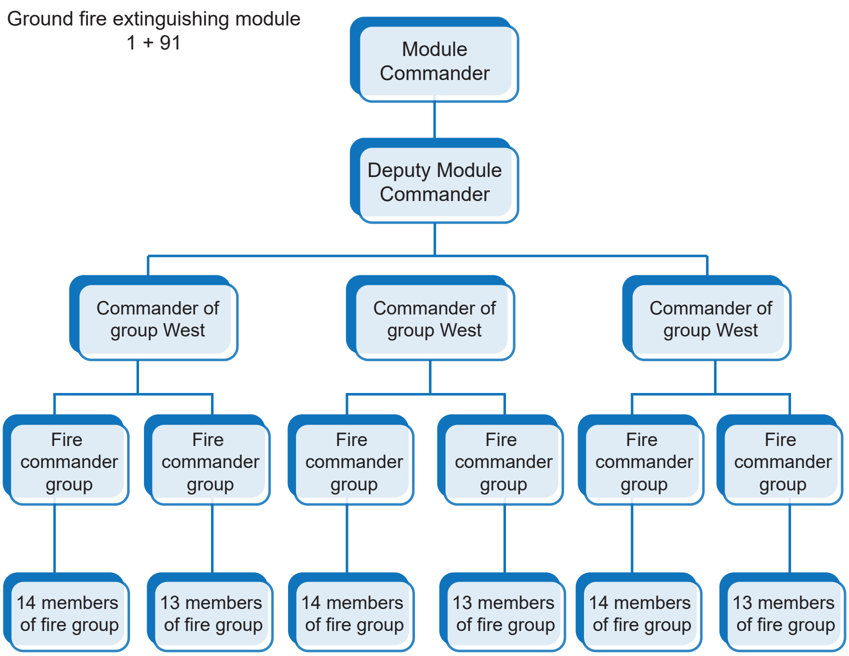


Figure 15.
Ground fire extinguishing module

Source: Modul 2014

The ground fire extinguishing module performs the following tasks:

- rescue of persons using ground vehicles and aircraft if their life or health is endangered in inaccessible areas, especially mountainous forest areas affected by fires
- extinction of large-scale forest fires and wildfires in inaccessible and difficult mountain terrains using ground and aircraft means
- transporting the personnel and material to the forest fire-fighting site on difficult terrain;
- air transport of special fire extinguishing agents and supply of intervention units in inaccessible areas affected by fire

Organizational division of the module:

- MODUL WEST (OR HaZZ in the city of Pezinok and the Fire and Rescue Corps of the capital city Bratislava)
- MODUL MIDLANDS (OR HaZZ in the city of Banská Bystrica and OR HaZZ in the city of Zvolen)
- MODUL EAST (OR HaZZ in the city of Poprad and OR HaZZ in the city of Prešov)

8. Conclusion

The preparedness of the Fire and Rescue Services of the Ministry of the Interior of the Slovak Republic is at an excellent level as it can be seen in the organization of individual modules and also in securing the technical equipment purchased in recent years. Despite the degree of preparedness of professional firefighters, it is still necessary to pay attention to the local level, i.e. to the preparedness of towns and villages (voluntary fire brigades), where, on the one hand, technical means have been delivered. On the other hand, it is necessary to pay increased attention to the training of fire brigade units and the cooperation between professionals and volunteer firefighters.

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László Halász

Climate Change and Extreme Weather Events

1. Introduction

The climate change or global warming significantly affects extreme weather events. The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2013) states that averaged over all land and ocean surfaces, temperatures have increased roughly 0.85°C from 1880 to 2012. Because oceans tend to warm and cool more slowly than land areas, continents have warmed the most. In the Northern Hemisphere, where most of Earth's land mass is located, the three decades spanning 1983 through 2012 have likely been the warmest 30-year period of the last 1,400 years, according to the IPCC. Fifteen of the top 16 warmest years have occurred since 2000, and 2016 was the warmest year ever on record, breaking the previous record by the largest margin ever. The most recent IPCC report determined that it is extremely likely (99% certainty) that the Earth's climate has warmed during the last 100 years. Although atmospheric temperatures have increased, most of the increased heat in the climate system has been stored in the ocean. This change in ocean heat content underlies most of the increase in global mean sea level of approximately 20 cm since 1880 (see next section). The current warming trend is of particular significance because most of it is extremely likely (greater than 95% probability) to be the result of human activity since the mid-20th century and proceeding at a rate that is unprecedented over decades to millennia. The term extreme weather event refers to *"the occurrence of a value of a weather or climate variable beyond a threshold that lies near the end of the range of observations for the variable"*. (IPCC 2012b, 30.) It is a weather event which is unusually intense or long, occasionally beyond what has been experienced before. Examples include very high (and low) temperatures, very heavy rainfall (and snowfall in cold climates), and very high wind speeds.

2. Definition of Extreme Weather Events

It is difficult to give a general definition of extreme weather events, because different countries use very different definitions. Generally, we follow the definitions used by the World Meteorological Organization (Guidelines 2016) and the Intergovernmental Panel of Climate Change. (IPCC 2012a) By definition, *extreme events* occur only rarely; they are noticeable because they are so different from the usual weather patterns; and they are often associated with adverse impacts on humans, infrastructure and ecosystems. As climate differs from location to location, the definition of an extreme event (weather or climate) and its threshold also differ from location to location. In other words, what is considered an extreme value of a given climate element in one location can be considered as being within the normal range in a different location. In addition to natural reasons, there are also practical reasons for the varying definitions; for example the need to focus on a particular sector of applications that requires specific thresholds to take actions. This is the case, for example, in defining heat-waves in a heat-health warning system for which a heat wave can be described specifically according to the potential impacts on human health. An extreme (weather or climate) event is generally defined as the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends *(tails)* of the range of observed values of the variable. Some climate extremes (e.g. droughts, floods) may be the result of an accumulation of weather or climate events that are, individually, not extreme themselves (though their accumulation is extreme).

Nevertheless, among climate science communities, extreme weather and climate events tend to be categorized into the following three types: (IPCC 2012a)

1. *Extremes of a single variable:* An extreme can be identified when a single climate variable (e.g. precipitation or wind) exceeds its specific thresholds, which can be varying percentile-based values, fixed absolute values and return period. Not all extremes necessarily have extreme impacts. Extreme weather or climate event can vary from place to place in an absolute sense (e.g. a hot day in the tropics will have a different temperature than a hot day in the mid-latitudes) and society tends to adapt to its climate 180 historical ranges of the intensity of extremes.

2. *Compound (multivariable) extremes:* Some climate extremes (e.g. droughts, floods) may be the result of an accumulation of moderate weather or climate events (this accumulation being itself extreme). In climate science, compound events can be:

a) two or more extreme events occurring simultaneously or successively
b) combinations of extreme events with underlying conditions that amplify the impact of the events, or
c) combinations of events that are not themselves extremes but lead to an extreme event or impact when combined

The contributing events can be of similar (clustered multiple events) or different type(s). There are several varieties of clustered multiple events. Examples of compound events resulting from events of different types are varied – for instance, high sea level coinciding with tropical cyclone landfall, or cold and dry conditions or the impact of hot events and droughts on wildfire, or a combined risk of flooding from sea level surges and precipitation-induced high river discharge.

3. *Weather phenomenon associated with extremes (e.g. thunderstorms and hail):* Some extremes may be linked with weather phenomena, which themselves may not be extreme. For example, sand storm forms in the arid region when strong winds blow loose sand.

3. Types of Extreme Weather Events

3.1. Primary impacts

Primary impacts are the ones that may directly be triggered by climate change.

3.1.1. Extreme temperatures

Heat waves are periods of abnormally hot weather lasting days to weeks. According to the WMO's Meteoterm vocabulary, (Guidelines 2016) a heat wave is an extreme weather event with marked warming of the air, or the invasion of very warm air over a large area; it usually lasts from a few days to a few weeks. In the IPCC glossary, a heat wave is a period of abnormally and uncomfortably hot weather.

The WMO recommends using a practical and qualitatively oriented definition of a heat wave. A heat wave is defined as follows: "A marked unusual hot weather (maximum, minimum and daily average temperatures) over a region persisting at least two consecutive days during the hot period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds." (Guidelines 2016, 10.)

To quantitatively reflect a heat wave event, the definition of heat wave should be complemented by characterization with the following 4 metrics:

- Magnitude: it should be computed based on an index or a set of indices of thermal condition(s) exceeding certain threshold(s). Such thermal index can be as simple as one meteorological element (i.e. Tmax) or as complicated as a combined index by multiple variables such as temperature, humidity or even including wind speed.
- Duration: will lead to the computation of the persistence of a heat wave and should be based on recording the starting time and the ending time of the event.
- Severity: is a measure which integrates two aspects of the event, its magnitude, and its persistence.
- Extent: is computed to inform on the geographical area affected and the widespread aspect of the heat wave.

Higher temperatures lead to increased rates of evaporation, including more loss of moisture through plant leaves. Even in areas where precipitation does not decrease, these increases in surface evaporation and loss of water from plants lead to more rapid drying of soils if the effects of higher temperatures are not offset by other changes (such as reduced wind speed or increased humidity). As soil dries out, a larger proportion of the incoming heat from the sun goes into heating the soil and adjacent air rather than evaporating its moisture, resulting in hotter summers under drier climatic conditions.

3.1.2. Extreme cold and snowfalls

Cold wave is a meteorological event generally characterized by a sharp drop of air temperature near the surface leading to extremely low values, steep rise of pressure, and strengthening of wind speed, or associated with hazardous weather, like frost and icing.

A cold wave is defined in this guideline in general terms as: “A marked and unusual cold weather characterized by a sharp and significant drop of air temperatures near the surface (maximum, minimum and daily average temperatures) over a large area and persisting below certain thresholds for at least two consecutive days during the cold season.” (Guidelines 2016, 14–15.)

The thresholds for a cold wave are determined by the rate at which the temperature falls, and the minimum to which it falls. This minimum temperature is dependent on the geographical region and time of year. Typically, a cold wave is associated with an invasion of very cold air caused by a polar or high latitude air-mass displacement to lower latitudes, or in some cases associated with or enforced by long radiative cooling during a blocking and clear sky atmospheric circulation. The polar vortex plays a significant role in the forming of a cold wave.

A polar vortex is an upper level low-pressure area lying near the Earth’s poles. There are two polar vortices in the Earth’s atmosphere, overlying the North and South Poles. Each polar vortex is a persistent, large-scale, low pressure zone that rotates counter-clockwise at the North Pole (called a cyclone), and clockwise at the South Pole, i.e. both polar vortices rotate eastward around the poles. The bases of the two polar vortices are located in the middle and upper troposphere and extend into the stratosphere. Beneath them lies a large mass of cold, dense arctic air. The vortices weaken and strengthen from year to year. When the vortex of the arctic is strong and well defined, there is a single vortex, and the arctic air is well contained; when weaker, which it generally is, it will break into two or more vortices; when very weak, the flow of arctic air becomes more disorganized and masses of cold arctic air can push equatorward, bringing with it a rapid and sharp temperature drop.

The position and strength of the jet stream have a big impact on mid-latitude weather. When the jet stream is strong, its fast-flowing winds provide a barrier between the cold air over the Arctic and the milder air further south. When it weakens, the jet stream slows and can develop kinks. This allows the cold Arctic air to spill out into the mid-latitudes and for warmer air to spill in – as has been the case recently. The strength and position of the jet stream can be gauged by a metric called the Arctic Oscillation (AO). When the AO is positive, the jet stream is strong. When it is negative, the jet stream is weak. The similar names and characteristics of the two polar vortices can cause confusion.

3.1.3. Extreme precipitation

The occurrence of heavy precipitation events is a major hazard that has often led to floods, landslides, as well as the loss of human lives and major economic losses. In many regions of the world it is likely that there have been statistically significant increases in the number of heavy precipitation events although it is not uniform in all regions. (IPCC 2013) It is also reported that for a range of emission scenarios, the projections until the end of the 21st

century indicate that it is likely that events of an annual maximum 24-hour precipitation rate having a 1-in-20 year return period (for the baseline period 1961–1990) will become a 1-in-5 to -15 year event, indicating a trend of more frequent extreme heavy precipitation events. (IPCC 2012b)

Since there are large variations in precipitation patterns throughout the world, it is not possible to define a single definition of heavy precipitation that is suitable for all regions. In the International Meteorological Vocabulary, heavy rain is defined only as "rain with a rate of accumulation exceeding a specific value". (Guidelines 2016, 18.) It is generally recognized that when a precipitation event is considered to be extreme, it relates to one of the following two contexts:

- a precipitation event is considered to be extreme when it exceeds a certain threshold that has a certain associated impact, i.e. a fixed threshold, or
- a precipitation event is considered to be extreme due to its rarity, i.e. a percentile-based threshold. The rarity of occurrence tends to take the form of upper 90,th 95,th and 99th percentile of precipitation. Such a percentile-based threshold is usually derived from a statistical cumulative density function or some conceptual distributions for precipitation extremes.

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Having considered these, heavy precipitation is defined in this guideline (Guidelines 2016) in general terms as a marked precipitation event occurring during a period of time of 1h, 3h, 6h, 12h, 24h or 48 hours with a total precipitation exceeding a certain threshold defined for a given location.

Wet days: A period of at least five consecutive days with daily precipitation exceeding 1 millimetre.

3.1.4. Drought and dry spells

Drought, a natural weather phenomenon that occurs in all climates, can differ greatly from other extreme events. Unlike other extreme events, such as floods, tornadoes, and hurricanes, which are weather events that are immediately detectable, drought, on the other hand, develop slowly and steady, making it difficult to determine its onset and end. In order to facilitate communication, management and response, drought can be categorized into four general types: (Guidelines 2016)

1. Meteorological: Meteorological drought is an atmospheric condition resulting in the absence or reduction of precipitation over a period of time.
2. Agricultural: Meteorological drought can lead to impacts on agriculture due to precipitation shortages, higher evapotranspiration and soil moisture deficits, which result in an agricultural drought.
3. Hydrological: Meteorological drought can also lead to hydrological drought, which occurs from depleted surface or subsurface water supplies.

4. Socio-economic: Socio-economic drought is the imbalance in supply and demand or the effect of water shortages on the economy (e.g. crop losses) and society (e.g. health). All these different types of drought have one thing in common: they all begin with a deficiency of precipitation (meteorological drought).

Drought can be numerically defined using indices that integrate temperature, precipitation and other variables that affect evapotranspiration and soil moisture.

3.1.5. Different types of storms

1. *Severe thunderstorms:* Severe thunderstorms are mesoscale convective storms that generate damaging hail, wind, or tornadoes; in the United States, a thunderstorm that produces a hail of at least 2.5 cm in diameter, three-second gust wind speeds of 93 km/h or more, or a tornado of at least EF-1 (Enhanced Fujita Scale) intensity is considered severe. Thunderstorms require a specific type of environment in which to grow. Namely, convective instability is required both to lift moist air parcels from the surface to generate precipitation in the form of rain and hail, and to generate updrafts that are strong enough to support hailstones in the air long enough to grow to threshold or greater size. To generate damaging winds, falling precipitation has to be sufficiently intense to drag air downward with it forcefully enough so that when this dragged-down air hits the ground, it can spread outward horizontally with damaging velocity. These downbursts, or straight-line winds or derechos as they are sometimes called, can contribute significantly to the damaging wind potential of a thunderstorm. Because of the requirement for convective instability, severe thunderstorms typically form in the summer months in both hemispheres, although in some locations the requisite instability can exist during cold seasons albeit over shallower depths. Because of the vertical shear requirement, however, severe storms do not occur everywhere there is warm air at the surface. Severe storms, for example, do not typically develop in the tropics because the vertical shear, which is a function of the environmental horizontal temperature gradient, or baroclinicity, is weak. Geography also plays a role in generating preferred environments. One of the reasons the United States has the highest probabilities of severe weather has to do with the country's geography. The Gulf of Mexico is the primary source of warm moist unstable air for the Great Plains. As low-pressure systems develop on the lee side of the Rocky Mountains, southeasterly winds ahead of the low draw the warm moist unstable air northwestward. At upper levels, strong southwesterly winds bring air from the Mexican Plateau, which is much drier and cooler. This configuration creates both a thermodynamically unstable environment and one with both wind speed and directional shear.

A tornado forms when changes in wind speed and direction create a horizontal spinning effect within a storm cell. This effect is then tipped vertically by the rising air moving up through the thunderclouds. The meteorological factors that drive tornadoes make them more likely at some times than at others. They occur more often in late afternoon, when thunderstorms are common, and are more prevalent in spring and summer. However, tornadoes can and do form at any time of the day and year. The distinctive funnel clouds of the tornadoes are actually transparent. They become visible when water droplets pulled from a storm's moist air condense or when dust and debris are taken up. Funnels typically grow about 200 meters wide. Tornadoes move at speeds of about 16 to 32 kilometres per hour, although they have been clocked in bursts up to 113 kilometres per hour. Most do not get very far, though. They rarely travel more than about ten kilometres in their short lifetimes. Tornadoes are classified as weak, strong, or violent storms. Violent tornadoes comprise only about 2% of all tornadoes, but they cause 70% of all tornado deaths and may last an hour or more. The most violent tornadoes come from supercells, large thunderstorms that have winds already in rotation. About one in a thousand storms becomes a supercell, and one in five or six supercells spawns off a tornado. Tornado season begins in early spring for the states along the Gulf of Mexico. The season follows the jet stream as it swings farther north, so does tornado activity. May generally has more tornadoes when warm, humid air collides with cold, dry air. The denser cold air is pushed over the warm air, usually producing thunderstorms. The warm air rises through the colder air, causing an updraft. The updraft will begin to rotate if winds vary sharply in speed or direction. As the rotating updraft, called a mesocycle, draws in more warm air from the moving thunderstorm, its rotation speed increases. Cool air fed by the jet stream, a strong band of wind in the atmosphere, provides even more energy. Water droplets from the mesocyclone's moist air form a funnel cloud. The funnel continues to grow and eventually it descends from the cloud. When it touches the ground, it becomes a tornado.

2. *Tropical cyclones:* Tropical cyclones (TC) derive their energy from latent heat acquired from evaporation of water at the ocean surface that is subsequently released upon condensation at greater heights. Earth's rotation drives cyclonic winds at low levels in the atmosphere toward the resulting low pressure (the eye). Although other factors are involved, the three primary conditions for tropical cyclone formation are: sufficiently high (>26°C) sea surface temperatures; sufficiently low vertical wind shear (change in wind velocity with height); and sufficiently high contribution from Earth's rotation (formation >5 degrees N and S). Seasonal TC activity is highest in summer, when surface ocean waters are warmest and shear is minimized; however, formation is possible in all seasons. The Western North Pacific is the most active ocean basin, both in terms of the overall number and intensity of tropical cyclones. (Woodruff et al. 2013) A hurricane is a typical tropical cyclone. Hurricanes are intense cyclonic storms that develop over the warm oceans of the tropics. These tropical storms go by other names in the various parts of the world: India/Australia – cyclones; western North Pacific – typhoons; and the Philippines – baguio. By international agreement, the term tropical cyclone is used by most nations to describe hurricane-like storms that originated over tropical oceans. Surface atmospheric pressure in the centre of a hurricane tends to be extremely low. The lowest pressure reading ever recorded for a hurricane (typhoon Tip, 1979) is 870 millibars (mb). However, most storms have an average pressure of 950 millibars. To be classified as a hurricane, sustained wind speeds must be greater than 118 kilometres per hour at the storm's center. Wind speed in a hurricane is directly related to the surface pressure of the storm. Hurricanes have no fronts associated with them like the mid-latitude cyclones of the polar front. They are also smaller than the mid-latitude cyclone, measuring on average 550 kilometres in diameter. Mature hurricanes usually develop a cloud-free eye at their centre. In the eye, air is descending creating clear skies. The eye of the hurricane may be 20 to 50 kilometres in diameter. Surrounding the eye are

bands of organized thunderstorm clouds formed as warm air move in and up into the storm. The strongest winds and heaviest precipitation are found in the area next to the eye where a vertical wall of thunderstorm clouds develops from the Earth's surface to the top of the troposphere. (Burt 2004)

Hurricanes are powered by the latent heat energy released from condensation. To form and develop, they must be supplied with a constant supply of warm humid air for this process. Surface air with enough energy to generate a hurricane only exists over oceans with a temperature greater than 26.5°C. Ocean temperatures this high only occur in selected regions and during particular seasons. Hurricane development does not occur if a temperature inversion exists in the atmosphere. Inversions develop in the tropics when subtropical high pressure systems produce sinking air. Also, hurricanes do not develop in the region 5° either side of the equator. Within this region the Coriolis force is negligible. A Coriolis force is required for the initiation of cyclonic flow. When it comes to hurricanes, meteorologists rely on the Saffir-Simpson Hurricane Wind Scale to help us understand the magnitude of the hurricane's impact. These 1 to 5 categorization scales do not address the potential for other hurricane-related impacts, such as storm surge, rainfall-induced floods, and tornadoes, but they do help residents (and disaster organizations) gauge the safety measures that must to be taken to prepare before a hurricane makes landfall. Use this breakdown to help you understand what is at stake.

Category 1: Winds range from 119 to 153 km/h and can be expected to produce some minor damage to property. Injuries to people and animals are generally isolated and limited to flying or falling debris. During a Category 1 storm, protected glass windows generally remain intact. Some roof damage to frame homes, apartments and shopping centres can also occur, as well as short-term power outages due to snapped power lines and downed trees.

Category 2: Winds range from 154 to 177 km/h and can be expected to produce extensive property damage. Greater wind velocities mean that debris pose a greater threat to humans and animals, while the roofing, siding and glass windows (protected and unprotected) of frame homes are more vulnerable to damage. In a Category 2 storm, significant structural damage to apartment buildings, mobile homes and shopping centres is also expected, as well as flooding in low-lying areas. Extensive power outages ranging from a few days to a few weeks are common, and residents are encouraged to stock up on potable water as filtration systems also fail during this time.

Category 3: Winds ranging from 178 to 209 km/h cause significant damage to property, humans and animals. Mobile and poorly constructed frame homes are often destroyed, and even well-built frame homes commonly sustain major damage. Significant damage to apartments and shopping centres (even those made of wood or steel) can be expected. Category 3 storms can also cause extensive inland flooding. Electricity and water are commonly unavailable for several days to several weeks after the storm, therefore it is important for residents to have their own stores of canned food and water.

Category 4: Winds range from 210 to 249 km/h and can cause catastrophic damage to property, humans and animals. Severe structural damage to frame homes, apartments and shopping centres should be expected. Category 4 hurricanes often include long-term power outages and water shortages lasting from a few weeks to a few months, so again, it is important for any remaining residents to have a significant non-perishable food and water supply at hand.

Category 5: Winds at or greater than 250 km/h cause catastrophic damage to property, humans and animals (read: you should be nowhere near this storm!). Complete or almost-complete destruction of mobile homes, frame homes, apartments and shopping centres should be expected, and nearly all trees in the area will be snapped or uprooted. Power outages can last for weeks and possibly months. Long-term water shortages should be expected as well, and most of the area will be uninhabitable for weeks or months.

3. *Extratropical cyclones:* Unlike tropical cyclones, extratropical cyclones derive much of their energy from the ambient horizontal temperature (and associated density) difference (gradient) in the atmosphere. This gradient represents a pool of potential energy that a developing storm can convert to rotational wind, or kinetic energy. As colder, denser air wedges itself under the warmer air, the center of gravity is lowered and the resulting reduction in potential energy is manifested as kinetic energy by the developing cyclone. The density difference across the temperature front is supported by vertical wind shear or increasing westerly wind speed with height in the mid-latitudes, which is responsible for the existence of the jet stream at higher altitudes. The extratropical cyclones developed through a process called baroclinic instability, which could only occur when a certain threshold of horizontal temperature gradient (or baroclinicity) existed. The observations of extratropical cyclones can begin to take on characteristics that are present in tropical cyclones, such as a warm core. In addition, they noted that the release of latent heat can become very significant for development, just as for tropical cyclones. The latent heat flux at the surface is a combined result of wind speed and the difference in specific humidity between the Earth's surface (be it land or water) and the air 10 meters above it. Cold dry air blowing across a warm moist surface will allow for the upward transfer (flux) of latent heat energy into the atmosphere.

3.2. Secondary effects

3.2.1. Different types of floods

1. *Flash floods:* Flash floods occur in small and steep watersheds and waterways and can be caused by short-duration intense precipitation, dam or levee failure, or collapse of debris and ice jams. Most flood-related deaths in the U.S. are associated with flash floods.

2. *Urban flooding:* Urban flooding can be caused by short-duration very heavy precipitation. Urbanization creates large areas of impervious surfaces (such as roads, pavement, parking lots, and buildings) that increased immediate runoff, and heavy downpours can exceed the capacity of storm drains and cause urban flooding. Flash floods and urban flooding are directly linked to heavy precipitation and are expected to increase as a result of increases in heavy precipitation events.

3. *River flooding:* River flooding occurs when surface water drained from a watershed into a stream or a river exceeds channel capacity, overflows the banks and inundates adjacent low-lying areas. Riverine flooding depends on precipitation as well as many other factors, such as existing soil moisture conditions and snowmelt.

4. *Coastal flooding:* Coastal flooding is predominantly caused by storm surges that accompany hurricanes and other storms that push large seawater domes toward the shore.

A storm surge can cause deaths, widespread infrastructure damage and severe beach erosion. Storm-related rainfall can also cause inland flooding and is responsible for more than half of the deaths associated with tropical storms. Climate change affects coastal flooding through sea-level rise and storm surge, and increases in heavy rainfall during storms.

5. *Inland flooding:* Most inland flooding results when ground conditions inhibit water drainage after intense and/or persistent rainfall. The flooding can take several forms, over a wide range of space (or area) and time scales and degrees of impact. There are several different physical processes which contribute to inland flooding in the U.K.:

Surface water (pluvial) flooding occurs when intense rainfall overwhelms local drainage capacity. It can occur anywhere, and can be particularly disruptive in urban areas. It is most commonly associated with summer thunderstorms, where the effects can be very localised. But more extensive surface water flooding can occur at any time of the year during extended wet periods in which the ground is saturated. While heavy rain is the dominant factor, surface water flood risk can be exacerbated by ground conditions that promote rapid runoff or prevent drainage: very wet ground, very dry and/or compacted ground, frozen ground or an abundance of concrete or other impermeable surfaces, blocked channels or uncleared trash screens. Another contributory factor is fallen leaves and tree debris during autumn, which can rapidly block drains and streams.

River (fluvial) flooding occurs when a river cannot adequately convey downstream the water flowing from surrounding land or other rivers. The excess water then spills onto a flood plain or other adjacent land. The speed at which a river's level and flow increases in response to rainfall depends largely on the size and shape of its catchment; small rivers can respond rapidly, on a timescale of a few hours or less, while peak levels and flows for major rivers such as the Thames or the Severn may only be reached several days after the rain has fallen. River or tidal flooding in estuaries can be more likely when tidal water levels are high, preventing river water from draining quickly into the sea.

6. *Groundwater flooding* is the emergence of ground water at the earth's surface. Groundwater is usually stored below the surface, often within layers of permeable rock (aquifers) such as chalk. This type of flooding is often not directly related to a single rainfall episode, and occurs over much longer timescales as groundwater levels slowly rise during and after an extended spell of wet weather.

7. *Snowmelt* following a very cold winter period with lying snow can occasionally cause significant flooding due to rapid or prolonged thaw, particularly in areas where widespread and prolonged snow-cover is unusual. Snowmelt usually occurs in association with heavy rain, with both components contributing to the flooding.

Note that all of the above types of flooding can often occur in combination with major events, particularly when the ground is already saturated. A prolonged period of wet weather (such as the summers of 2007 and 2012, and the autumn and early winter of 2012) may lead to a similarly prolonged period of very elevated flood risk. This may contain numerous individual river, surface water and groundwater flood events, as each successive period of rain tends to make the ground conditions even more sensitive to further rain.

3.2.2. Wildfire

A wildfire is simply an uncontrolled fire that is wiping out large fields and areas of land. These are typically fires that start out of a lightning strike, or the carelessness of people, or accidentally, or even arson, that goes unnoticed and gets out of hand. These fires sometimes burn for days and weeks. They can wipe out an entire forest and destroy almost every organic matter in it. Wild fires can also be termed forest fires, grass fires, peat fires and bush fires depending on the type of vegetation being burnt. Note that these fires tend to thrive in very warm and dry climates, rather than the thick, moist rainforest types.

3.2.3. Wildfires and forests

The destructive nature of a wildfire in a forest is inconceivable. A forest is an entire ecosystem consisting of biotic factors like animals, insects, birds, bacteria, plants and trees. It also consists of abiotic factors like water, rocks and climate in that forest area. If a wildfire strikes such an ecosystem, all life forms will be lost. The air and water will be heavily polluted. The soils will be badly degraded and other abiotic elements will be affected including water catchment areas.

Fires that burn organic material in the soil are called ground fires. This is a slower burning fire, usually under litter or under vegetation. They burn by glowing combustion.

Some fires burn on the surface of the ground. They burn dry leaves, broken twigs and branches and other materials on the ground. These fires spread quickly and are known as surface fires.

Weather plays a major role in the birth, growth and death of a wildfire. Drought leads to extremely favourable conditions for wildfires, and winds aid a wildfire's progress – weather can spur the fire to move faster and engulf more land. It can also make the job of fighting the fire even more difficult. There are three weather ingredients that can affect wildfires:

- temperature
- wind
- moisture

As mentioned before, temperature affects the sparking of wildfires, because heat is one of the three pillars of the fire triangle. The sticks, trees and underbrush on the ground receive radiant heat from the sun, which heats and dries potential fuels. Warmer temperatures allow for fuels to ignite and burn faster, adding to the rate at which a wildfire spreads. For this reason, wildfires tend to rage in the afternoon, when temperatures are at their hottest.

Wildfire (also known as bushfire in Australia) requires knowledge not only of how meteorological and hydrological factors will change, but also of how biomass characteristics will change. The meteorological conditions are complex because there are two different sets to consider that are somewhat hydrologically different from each other: convective storms and drought. Convective storms generate heavy rain, which is capable of extinguishing fire and, more importantly, lightning, which can ignite fire. These storms do not have to be severe, i.e. produce hail, damaging winds, or tornadoes; they just need to produce lightning. Lightning strikes can initiate fires even when the vegetation is not exhibiting drought conditions; however, drier biomass is more likely to ignite and facilitate the spread of fire. Wind can also contribute to the spread of wildfire. And even in the absence of lightning, anthropogenic sources such as cigarettes, campfires, arson, and even downed power lines frequently provide more detail on the climate and human factors associated with wildfire. Given the strong connection between fire and climate.

In general, the increases occur at mid to high latitudes with projected decreases in equatorial regions. The increases at mid and high latitudes are primarily the result of increased precipitation seasonality superimposed on an increase in temperature. The decreases are a result of relatively strong increases in precipitation during the dry season, reducing the amount of dry fuel available for burning. However, these results are far from guaranteed. Even though significant portions of the globe indicate an increase in wildfire risk, many areas lack significant consensus. For example, Southern California, Southern Chile, and South-Central Australia all show what appears to be increases in fire probability but less than 33% of the models agree in that respect.

4. Extreme Weather Events in the World

The data of extreme weather event can be gathered from measurements or a measurement database and it can also be generated by computer modelling. This last method is very useful in the prediction of the future. Society's perception of climate variability and climate change is largely formed by the frequency and the severity of extremes. This is especially true if the extreme events have large and negative impacts on lives and property. As the resolution of climate models and the treatment of physical processes have improved, the simulation of extremes has also improved.

Mainly because of increased data availability (e.g. daily data, various indices, etc.), the modelling community has now examined the model simulations in greater detail and presented a comprehensive description of extreme events in the coupled models used for climate change projections. Some extreme events, by their very nature of being smaller in scale and shorter in duration, are manifestations of either a rapid amplification, or an equilibration at a higher amplitude, of naturally occurring local instabilities. Large-scale and long-duration extreme events are generally due to persistence of weather patterns associated with air–sea and air–land interactions. A reasonable hypothesis might be that the coarse-resolution AOGCMs might not be able to simulate local short-duration extreme events, but that is not the case. The assessment of the recent scientific literature shows, perhaps surprisingly, that the global statistics of the extreme events in the current climate, especially temperature, are generally well simulated by the current models. These models have been more successful in simulating temperature extremes than precipitation extremes.

4.1. Primary events

4.1.1. Extreme temperatures

The IPCC Fifth Assessment Report (IPCC 2012b) noted that: "A large amount of evidence continues to support the conclusion that most global land areas analyzed have experienced significant warming of both maximum and minimum temperature extremes since about 1950…" and concludes that: "It is […] very likely that human influence has contributed to observed global scale changes in the frequency and intensity of daily temperature extremes since the mid-20th century, and likely that human influence has more than doubled the probability of occurrence of heat waves in some locations". (IPCC 2012b, 8.)

4.1.2. Heatwaves

A heatwave in Central Europe in the summers of 2015–2017 was influenced significantly by climate change. (Dong et al. 2016) Deadly heatwaves in Pakistan and India in May and June 2015, causing thousands of deaths, were also exacerbated by human-induced climate change, (Wehner et al. 2016) as well as the European heat wave, which was associated with tens of thousands of excess deaths. Climate change tripled the risk of record-breaking heat over northwest China in July 2015, which culminated in 28 counties breaking maximum daily temperature records. (Miao et al. 2016)

In the last five years alone, a number of destructive storms, extreme heatwaves and bushfires have occurred around the world, including Australia. The influence of climate change on this increasingly severe and damaging extreme weather has been demonstrated more clearly through the development of climate attribution science, where models are used to examine how much more likely extreme weather events were the result of climate change.

Regarding future projections, the IPCC Fifth Assessment Report, (IPCC 2012b) stated that: "It is also very likely that heat waves, defined as spells of days with temperature above a threshold determined from historical climatology, will occur with a higher frequency and duration." (IPCC 2012b, 60.) European heat wave, which was associated with tens of thousands of excess deaths and prompted the seminal paper by Stott et al. (2004), whose methods form the groundwork for much subsequent work in this field (e.g. fraction of attributable risk).

4.1.3. Extreme cold weather

The decrease in the number of frost days in Southern Australia simulated by HadAM3 with anthropogenic forcing is in good agreement with the observations. The increase in the number of warm nights over Eurasia is poorly simulated when anthropogenic forcing is not included, but the inclusion of anthropogenic forcing improves the modelled trend patterns over western Russia and reproduces the general increase in the occurrence of warm nights over much of the Northern Hemisphere.

Scientists compared the number of frost days simulated by a model with observations. The 20th century simulations include the variations in solar, volcano, sulphate aerosol, ozone and greenhouse gas forcing. Both model simulations and observations show that the number of frost days decreased by two days per decade in Western USA during the 20th century. The model simulations do not agree with observations in Southeastern USA, where the model simulates a decrease in the number of frost days in this region in the 20th century, while observations indicate an increase in this region. (Meehl et al. 2004)

Several recent attribution studies have examined extreme cold events in the context of retreating Arctic sea ice. By prescribing reduced Arctic sea ice cover but historically observed ocean temperatures outside of the Arctic in two different global climate models, (Screen et al. 2015a and 2015b) find that ice loss is associated with a decreased likelihood of extreme cold events (as well as decreased variability of temperature) over nearly the entire Northern Hemisphere land areas. The exception is the Central Asian region, where the probability of extreme cold events increases with ice loss, in agreement with earlier studies.

4.1.4. Extreme precipitation

Extreme precipitation can typically be traced to forcing associated with strong vertical motion and significant water vapour. Extreme precipitation is associated with an array of meteorological processes including tropical cyclones, extratropical cyclones, monsoons, atmospheric rivers and localized convection. (Kunkel et al. 2013) Changes in extreme rainfall can be quantified using empirically defined metrics such as trends in the frequency with which some specified threshold is exceeded. Alternatively, statistical methods rooted in extreme value theory (Coles 2001) can be used, allowing return levels for the most extreme events to be quantified. (Kunkel et al. 2013) More intense and more frequent extreme precipitation events have long been projected in a warming climate. It is likely that since about 1950, the number of heavy precipitation events over land has increased in more regions than it has decreased. Confidence is highest for North America and Europe where there have been likely increases in either the frequency or intensity of heavy precipitation with some seasonal and/or regional variation. It is very likely that there have been trends towards heavier precipitation events in central North America. Global atmospheric water vapour concentrations are robustly expected to increase with temperature at a rate of around 6–7% per °C, approximately consistent with the saturation value as determined by the Clausius–Clapeyron relation, because observed and projected changes in relative humidity are small. (Wright et al. 2010) Global mean rainfall values cannot increase at this rate because of global energy budget constraints. (Held–Soden 2006) Extreme rainfall events are not subject to these constraints, and a simple hypothesis is that the intensity of such events should increase at the rate that water vapour does. (Allen–Ingram 2002) Some scientists concluded that moisture availability in recent years was 1% to 5% higher for an extreme precipitation event in New Zealand because of anthropogenic greenhouse gases. (Dean et al. 2013) This would be the case if the atmospheric circulation (including the strength of convective updrafts) were to remain constant in amplitude and structure.

4.1.5. Severe storms

Climate-driven changes may differ across basins (or smaller scales), and similar changes may affect tropical cyclones in different basins in different ways. The climate drivers of observed trends in landfalling tropical cyclones are difficult to assess because of the storms' small scale, infrequent return period, and high natural inter-annual and even multi-decadal variability. It is easier to assess trends at larger scales, using basinwide measures of tropical cyclones in intensity, frequency and duration, such as the Power Dissipation Index (PDI) or the Accumulated Cyclone Energy (ACE), which are defined as the sum of the maximum one-minute sustained wind speeds cubed or squared respectively, at six-hourly intervals, for all periods when the cyclone is at least tropical storm strength. These measures indicate a robust increase in the activity of the North Atlantic tropical cyclones since the 1970s. At a global scale, scientists estimate that the proportion of Category 4 and 5 storms has increased over the last several decades by ~25–30% per degree of warming. (Holland–Bruyère 2014)

4.1.6. Tropical cyclones

In each region of the globe which is prone to tropical cyclones, a Regional Specialized Meteorological Center, under the World Meteorological Organization (WMO), determines when a given system is a tropical cyclone and determines its intensity from available observations. The intensity of a tropical cyclone is conventionally understood to indicate its maximum sustained wind speed. This is only a loose guide to the potential severity of a given storm's impacts, however, hazards associated with cyclones include both coastal and freshwater flooding, as well as winds. A specific tropical cyclone event might also be defined for attribution purposes by storm surge, precipitation, storm size, economic damage, or other variables available.

Hurricane Harvey hit Texas in August 2017, flooding one of the largest metro areas in the United States. Less than two weeks later, thoughts turned to hurricane Irma, among the strongest Atlantic hurricanes ever measured. As Hurricane Sandy made its way to the Eastern coast of the United States in October 2012, meteorologists called the storm unprecedented in terms of its potential for damage and fatalities, due to its path along the densely populated urban coast. Few events on Earth rival the sheer power of a hurricane. Also known as tropical cyclones and typhoons, these fierce storms can churn the seas into a violent topography of 15-meter peaks and valleys, redefine coastlines and reduce whole cities to watery ruin.

Even with good observations, the severity of an event may be very diverse in different variables. A storm may have weak winds, for example, but still cause a major disaster due to precipitation, storm surge, or high vulnerability. Similarly, attribution studies may reach different conclusions depending on which variable is considered, without necessarily implying any contradiction. Many studies have examined whether long-term trends exist in tropical cyclone statistics. Assessment of these trends is difficult due to the shortness of observational records in many basins; large natural variability, including low frequencies may obscure any longer-term trends and changes in observing systems and practices over time, which introduce heterogeneities into the observations even in those basins that do have relatively long-term records. (IPCC 2012b) Synthesis studies typically find that long-term trends cannot be clearly detected in tropical cyclone numbers, intensities, or integrated measures of activity, (Knutson et al. 2010) using specified thresholds of statistical significance against a null hypothesis of zero trend. (Walsh et al. 2015) An exception may be the frequency of the most intense storms by limited resolution. (Zhao–Held 2010) Based in large part on these new models, broad consensus has emerged as to the expected future trends and their levels of certainty. (Knutson et al. 2010) The global frequency of tropical cyclone formation is projected to decrease, (Camargo et al. 2014) but there is less confidence in this conclusion than in the increase in intensity; some credible models produce increases in frequency. (Seneviratne et al. 2012) The uncertainty is still greater in projections of tropical cyclone frequency in individual basins. Changes in the frequency of the most intense storms are related to changes in both the frequency of all storms and the average storm intensity, and thus are less certain than the intensity changes alone since reduced frequency and increased intensity have opposing effects. A group of researchers state that the frequency of the most intense storms "will more likely than not increase substantially in some basins under projected 21st century warming". (Christensen et al. 2013, 1252.) Precipitation in tropical cyclones is expected to increase, because of the increased water vapour content of the atmosphere, similarly to other extreme precipitation events; Christensen et al. express "medium confidence" in this projection. Several studies have used climate model projections to estimate the effect of greenhouse gas increases on future severe convective storm activity in the United States. These studies show that the climate models project conflicting signals for the two primary predictors of severe convective storm activity over the U.S. plains, where storm activity is greatest in the current climate. (Trapp et al. 2007) Convective instability increases in a warming climate, but wind shear decreases. Changes in storms will depend on which of these dominates the other. Studies to date suggest that instability wins and that severe convective storm activity will increase. This conclusion could be sensitive to the details of the environmental index chosen.

4.1.7. Drought

The extreme drought in western Canada in 2015 was likely to be a result of human-influenced warm spring conditions preceding dry May to July weather. (Szeto et al. 2016) The IPCC Special Report on Extremes (Seneviratne et al. 2012) noted that on a global scale, and owing in part to the variety of ways to define drought, there were not enough direct observations of drought-like conditions to conclude that there were robust global trends, but some regions of the world have experienced more intense and longer droughts. The IPCC Fifth Assessment Report (IPCC 2012b) notes that some studies find an increase in the percentage of global land area in drought since 1950, but the inter-annual and decadal-scale variability is high, and the results depend on datasets and methods used. The attribution section assigns low confidence to attributing changes in drought over global land areas since the mid-20th century due to observational uncertainties and again high variability. (Bindoff et al. 2013)

Regarding projections of future drought over the 21st century due to human influence, the IPCC Special Report on Extremes expressed "medium confidence that droughts will intensify in the 21st century in some seasons and areas, due to reduced precipitation and/or increased evapotranspiration. This applies to regions including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa". (Seneviratne et al. 2012, 113.)

While drought is acknowledged to be a complex phenomenon due to the many physical processes involved and the broad range of societal factors that influence its occurrence and intensity, some aspects of drought are influenced by temperature in ways that are better understood, and thus more amenable to attribution than others. In particular, temperature exacerbates hydrological drought in some regions by increasing surface evaporation, so that increasing temperature causes an increasing risk of hydrological drought even if precipitation does not change.

4.2. Secondary effects

4.2.1. Floods

1. *Sea-level rise and coastal flooding:* In contrast to the complicated picture for freshwater floods, the severity and frequency of coastal floods is clearly increasing. (Sweet–Park 2014) In New York City, for example, flooding that occurred an average of 19 days per year from 1920 to 1970 now occurs an average of 99 days per year. (Ezer–Atkinson 2014) Current evidence suggests that the rise in mean sea level is generally the dominant cause of any observed increase in the frequency of extreme coastal flooding events, (Zhang et al. 2014) although there is some evidence for multi-decadal variability in sea level extremes. (Wahl–Chambers 2015)

As climate change continues, coastal flood frequency is expected to increase dramatically. Projections of an increase are robust, mainly because the regional sea level will continue to rise at most global locations and over the long run (although there may be periods during which it could go down) from the continued thermal expansion of ocean water, melting of ice and changes in terrestrial water storage. Ocean warming and expansion is expected to continue and to penetrate deeper into the ocean with a rate that is linked to atmospheric feedbacks and ocean heat uptake (diffusivity). (Kuhlbrodt–Gregory 2012) Glaciers (land ice) are expected to shrink dramatically over the 21st century, with the maximum contribution to sea level arising from the Arctic, Alaska and glaciers peripheral to the Antarctic and Greenland ice sheets. Finally, other factors, like storage on land (i.e. reservoirs and groundwater withdrawal) may influence the sea level, but are generally assumed to be smaller and have less uncertainty. The probability of a 0.57 m tidal flooding event in southeast Florida in September 2015 increased by more than 500% since 1994, due to a 10.9 cm sea-level rise related increase in monthly highest tides. Coastal flood risk due to storm surge is projected to increase due to both sea-level rise and tropical cyclone intensity change, though the influence of the latter is more model-dependent. (Emanuel 2008)

2. *Pluvial, or rain-related flooding* is perhaps more straightforward, as it principally involves knowledge of how heavy precipitation events may change in the future. Here we will focus, from a heavy precipitation standpoint, primarily on pluvial flooding. Unlike the analyses of how climate change will impact specific types of weather systems such as tropical cyclones, extratropical storms and severe thunderstorms, the thermodynamics

connecting a warming atmosphere to changes in precipitation are fairly straightforward. The Clausius–Clapeyron relationship states that the saturation vapour pressure for water increases exponentially with temperature. More simply stated, the warmer the air, the more moisture it can hold (which is not entirely correct because water vapour can exist even in the absence of air). And as that moister (from an absolute standpoint) air rises, more of it condenses, which leads to the expected result that more intense, if not more frequent, precipitation events will occur as climate change proceeds. In the last couple of years, serious floods hit India, China, the USA, several parts of Europe and Central Asian countries. In a strong association with poor fresh-water quality and hygiene and a lack of sewerage and sanitation, this type of disaster can be very devastating and dangerous for the locals. Since 1990 over 450 floods and more than 300 heavy windstorms in the region have been classified as disasters. About 40 million people were left in need of basic survival requirements, such as food, water, shelter, sanitation and immediate medical assistance.

Although there is a wide agreement on and awareness of direct damage to societies and people's health, there is a lack of knowledge about assessing environmental concerns and health effects associated with exposure to the complex contamination of water bodies and soil that follows extreme weather events. Overall losses resulting from weather- and climate-related events have clearly increased during the past 20 years in EU countries.

Under severe weather conditions, water and wastewater services are no longer beneficial delivery services, but a significant source of chemical and biological contamination. Sometimes this is irreversible and reaches beyond local and national borders.

4.2.2. Extreme snow and ice storm

Severe winter weather includes snow and ice (freezing rain) storms, often accompanied by wind. Impacts of a snow or ice storm are compounded by wind as well as by the population of the area impacted by the storm. Region-specific impact indices have been developed, for example, the Northeast Snowfall Impact Scale (NESIS) in the U.S. which combines snowfall amounts and the number of people residing in the affected area. The absence of universal metrics for assessing heavy snow and ice events complicates the analysis of trends and attribution studies. In addition, snowfall measurements are known to suffer from heterogeneities such as gauge undercatch, and data on snow depth are of limited value for determining the snowfall from a single storm, as compaction and drifting are common with winter snow events. Lack of in situ measurements hinders the analysis of extreme snow and ice events in sparsely populated areas. Overall snow cover has decreased in the Northern Hemisphere, due in part to higher temperatures that shorten the time snow is on the ground. (Derksen–Brown 2012) However, few studies have addressed trends in heavy snow and ice events, especially over regional and larger spatial scales. For the entire Northern Hemisphere, the summary in the preceding section *(Extratropical cyclones)* showed that there is mixed evidence for trends in the frequency and intensity of cold-season storms, regardless of whether they produce snow and/or freezing rain. (Seiler–Zwiers 2015a and 2015b) Several studies of overall storm frequencies also indicate a northward shift in the primary tracks during winter. (Wang et al. 2013) Theory suggests that for the coldest climates, the occurrence of extreme snowfall should increase with warming due to increasing atmospheric water vapour, while for warmer climates it should decrease due to decreased frequency of sub-freezing temperatures, though by less than mean snowfall decreases. Attribution of extreme snow and ice events suffers from a similar challenge as some other extreme event types in that the events are strongly governed by the atmospheric circulation, for which externally forced changes are uncertain. For this reason, attribution of extreme snow and ice storm events may benefit from an emphasis on the thermodynamic state during particular events, as argued by some researchers. (Trenberth et al. 2015) Conditional attribution studies of snow and ice storms have lagged behind similar studies for other event types.

4.2.3. Wildfire

Although wildfires are not meteorological events, their likelihood and extent can be influenced by climatic factors. Wildfires are often large and rapidly spreading fires affecting forests, shrub areas and/or grasslands. Wildfires occur in many areas of the world, especially those with extensive forests and grasslands. (Romero-Lankao et al. 2014) While most wildfires are started by lightning, a substantial number are caused by humans, especially in the vicinity of populated areas.

Understanding how climate change will affect regional temperature, precipitation, lightning, drought, surface wind speed and direction, and the growth of biomass is challenging and requires more than just the output from a general circulation model (GCM). A standard approach is to use output from GCMs as input to Dynamic Global Vegetation Models (DGVMs). The DGVMs simulate the climate-based processes controlling plant growth and death in different vegetation types, and many of these models have incorporated a fire module. (Arora–Boer 2005) Recent advances in some DGVMs have improved their ability to represent historical patterns of burning, (Prentice et al. 2011) although this remains an active area of research. Many of the wildfire studies use output from the CMIP3 (Coupled Model Intercomparison Project – Phase 3) suite of models, which has been available since ~2006 (Meehl et al. 2007) but which was also used by the IPCC for their Fourth Report.

The most common metric of wildfires is the area burned, either by a single wildfire or by all wildfires during a fire season in a particular region.

Attribution of wildfire trends and extreme events is complicated by:

1. The role of humans in ignitions, fire suppression and management of forests and other biomes. (Gauthier et al. 2015)
2. The importance of lightning, hence small-scale thunderstorms, in igniting large fire outbreaks.
3. The importance of larger-scale weather in the wildfire spread and growth into major events (specifically, winds and humidity for fire spread, and rain for extinguishing a fire outbreak. (Abatzoglou–Kolden 2011)
4. The health of the forest (e.g. a white pine bark beetle infestation).

Thus, attribution studies need to consider three time/space scales:

- individual large fires, which are controlled primarily by short-term weather patterns
- regional-scale within season extreme fire periods, which are driven by seasonal weather patterns and

- large fire seasons, which are regional-scale events resulting from climate teleconnections associated with persistent blocking ridges that cause extended fire seasons (with delayed season-ending rains)

Analysis of wildfire trends and extremes is limited by the availability of consistent data records. For example, fire surveillance methods have improved in recent decades; the area actually burned by a fire can be less than the area within the fire perimeter; and some metrics of fire activity include only large fires. There has been an overall increase in the area burned in the United States over the past several decades. The increase is especially apparent in the West. Trends are less apparent in Canada, where the area burned by large fires increased from the 1960s to the 1980s and 1990s, after which there has not been an increase. (Krezek-Hanes et al. 2011) Globally, however, fire weather season lengths showed significant increases during 1979–2013 across more than 25% of the Earth's vegetated surface, resulting in a 19% increase in the global mean fire weather season length. (Jolly et al. 2015)

Wildfires are closely associated with heat and drought, so some of the attribution issues pertaining to extreme wildfires and their likelihoods are covered in the preceding subsections on heat and drought.

5. Extreme Weather Events in Hungary

Weather extremities caused by climate change can lead to various disasters, severe short- or longer-term situations or series of events. There have been many examples of such events in Hungary in the near past. Just think of the extreme cold and blizzard on 15 March 2013 (actually lasting for several days) or the flood on the Danube in June 2013, hitting all-time records in several places in terms of water levels.

5.1. Primary effects

5.1.1. Extreme temperatures

Hungary has a continental climate, with hot summers with low overall humidity levels but frequent showers and frigid to cold snowy winters. Average annual temperature is 9.7°C. Temperature extremes are about 42°C in the summer and −29°C in the winter. Average temperature in the summer is 27°C to 35°C and in the winter, it is 0°C to −15°C. The average yearly rainfall is approximately 600 mm. (Lakatos–Bihari 2011)

In Central and Western Europe, both the warm and cold tails of the temperature distribution in winter warmed over the entire 20th century. Warming of winters during 1946–1999 occurred in both the warm and cold tails for both Tmax and Tmin, with the largest warming in the cold tail for Tmin. There is more evidence for summer warming in the first half of the century compared with the second half. (Christensen–Christensen 2007)

More and more studies underline that there will be significant annual average air-temperature increase globally and in Europe, as well. A European Environmental Agency (EEA) report presented that the annual average air-temperature change (increase) will vary from 0.34°C to 2.47°C in European territory.

Increasing air-temperature is predicted for the Danube Basin, as well with higher than 1°C temperature increase in the Eastern and South-Eastern part of the basin. For Central Europe, including the Danube Basin, approximately 60% increase is predicted in the maximum number of consecutive dry days. The summer of 2012 was very hot and dry in South-East Europe; it was the hottest and third-driest on record in Serbia. For this part of South-East Europe (including parts of Northern Serbia and Southern Hungary, as well as smaller areas in Bosnia–Herzegovina, Croatia and Romania), the change of the likelihood of an extreme summer such as the one of 2012 between the decades of 1960–1970 and 2000–2010 was assessed. This was done by studying decade-long model simulations (general circulation model and an embedded dynamical regional climate model) and observations. From this study it was concluded that the magnitude and frequency of heat waves have increased considerably in South-Europe between the 1960s and the 2000s. In addition, indices combining temperature and precipitation to assess changes in dryness and heat stress risk have been analysed; these results also show an increase in return time, although the results are subject to uncertainties. (Christensen–Christensen 2007)

In the last years several efforts were carried out worldwide in order to estimate the regional impacts of the global climate change, from which the PRUDENCE project (completed in 2004) provided the first comprehensive projections for the European region. At the Hungarian Meteorological Service, the 50 km resolution results of five regional climate models used in the project were analysed, and the tendencies of precipitation-, temperature-, and wind-related extreme parameters were intensively examined providing a good basis for the preparation of National Climate Strategy of Hungary, which is a guideline for the Hungarian policy makers to define the main track of the adaptation policy to the impacts of the climate change in Hungary.

The results of model calculations show a temperature increase in Hungary in 2040 compared with 1961–1990. This projected increase is 0.8–1.8°C on an annual basis. For the seasons slightly different results are obtained: for spring, summer, autumn and winter, increases are projected of, respectively, 1.0–1.6°C, 0.5–2.4°C, 0.8–1.9°C and 0.8–1.2°C.

The number of frosty days is expected to decrease in 2040, compared with 1961–1990, in all parts of the country, by 12–15 days. The areas at higher altitudes are expected to show a larger (more than 14 days in average) reduction, while the southern, lower areas are expected to show a smaller change. The number of frosty days shows a definite reduction tendency, which will decrease the heat consumption due to a higher average temperature and a shorter heating period. The number of days with heat alert shows an increasing tendency in 2040, compared with 1961–1990 (by 14 days in the southern regions of the country), and this will cause a higher cooling demand, thus higher energy consumption. (Szépszó 2008)

The largest temperature increase is expected in summer, and the smallest increase in spring. The expected summer warming of Hungary in 2071–2100 compared with 1961–1990 ranges from 4.5–5.1°C (scenario A2) and 3.7–4.2°C (scenario B2). For spring, the expected temperature increase inside Hungary is 2.9–3.2°C (scenario A2) and 2.4–2.7°C (scenario B2). (Pongrácz et al. 2011) Projected spatial gradients of warming for summer and winter by the end of the 21st century show increasing values from north to south in the summer, and increasing values from west to east in the winter; differences are between 0.4 and 0.8°C.

By the end of the 21st century, countries in Central Europe will experience the same number of hot days as are currently experienced in Southern Europe. Regarding the temperature extremes, the model results render the increase not only for the individual warm extremes (warm, summer and hot days), but also the heat waves and hot periods will occur more often. As further consequence of the regional climate change over Hungary, the frequency of frost days and freezing periods will be expectedly reduced. All this (i.e. the decrease of cold and increase of warm extremes) fits well into our view about the mean warming tendencies over Hungary, the colours mean:

Yellow: Severe weather is possible over the next few days and could affect you. Yellow means that you should plan ahead thinking about possible travel delays, or the disruption of your day to day activities.

Orange: There is an increased likelihood of bad weather affecting you, which could potentially disrupt your plans and possibly cause travel delays, road and rail closures, interruption to power and the potential risk to life and property. Orange means you need to be prepared to change your plans and protect you, your family and community from the impacts of the severe weather.

Red: Extreme weather is expected. Red means you should take action now to keep yourself and others safe from the impact of the weather. Widespread damage, travel and power disruption and risk to life is likely. You must avoid dangerous areas and follow the advice of the emergency services and local authorities.

5.1.2. Extreme precipitation

In Central and Western Europe, significant increasing precipitation trends over the 20th century dominate in winter for both average precipitation intensity and moderately strong events. Simultaneously, the length of dry spells generally increased insignificantly. (Nováky 2007)

Due to the increasing evaporation of sea surfaces and the higher vapour absorption capacity of warmer air, the atmosphere will be more humid, evaporation and rainfalls will become more intense, and there will be a stronger hydrological cycle. The system will contain more thermal energy, leading to more intense rainfalls: the given quantity will arrive more suddenly, more tropically, like a deluge.

Observed changes in annual precipitation highlights that the southern part of Europe including the Danube Basin is significantly affected. The observed annual precipitation decreased in most parts of the Danube Basin, especially in the Carpathian Mountains, which are the dominant recharge area of the groundwater resources in the lower part of the Carpathian Basin. It was reported that simulation results showed significant increasing trends in maximum number of consecutive dry days for three European regions when different IPPC climate scenarios were applied. (IPCC 2012b)

The annual precipitation amounts significantly decreased in the 20th century. It is most significant during spring when the sum of precipitation is only 75% of the sum in the beginning of the 20th century. The summer precipitation amount did not change in the past 100 years. The autumn and winter precipitation decreases are 12–14%. The winter precipitation is the lowest in comparison to the other seasons. (IPCC 2012b)

In case of precipitation, it is emphasized that for the end of the 21st century the reduction of the number of days with precipitation has to be considered, while at the same time the frequency of the days with heavy (and very heavy) precipitation will expectedly increase (and consequently, the number of days with light precipitation will be reduced).

The domestic and international weather-related phenomena of the past period have directed attention to the set of problems in connection with extreme weather conditions and have brought into public awareness such concepts that have not yet been thoroughly clarified. More and more scientific disciplines realize today that the changes of weather, climate and climatic conditions realise an actual risk. It appears that those extreme weather phenomena are increasing more frequently which often result in human casualties and cause significant collateral damage.

It is problematic that the decreased amount of precipitation falls in a more intensive pattern which decreases the potential utilisation of the water and increases the runoff, which increases the risk of floods. (Nováky 1991)

5.1.3. Severe storms

As far as wind events are concerned, no significant changes could be detected in the range of lower and *ordinary* wind speed values, the occurrence of intensive and stormy winds will likely increase, however, the projected change has very small magnitude. The simulations show that the daily maximum wind speed is not the most appropriate indicator for extreme storm events. In the last few years several tornados were observed in Hungary. Two types of tornadoes exist, one of them, the so called mezocyclonis is formed of supercells, and the other is formed of weaker storms. In Hungary the strongest tornado formed at Mezőkövesd in 2009, it was EF-3 strong.

Hail is usually an accompanying phenomenon of heavy thunderstorms (and therefore local in nature), with wind storms. It occurs when updrafts in a thunderstorm transport raindrops into the extremely cold layers of the atmosphere, and the drops freeze there to a solid state. The hailstones formed in this way fall on the ground with a downdraft of the storm. *Hailstones* are almost always formed in a hail storm, but in most cases they melt by the time they reach the ground. Whether hail is generated depends on the size the hailstones reach in the cloud. After a certain size threshold, hailstones can no longer melt while they are falling. The more intense a thundercloud is, the bigger are the hailstones reaching the ground.

5.1.4. Droughts

Negative impacts caused by global warming occur more and more, year by year in Hungary, as well. Climate change in our country led to more frequent extreme weather conditions, causing more cases of destructive, stormy wind, deluging rain, snow storms and major temperature fluctuations. However, these sudden weather changes cannot always be predicted, therefore it is difficult to prepare for the protection and mitigation of losses, thus damage prevention poses new challenges for professionals. Recently, these events have caused serious damage in several inhabited areas of Hungary, and tackling the consequences was a difficult, complex and expensive project. (Szucs–Madarasz 2013)

By analysing the impact of weather extremities on natural and artificial environment and remediation efforts taken to mediate their consequences, we can conclude that more precise knowledge of these phenomena, preparation for damage elimination, and experience of organizations involved in loss prevention can provide useful basic information by different types of catastrophes.

5.2. Secondary effects

5.2.1. Floods

Hungary's climate is strongly influenced by 3 air currents, which may not be disregarded from the point of view of flood protection:

- Atlantic air current (from the West)
- Continental air current (from Eastern Europe)
- Mediterranean air current (from the South)

Continental air currents cause drought and heat in summer and long-term cold in winter. The humid air currents from the Atlantic Ocean and the Mediterranean Sea, on the other hand, may moderate the extreme temperatures but may also bring large amounts of rain. These air currents can lead to intense and extensive rainfalls in any period of the year. As a result, heavy and long-lasting floods, as well as inland waters can be expected on any river and in their catchment areas.

Different types of floods are observed in the Carpathian Basin. Floods originating from snowmelt accompanied with rainfall are typical for major rivers with headwaters in high mountains; they occur usually in late winter or early spring months, from February to April. The largest rivers, the Danube and Drava have Alpine regime and snowmelt-dominated floods occur later, usually in May–June. Rainstorm generated flash floods on small streams may appear any time in the warmer half year. Floods caused by ice jams became extremely rare in the last 40–50 years, which can be explained by both anthropogenic (river training, barrages, reservoirs, cooling and waste water inlets) and climate impact, in particular by increasing winter temperatures. (Takács 2011) Floods of medium and large rivers (the Danube, Drava, Tisza and their tributaries) propagate on floodplains constrained by flood embankments, i.e. in the main channel and on the so called flood berm. Valleys and floodplains of small streams are seldom protected from inundation. Floods can be characterised by frequency of flood crests and peak discharges.

Although there is as yet no proof that the extreme flood events of recent years are a direct consequence of climate change, they may give an indication of what can be expected: the frequency and intensity of floods in large parts of Europe is projected to increase. In particular, flash and urban floods, triggered by local intense precipitation events are likely to be more frequent throughout Europe. (EEA 2007)

Frequency of extreme floods of the Danube and Tisza rivers was examined taking into account only ice free floods, with flood crests exceeding 700 cm for the Danube at

Nagymaros and 800 cm gauge readings for the Tisza at Szolnok. During 1901–2010 extreme floods occurred on the Danube 10 times and on the Tisza 14 times, but frequencies changed considerably in time. Extreme floods occurred only twice in the first half of the period on the Danube and four times on the Tisza, while more than half of 24 extreme flood events on the two rivers were observed during the last two decades between 1991–2010. Flood crests on the Tisza in 1997, 1998 and 2000, and on the Danube in 2002 and 2006 exceeded the earlier observed peaks.

Similarly to rivers in Hungary the frequency of extreme floods on some big rivers of Central Europe also increased in the last two decades. (EEA 2012)

Extreme floods became more frequent on some tributaries of the Tisza (Körös, Hernád), but no significant change in frequency of extreme floods is observed for other rivers (Szamos, Bódva, Zagyva, Rába). (Szlávik 2002) The frequency of floods seemingly increased in some smaller rivers, especially those originating from the northern parts of the Carpathian Range, or Mátra Hills inside of Hungary, however limited flood frequency analyses do not allow to make a final conclusion.

The frequency of extreme floods, flood crests of major rivers (the Danube, Tisza and their main tributaries) has been growing quite unambiguously during the last 110 years, however flow peaks being directly connected to climate do not show any significant tendency. The increase of flood crests and peak stages can be explained more by non-climatic factors, like land use changes, (Szlávik 2002) worsening conditions of flood propagations on flood berms during the last decades due to the growing sedimentation, changing canopy cover, and some geomorphologic processes like formation of bank-side bars.

The height of the levees (the design flood level) was calculated as the hundred-year flood level plus 1.0 metre safety height. In case of floods, exceeding the design flood level the opening of emergency storage reservoirs facilitated the reduction of flood peaks. Flood levels have increased considerably in the past decades. This was due to the weather's becoming more extreme, due to the reduction of discharge capacity of the channel, and due to anthropogenic impacts on the catchment basin. In Hungary, draining of the Tisza wetlands began in the 19th century and today some 500,000 people, 5% of Hungary's population, live on land reclaimed from the Tisza. As a result of efforts to reduce flood impacts by building higher dikes and continued river bed regulation, there is a deposit of silt within the main bed, which has inadvertently increased flood risks. In addition to the altered nature of floodplains, the reduction in upper and mid-catchment water retention leads to more flood events downstream where river channels and small floodplains no longer contain peak water levels, even from minor flood events. The lack of coordinated mechanisms for mitigating flooding already in the upper catchment may lead to compounded impacts downstream.

5.2.2. Wildfires

The total forest area in Hungary is 2 million hectares (ha), the forest cover index is 20.5% of the total country area. The highest forest density is found in low mountain ranges, whereas in the lowlands it is typical to find mosaic land use structure.

Approximately 600,000 ha of the Hungarian forests were planted between 1950 and 1980. Before the recent political changes, 99% of the forests were in state ownership.

During the complicated process of change in the political system, a basic change in forest ownership relations took place, and as a result of this change approximately 730,000 ha of the forests became privately owned.

Forest fire hazard strongly depends on weather conditions. Fire danger started to rise in April and it reached the *very high* level more times during the year. Although the fire dangerous periods were forecasted from April, there were lots of wildfires in the endangered parts of Hungary from the beginning of March. For example, the 2012 fire season reached out to autumn (in the middle of October). Forest fires have multiplied in the last few decades in Hungary. The reasons can be found in climate extremities, less precipitation, the increase of mean annual temperature and a series of winters without snowfall. Due to the warming, the dangerous period of wildfires has extended, which may issue in the increase of such fires, especially if the socio-economic circumstances remain the same. The average rate of fires smaller than 1 ha is almost 50%. The most problematic and the most prevalent type is the so called *average size* forest fire (between 1 ha and 10 ha), which adds up to the other 40% of the total number of fires. (Földi–Kuti 2016)

95% of forest fires are surface fires. Surface fires, when surface litter and other dead vegetal parts and smaller shrub burn have been common in the Hungarian forests. They can develop in the whole fire season. Canopy fires mostly develop in coniferous forests, mainly in the Great Hungarian Plain during summer. Ground fire is not significant in Hungary, though – due to partial, relatively thick peat – it is not unknown either. Small fires under 1 ha extent give 62% of the total of forest fires. This fact well depicts that the capacity of fire fighters and disaster prevention services are overloaded by spot fires. Small fires are usually low intensity surface fires where dry grass and small twigs are burning. Forest fires beyond 100 ha rarely occur in Hungary, in which mainly conifers, native poplars and locusts are burnt. Spring vegetation fires usually burn with low or medium intensity in broadleaf forests, juvenile growths, shrubs and grasslands. Fire totally or partially consumes forests and causes serious harms. 40–45% of spring fires burn in the northern areas (Borsod-Abaúj-Zemplén county, Heves county, Nógrád county) which indicates these areas as high forest fire danger zones. In these areas not only traditional grassland management methods, but other social-economic factors add to the forest fire danger.

Forest litter, needles, dead twigs and branches get totally dry in arid summer periods (June–August) without rainfall and start easily burning as a consequence of negligently lighted fire. Coniferous forests are highly endangered, as a small litter layer fire can even result in canopy fire in this period. Unlike spring fires, summer fires usually burn in the Great Hungarian Plain. These fires burn almost every year in the poor sites of Bács-Kiskun county and Csongrád county. Due to climate and vegetation circumstances, naturally induced forest fires are of no account (about 1%) in Hungary. 99% of the forest fires are human induced (negligence or arson). Most fires are induced by the negligence of adults and infants and only a small proportion of fires are caused by arsonists. Typical forest fire causes are the incorrectly extinguished fires of hikers, and the illicit agricultural fires. The most part of the total burnt area was due to incorrectly extinguished fires. There are a lot of fires with unknown causes. The cause of the fire is not directly verifiable in many cases. If the circumstances of the forest fires are undetermined, the cause is registered as *unknown.*

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Júlia Hornyacsek

The Protection of the Population against the Impacts of Power Outages Caused by Extreme Weather

1. Introduction

In the everyday life of the population, the main source of energy is electricity, the lack of which renders citizens vulnerable and prevents the normal operation of macro and micro communities. Service providers, the public and the protection entities had to face serious difficulties in this regard.

Due to climate change, such events cannot be excluded in the future, their number is likely to increase, and so, it is important for protection agencies, municipalities and the citizens themselves to do their best in order to reduce population vulnerability and to enhance protection. Institutions and authorities, and even the population are not prepared for overcoming the consequences of these phenomena, so, the people are vulnerable. Researches related to climate change cover many areas beyond the investigation of causes; they tackle the issue of adaptation, which has much literature, but only a few studies investigate the impacts resulting from the weather and the consequences of a power failure, from the perspective of population vulnerability.

It is therefore timely to map how such a situation would affect families, what this means in their way of life, how prepared they are to deal with such problems, and what role protection entities, municipalities and service providers have in defining protection. The question arises as to electricity and the lack of it, i.e. what is the most sensitive issue for the population, where they can expect effective help, and how to increase their willingness to provide self-care. I have assumed that self-care is on a low level, professional bodies and service providers concentrate on resolving problems, and protecting and helping people; in such cases, they can focus less on other important issues, so, citizens have to deal with these situations mostly on their own or relying on their families and friends.

In this research, I have aimed at exploring extreme weather phenomena that dominate amongst the consequences of climate change and their impacts, especially on power outage.

I have investigated the population in Hungary with the help of a questionnaire survey. What problems they face when there is a power outage, how and from where they receive assistance, how prepared they are and what solution proposals they use to reduce vulnerability. Based on the results of the survey and the data in the literature, I have made recommendations on how to reduce the vulnerability of the population to power outages and to enhance the methods of protection. First, I have analysed disaster tendencies and extreme weather phenomena and their consequences.

2. Disaster Tendencies, Extreme Weather Phenomena and their Consequences

Nowadays, the negative impacts of climate change pose a significant challenge for the states, protection entities and the population alike. (Padányi–Halász 2012) Consequently, the temperature on Earth is steadily increasing, (Grosjean 2005) also extremities in weather, both warmth and cold. (Braun–Kramer 2003) As a result, droughts develop more and more in larger areas, which can lead to famine (Reichardt 1991) and have a particularly negative impact on dry areas. (Afrika szarvánál 2017) In dry areas, not only famine and the loss of agriculture threaten the lives of the population, but often forest and bushfires, too. The nature of precipitation has changed, dry periods are often followed by sudden heavy rainfalls, (Tűzvész után áradás 2018) resulting in flash floods (Ebbe und Flut s. a.) as well as land- and mudslides. It is important to review the issues that need to be taken into account when addressing these phenomena.

2.1. Disaster tendencies

With the impacts of weather anomalies, one should count with increasingly complex natural disasters. These tendencies have necessitated the collection of data on disasters of such nature and the drafting reports to serve as support for government decisions. The international organization that collects data based on statistics related to the topic is the Centre for Research on the Epidemiology of Disasters (CRED) that has an enormous database and up-to-date information.[1]

Based on the report, it was already established in 2001 that the number of flash floods, high intensity storms and wild fires are increasing and causing significant damages. These disasters are unfortunately listed in the statistics in *top* rankings.

In 2016, the report on world risks proved that amongst the threatening phenomena between 1980 and 2015, considering the numbers and the extent of damages caused by them, floods and storms were the most significant ones.

[1] CRED was established in 1971 in Brussels, in the Public Health School of Louvain Catholic University. Since 1980, CRED has been part of the Emergency Preparedness and Response Program of WHO covering the entire world. Since then, CRED has considerably increased its international network and works closely with a number of UN agencies, intergovernmental and governmental organizations, non-governmental organizations, research institutes and other universities. (CRED)

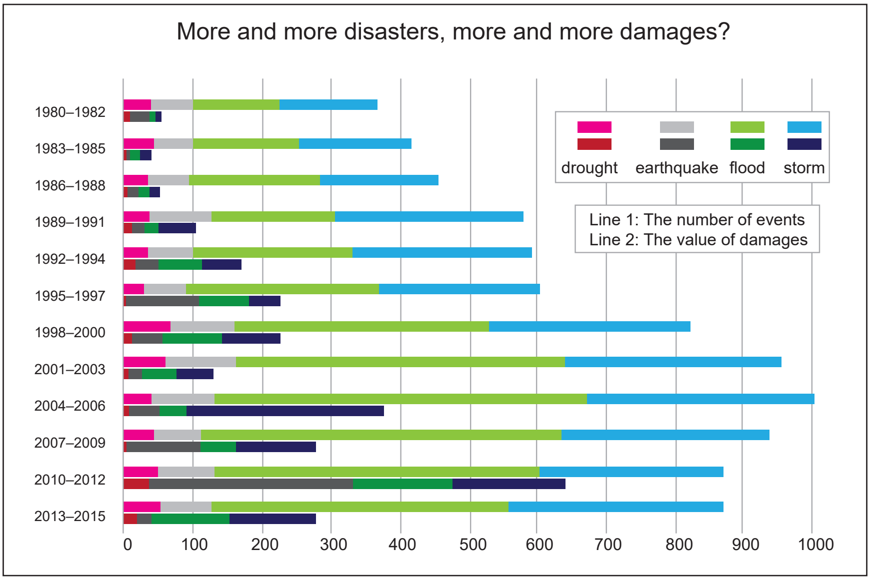

Figure 1.

The number of disasters and the value of damages caused by them between 1980 and 2015

Source: Made by the author based on WeltRisikoBericht 2016

2.2. Extreme weather phenomena and their consequences

The lives of humans are greatly influenced by the most important parameters of the atmosphere surrounding the Earth such as temperature, humidity, air pressure, precipitation and processes in the atmosphere, the equilibrium state of the atmosphere, cyclones, anti-cyclones, etc. Weather elements such as cloud conditions, temperature, the quantity and form of precipitation have the most direct impacts on all of us, including, of course, weather fronts.[2] Extreme weather due to climate change and its consequences does not only affect humans but also the built and natural environment.

They can cause damage, so, it is important to know their consequences. Extreme weather phenomena include *extreme cold temperatures and ice, extreme hot temperatures and persistent droughts, wind storms, snow storms* and their combination as well as *torrential rainfalls* resulting in emergencies or disasters.

These weather phenomena often endanger the health of the population, (Wetter s. a.) their normal lifestyle, and material property. (Buckley 2005; Láng 2007) Their main characteristic is unpredictability and the deviation from normal weather tendencies, their incidence, intensity and damages caused by them. (OMSZ 2018) All this makes it difficult to prepare for coping with them, to reduce the vulnerability of the population against them and

[2] It is a border surface between the air mass of different thermodynamic properties, mostly of different temperatures, whose cold, hot and obstructive forms are distinguished. (Holicska 2008)

to mitigate the damages. In addition, they burden the capacities of rescue forces and health care personnel, considerably making it difficult to perform their basic tasks (e.g. firefighting).

In order to make suggestions on how to reduce the population's vulnerability and to increase protection, I have investigated the various types of weather and named their potential effects as identified damages.

I have performed the research by analysing recent disasters associated with extreme weather and have identified the effects, i.e. defining variables as damages, and their attributes. Subsequently, I have investigated the probability of occurrence of the given damages in the matrix of different weather phenomena and summarized them in a Table 1. I have used the terms low, medium and high to characterize them. I regarded it as *low* if the damage occurred with 30% probability, *medium* if it occurred between 31 and 75% probability, *high* if it occurred with probabilities above 75% (coded by numbers 1, 2 and 3).

It can be traced in literature and in case studies, (BARBER 1995) and it was also verified by my investigations, that during extreme weather, the number of possible types of damages or negative effects (as variables) is above twenty (see Table 1). Most of the damages are caused by torrential rains, extreme cold and wind storms.

However, a problem would certainly be caused by the failure of food supply, occurring with the same likelihood. The probability is low that the administration would be suspended, and the occurrence of wall or landslides is also unlikely. However, if they occur, their mortality index is high and would cause large damages.[3] Power outages are most likely to occur in all cases and they would not only make life difficult, but would also have an impact on rescue or damage elimination, therefore, I have investigated it in a separate chapter.

Table 1.

Damages related to extreme weather and the probability of their occurrence

Damages/ Variables	**Extreme weather phenomena and their probability**					
	extreme heat	**extreme cold, icing**	**windstorm, tornado, thunderstorm**	**snow-storm**	**torrential rain**	
damages to buildings	low (1)	low (1)	medium (2)	medium (2)	medium (2)	8
damages to roads and bridges	low (1)	low (1)	medium (2)	low (1)	medium (2)	7
damages to water and canalization network	low (1)	medium (2)	low (1)	low (1)	medium (2)	7
failure of gas and distance heating services	low (1)	medium (2)	low (1)	low (1)	medium (2)	7
failure of power supply	medium (2)	high (3)	medium (2)	high (3)	medium (2)	12
failure of waste removal	low (1)	medium (2)	medium (2)	medium (2)	medium (2)	9
inundations	low (1)	low (1)	low (1)	low (1)	big (3)	7

[3] The rate of death tolls in a disaster.

landslides, collapse of river bank walls	low (1)	low (1)	low (1)	low (1)	medium (2)	6
fires, explosions	medium (2)	low (1)	medium (2)	low (1)	low (1)	7
failure of transportation and traffic	low (1)	medium (2)	medium (2)	medium (2)	low (1)	8
emergence of epidemics	medium (2)	low (1)	low (1)	low (1)	medium (2)	7
failure of public administration	low (1)	low (1)	low (1)	low (1)	low (1)	5
deterioration of public security	low (1)	low (1)	medium (2)	medium (2)	medium (2)	8
deterioration of health	high (3)	medium (2)	low (1)	low (1)	low (1)	8
damage to plant life	high (3)	high (3)	medium (2)	low (1)	medium (2)	11
damage to animal life	medium (2)	medium (2)	low (1)	low (1)	medium (2)	8
damages to the agriculture	high (3)	low (1)	medium (2)	low (1)	high (3)	10
failure of public food supply	low (1)	medium (2)	medium (2)	medium (3)	low (1)	9
exhaustion of health care capacities	medium (2)	medium (2)	low (1)	low (1)	low (1)	7
failure of news and communication services	low (1)	medium (2)	medium (2)	low (1)	low (1)	7
	30	**33**	**31**	**28**	**35**	

Source: Drawn by the author.

It is also apparent from the table above that the loss of power supply is a very common problem, therefore, I investigate its effects, vulnerability and sensitivity. First, let us consider the system and characteristics of power supply in Hungary.

3. The System of Power Supply in Hungary and its Vulnerability

Nowadays, electricity has become a decisive source of energy, the lack of which essentially affects our lives. It is the basis of the operation of machines, heating and air conditioning systems in households. Media devices, mobile phones, etc. cannot be used without it. The operation of authorities, service providers, education, healthcare, etc. is unimaginable without electricity. Life in our age is exposed to the convenience of electricity, but its failure would make families vulnerable, i.e. they would become exposed. To identify the vulnerability points of this service, we have to know the system of electricity supply and the process how it reaches the consumers.

The entirety of devices for production, transmission and distribution of electricity is also called electrical works, and their cooperating system is called the electric energy system. It consists of power plants, network connections and so-called stations (transformers, circuit breakers, disconnectors, control and protection equipment). Electricity is produced in power plants by power generators. Earlier, only direct current was produced, but nowadays, thanks to the invention of Hungarian scientists (Bláthy, Déry, Zipernowsky), the transformer, alternating voltage is transformed into low voltage, so, electricity can be well transmitted and has a low specific loss.

The aggregate production of large power plants made up, already in 2006, 93.17% of the total domestic electricity production, and provided 72.17% of the total domestic electricity consumption. The supply is balanced and the remaining demands are covered by electricity import. (NAGY–DOMINA 2008)

The operation of power plants and the introduction of possible service restrictions are stipulated by law in order to ensure generation of electricity in emergencies. For example, strict rules apply to electricity traders and other operators of the organized electricity market supervised by the Hungarian Energy and Utilities Regulatory Authority regarding reliability, continuity of supply, operational safety, customer relations, characteristics of electricity quality and quality of supply and other typical services related to its core activity. (ALFÖLDI 2016)

Electricity production is balanced and the production in Hungary can cover a substantial part of our demands. The production by the power plants in Hungary made up 71.38% (31.70 TWh) in 2016 of the total usage, and 28.62% (12.71 TWh) were imported. The volume of import–export balances decreased by 7.12%, the production in Hungary was by 4.79% more than the volume of the previous year. Domestic electricity production was more by 4.79% in 2016 than in 2015. The production by large power plants increased by 3.92%, the one by small power plants by 9.99%. The total usage of electricity (gross production and import and export balance) in 2016 was 44.41 TWh, up by 1.08% over the previous year. (ALFÖLDI 2016)

The power plant production technology is reliable. Disasters or other risk factors can only hinder and interfere with production to a small extent. Therefore, due to organizational and business policy, there is a relatively little risk of a power outage due to the fault by the producers.

The electricity from the power plants[4] is transmitted to the consumers[5] through the *electric energy network (grid).*

It consists of collective rails, overhead lines and cables. Since small consumers receive electricity through this network, we need to describe its features. The current system of *electricity grid or network* cannot be separated from its development and evolvement. In the 1800s, community–city power stations were first established together with local networks. They were followed by the establishment of district power plants and medium voltage district networks in the middle of the 20th century. High-power, nationwide power plants and high-voltage networks have been built since then; and the conditions for joining international networks have also been established. The two-tier system of public limited companies was formed in the 1990s, whose components were the Hungarian Electricity Ltd. (MVM Zrt.), the power and utility companies and the Fundamental Grid Society. Later, in order to be able to connect – if necessary – foreign sources to the system as well, when the joint organization of the Polish, Czech and Slovak energy systems, the CENTREL regional association was established, Hungary also joined it. It consisted of four electricity companies

[4] *Power plant:* an energy conversion facility located on one site which, using its primary source of energy, generates electricity, including an energy storage power plant for licensing purposes. (NAGY–DOMINA 2008)

[5] *Consumer:* who buys electricity for using it at its own user site from a public network or through a private electricity line not by transmission. (NAGY–DOMINA 2008)

(the Czech EEPS a.s., Hungarian MVM Zrt., the Polish Polskie Sieci Elektroenergetyczne SA and the Slovak Slovenská Elektrizaená Prenosová Sústava a.s.).

By the end of the century, Hungary also joined the international organization, UCTE (Union for the Coordination of Transmission of Electricity). By doing so, Hungary was *directed* by three international associations: CENTREL, (later forming part of the latter): UCTE,[6] and SUDEL, the association of the southern member states. (Pál s. a.) Also see Figure 1.

At the end of 2008, ENTSO-E (European Network of Transmission System Operators for Electricity) was established. The organization was prepared gradually, and on 1 July 2009, it started its actual operation. The predecessor organization and the synchronous alliances (UCTE, NORDEL, UKTSOA, ATSOI, BALTSO) gradually passed on their tasks to the new one and terminated on 1 July 2009. (Alföldi 2016)

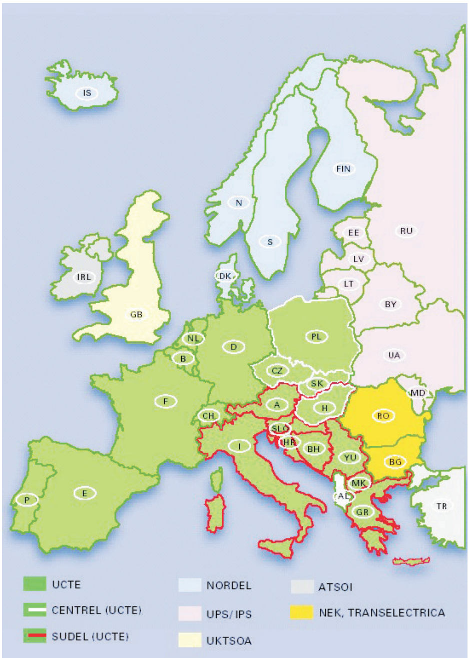

Figure 2.
European electric energy systems

Source: Pál s. a.

The exposure of networks to hazards is higher than that of power plants.[7] In most cases, power outages are caused by network injuries and failures triggered by extreme weather.

[6] Union for the Coordination of Transmission of Electricity, which was responsible for coordination between the members of the organization, and for widening the European network, as well as providing electricity for the 400 million consumers concerned. The members were 29 transmission network operators in 24 countries.

[7] On a national level, the basic network is managed and supervised by MAVIR Zrt. (Hungarian Independent Electric Energy Transmission Operator Company Limited); it also performs the international coordination. There are six service providers, the cooperation of their activities are also performed by MAVIR Zrt. The power lines are owned by MVM OVIT National Power Line Company Limited. (MVM csoport 2018)

3.1. The consequences of a power outage and the necessary population protection duties

Below, by examining power outage cases, I have systemized the problems and consequences[8] occurring during a long-lasting power outage, and I have defined the tasks to be done. The basic situation is an extreme power outage, lasting several days.

Table 2.
The consequences of a power outage and the necessary population protection duties

	Consequences of a power outage	**Protection tasks to be performed to protect the population**
1.	refrigerators stop working, food goes bad	ensuring energy sources food distribution raising awareness of the danger of epidemics
2.	business units do not work, food supply is hampered	restrictions on the purchase of foodstuffs setting up emergency points of sale
3.	electric heating and individual heating stops	setting up other heating options (mixed combustion fireplaces, etc.)
4.	no lights, no electrical machines work	distribution of candles, torches, battery-powered lights, solar energy lamps
5.	the water supply is hampered and stops	water usage restriction, water distribution
6.	info-communication equipment and household appliances do not work	use of battery-powered radios, setting up other options for the flow of information
7.	health care is hampered	activating health care units of humanitarian organizations, setting up emergency hospitals and health care facilities
8.	public order is disrupted, looting	increasing police forces, involving NGOs in policing
9.	traffic disruption	maintaining police surveillance of traffic
10.	production is hampered or stops	setting up power generators
11.	disruption in animal husbandry (poultry hatchery, etc.)	setting up power generators, dislocation of animals if needed
12.	failure of banking services	elaborating and using manual solutions
13.	disruption in medication supply	setting up mobile medication supply points
14.	educational institutions do not accept children	children supervision with the help of volunteers

Source: Drawn by the author.

[8] New York, 13 July 1977: the events of the 25-hour power outage; power outage due to lightning in Hamburg, series of power outages in India, power outage in Hungary in 2018. (PINTÉR 2018; Blackout77 1977; Blitzeinschlag 2018; Amsterdam 2018)

It can also be seen from Table 2 that the population has to cope with many negative impacts, thus, the professional entities responsible for the safety and security of citizens should also participate in the protection of the population.

4. Questionnaire Survey: "The impacts of power outages on the population due to extreme weather"

Nowadays, in the era of developed civilizations,[9] electricity is an indispensable part of our everyday life. The world around us has many services that make our life easier. Machines and systems work with electricity, so, electricity is a constant accompaniment of our daily life. Our comfort, however, has a price: we are vulnerable to energy systems, including electricity. In the previous section, I have shown that, in the context of global climate change, disasters may also develop, in particular due to the extreme weather phenomena. I have proved that, in these cases usually, there is no electricity supply and therefore, most likely, in the event of a temporary or long-lasting power outage, the normal life of the population is disrupted. A question is how electricity arrives in the households, through which services and service providers we receive it and what the consequences are if there is no electricity. There is another question as to how well the population is prepared for these situations, from whom they receive help if needed and how inclined they are to self-care. In order to clarify the questions, I have conducted a questionnaire survey.

4.1. The design, the hypotheses and the objectives of the survey

In this survey, I have used the in-group design in a pre-test/test format. (Konta 2009) The preparation and conduct of the survey went on in the following 12 phases:

[9] Here: communities with social, economic and intellectual development and their systems. Useful reading on the topic: Elias 1969, 1983.

Table 3.
Survey design

Phase 1 Selecting the topic and defining the objectives.	Phase 2 Conceptualizing and defining the concepts, defining the *indicators* necessary for measuring them and the *dimensions* of the different aspects of the concepts.	Phase 3 Defining the variables, operationalization, i.e. making the given concept measurable (assigning data to specific properties).
Phase 4 Formulating hypotheses, creating the main hypothesis and the sub-hypotheses.	Phase 5 Creating the tool: questionnaire. Trial completion, corrections.	Phase 6 Determining the multitude, selecting the sample randomly.
Phase 7 Determining the form of the survey.	Phase 8 Conducting the survey.	Phase 9 Sorting and filtering data.
Phase 10 Evaluating the results, deducting conclusions.	Phase 11 Comparing the results with literature and hypotheses.	Phase 12 Recommendation.

Source: Drawn by the author.

During the survey, I have always striven to align the formulation of the problem, the objectives and the methods. Let us now examine the most important elements of the Table.

Main hypothesis: I have assumed that today the population is significantly affected by power outages; it is forced to solve the problems usually by itself, and that the people are open to expand their knowledge of extreme weather and power failure and to enhance their self-care.

Sub-hypotheses:

1. The cause of a long-lasting power outage is, in most cases, the fall and the damage to the pylons and pillars.
2. The main reason for the delayed repair time was that the service provider capacity was insufficient.
3. Mostly, they can repair the failures in 3 to 6 hours.
4. Most people do not have any information on the causes.
5. Mostly, the population is not informed by the protection entities or the service provider when the system would be up again.
6. A power failure is very disruptive to the way of life of most people.
7. The majority of the population is mostly annoyed by the fact that they cannot operate TVs or radios at this time.
8. Most people experience as the biggest damage if refrigerators do not work and food goes bad.

9. Most of the population should solve the problem in such cases on their own, they cannot expect the assistance of the municipality or service providers.
10. Most of the population would have needed backup power sources, but they did not get any.
11. Most families do not have a home backup power source.
12. According to the opinion of the majority, not the service providers are to be blamed for the delay in repair, but the weather makes it difficult.
13. The elderly does not pile up reserves for extreme weather because they do not have the resources to do so.
14. The population would be open to increasing their knowledge in any way on power outages.
15. A long-lasting power outage would cause the greatest concern to most of the population in extreme weather.
16. The majority of the population would like to have backup power sources and reserve food supply and would expect to receive them entirely from a central source.
17. The majority of the population would expect help from the local government.
18. The majority of the population would welcome an increase mainly in the provider capacity of protection against power outages.

The theoretical objective of the survey is to provide a scientific background for the resolution of the tasks of population protection due to extreme weather phenomena.

Its practical objective is to measure and assess, with a wide-ranging research how citizens are affected by long-lasting power outages due to storms and how the negative impacts may be reduced.

The methodological objective of the survey is to verify the fact-finding method and its indicators, the measurability of this field, and to provide a basis for solving population-protection issues.

Dependent variable: the impact of the extreme weather and the power outage on the population, the status of assistance, piling up reserves and the willingness to do so.

Independent variable: age, residence, financial situation, indicators of the responders living in one household.

I have endeavoured throughout the research to keep the survey valid, reliable, and objective, i.e. it should measure what I was targeting in the research and be repeatable, meaning that in a given case, it should produce similar results when repeated as in this survey if the circumstances are identical.

4.2. Questionnaire as a measuring instrument and the evolution of the sample

The questionnaire was made in an electronic form and shared by email and social media randomly with the responders, with the following interface.

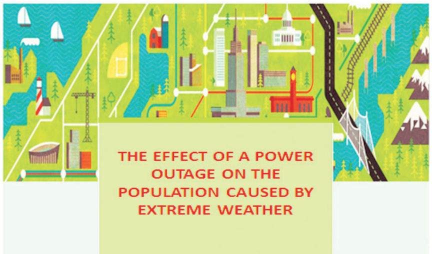

Figure 3.
Appearance of the electronic questionnaire on the web interface

Source: Made by the author.

The instrument was a questionnaire with 21 questions, in which there were 3 groups of questions as below:

- questions on power outage 11
- questions of preparation 6
- questions on piling up (accumulating) reserves and backup, on the care of the population and recommendations on the solutions 4

The 21 questions have been formulated in the form of a multiple choice, ranking and explanatory question. I have combined the response possibilities of simple and multiple choices, assignment and short text answers.

4.2.1. Characteristics of the sample

The sample was selected randomly, shared online, and 250 persons completed the questionnaire. Not all questions have been answered by everyone, therefore, at a given question, I have indicated the number of responders. During the online survey, I have worked with five major socio-demographic variables, which were also the dividing variables of the significance analysis (independent variables). Of the 250 completed questionnaire replies, 248 have answered the stratification questions. (Graph made by the author.) The sample was as shown below: *Breakdown of responders by gender:* out of 248 persons 38.7%, i.e. 96 persons were *women;* 61.3%, i.e. 152 persons were *men.*

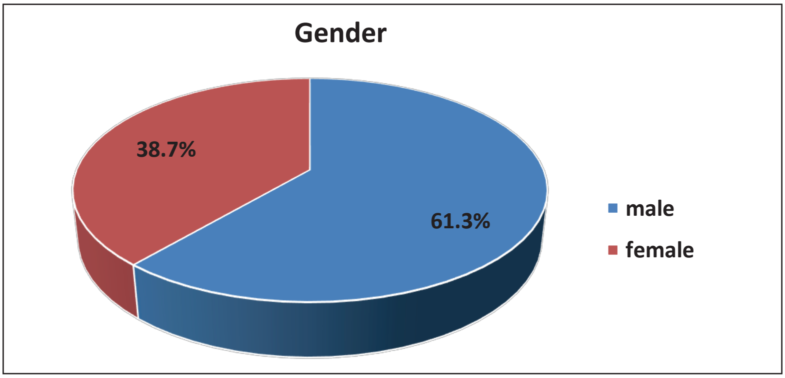

Figure 4.
Gender of responders

Source: Made by the author.

Breakdown by age: 4.4% of 248 persons, i.e. 11 persons were under 20 years. 61.7%, i.e. 153 persons were between 20 and 40, 25%, i.e. 62 persons were between 41 and 60, 8.9%, i.e. 22 persons were over 60 years of age. Based on the self-classification of responders by age groups, most of the responders were middle-aged people. The least were the youngest age group, under 20 years (4%), and its double was the proportion of the elderly (9%).

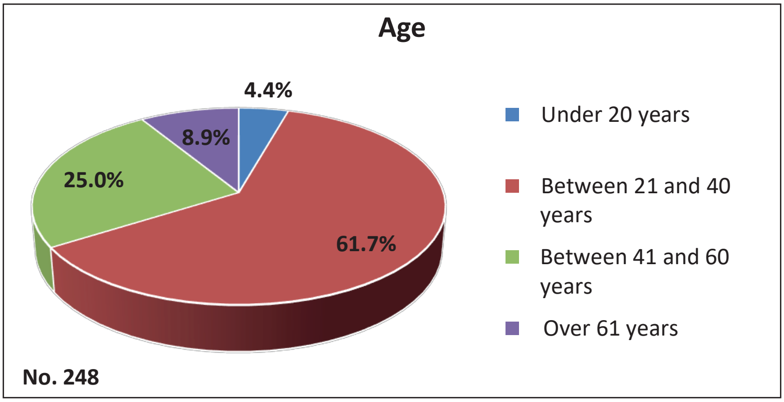

Figure 5.
Breakdown of responders by age group

Source: Made by the author.

Breakdown by residence, from the responders, 28.3%, i.e. 70 persons lived in the *capital city,* 19%, i.e. 47 persons lived in *large* cities, 34%, i.e. 84 persons lived in *small towns,* 18.6%, i.e. 46 persons lived in *villages.* The majority lives in small towns, where the electricity provider can be reached relatively quickly and therefore, it can respond to the failures fast, and this may possibly stratify the opinions.

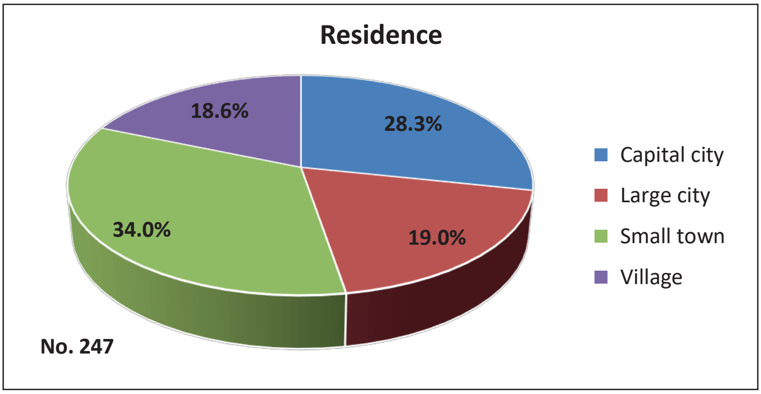

Figure 6.
Breakdown of responders by residence

Source: Made by the author.

According to the size of the household of the responders, 7.3% of the responders, i.e. 18 persons *live on their own,* 23.8%, i.e. 59 persons live in *two-person* households, 23.4% in *three-person* households, i.e. 58 persons; 25% in *four-person* households, i.e. 62 persons, 10.5 % in *five-person* households, i.e. 26 persons; 10.1% in *over five-person* households, i.e. 25 persons. A quarter of the responders live in two-, another quarter in three- and anther quarter in four-person households. Those in five-person households or over and those living on their own, the smallest group, represented approximately the same proportion.

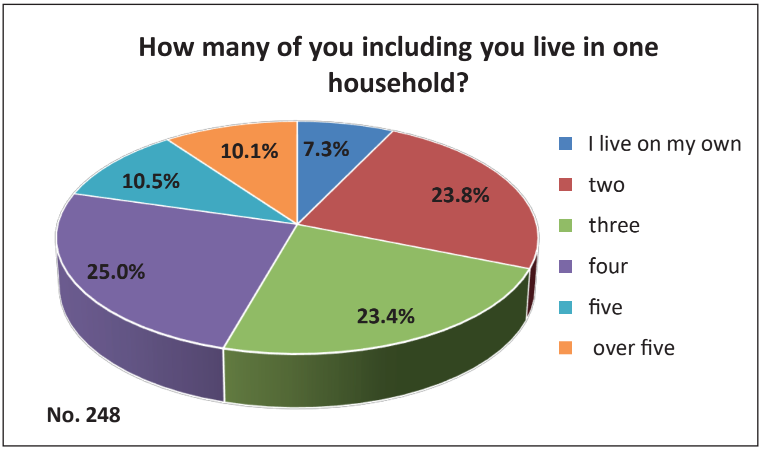

Figure 7.
Indicators of responders living together

Source: Made by the author.

Subjective income situation of those living together. I have investigated the question on the financial situation not by creating a complicated variable, or by co-applying subjective and objective indicators, but with a simple self-classification question. I have asked the responders to classify themselves in the categories specified by them. Responses have shown that 29.8%, i.e. 73 people *live without worries,* 46.9%, i.e. 115 people *get along with a smart budgeting,* 17.1%, i.e. 42 people *sometimes have minor financial problems,* 3.7%, i.e. 9 persons *often have financial problems* and 6 people, i.e. 2.4% *do not know.* One third of the responders, therefore, live without worries, almost half of them get along with smart budgeting, but still have adequate financial security, 17% sometimes have minor financial problems, and 4% were on the opinion that they often have financial problems.

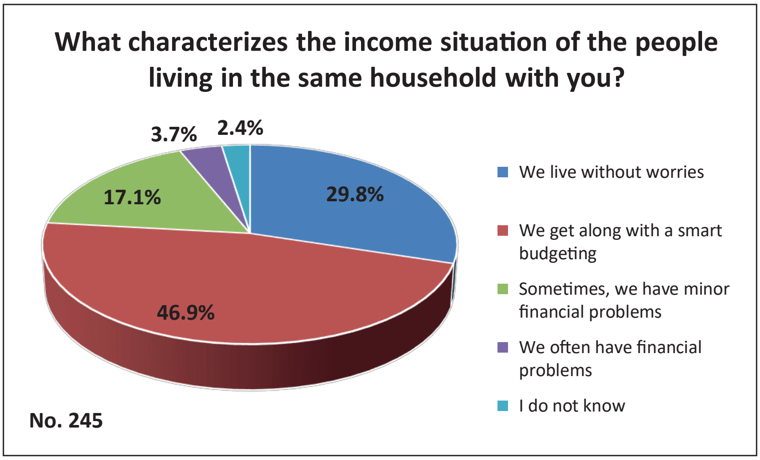

Figure 8.
Subjective income situation of responders

Source: Made by the author.

4.3. Answers to questions in block 1 of the questionnaire

This block asks about their own experience concerning long-lasting power outages. The survey was directed at the causes, duration and impacts of power outages and reveals related experience.

In this group of questions, I have measured if there was a long-lasting power outage at their residence and what the cause of the delayed repair was. Those, who already suffered from a longer power outage, what experiences they preserved. I have also searched for answers such as: where they received assistance and information on the malfunction, what problems were caused by a power outage in their households, what they felt was the worst in a given situation. Let us take a look at the answers.

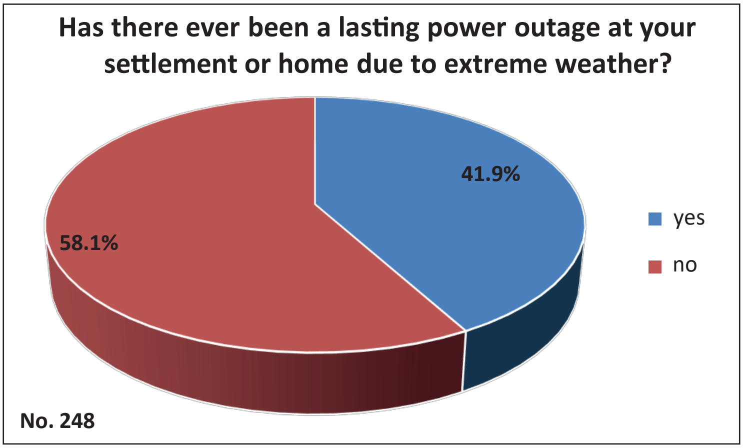

Figure 9.
Has there ever been a long-lasting power outage at your settlement or home due to extreme weather?

Source: Made by the author.

42% of the responders were already involved in such an event. I have taken their answers into account concerning their experience. For 58.1% of the responders, i.e. 144 persons, there was no long-lasting power outage due to extreme weather. However, 41.9%, i.e. 104 people, almost half of the responders, already had.

1. What was the reason for the power outage?

Many have responded to this question surprisingly that they do not know (nearly a quarter of the responders). Most of them (50 persons, 48.1%) have identified the causes as wire breaks due to winter icing or wind storms. The responders have named as the second commonest cause of failure the transformer housing components (23 persons, 22.1%), the third commonest cause was the fall of the pylons (16 persons, 15.4%), i.e. technical reasons; but the proportion of those who did not know the cause (22.1%) was high. This is interesting because the lack of information makes it difficult for the people to interact in such cases and can lead to panic.

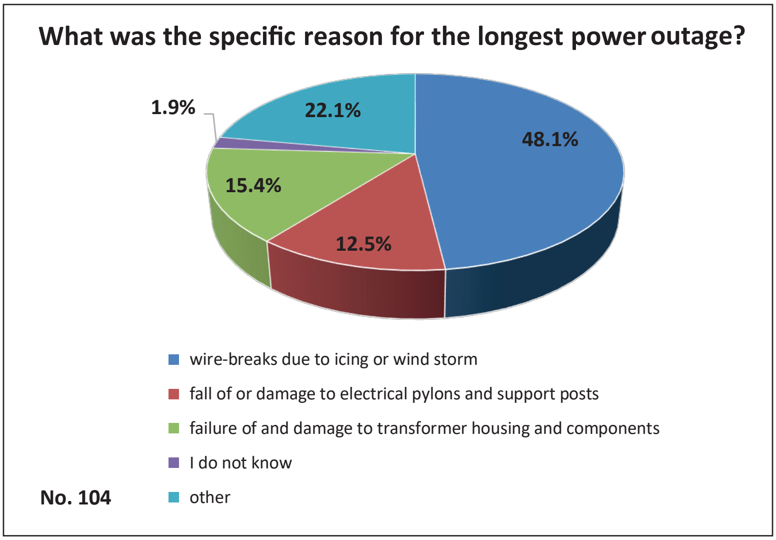

Figure 10.
What was the specific reason for the longest power outage?

Source: Made by the author.

It is important to know when a power failure occurs, how long it takes to do the repair, i.e. a shorter or longer time to resolve the problem. Since every responder has a different idea on short and long time, I have interpreted the answers to questions regarding delayed repair together with the questions following it.

2. What do you think was the reason for the long-duration repair?

It can be stated that based on multiple-choice questions, the responders think the main reason for delayed repair is the *scarce expert capacity of the service provider when there are storms at many places* because more than two thirds replied so (69.9%). The second most frequently occurring cause: *the work of protection entities and service providers is not fully coordinated* (30.1%). This was followed by the third commonest: *the cold and stormy winds hindering repair* (25.3%). 7.2% thought there was *too little phone capacity for notifying the failure, this is why it took so long to report.* At the same time, 20% felt that the problem was solved within a short time.

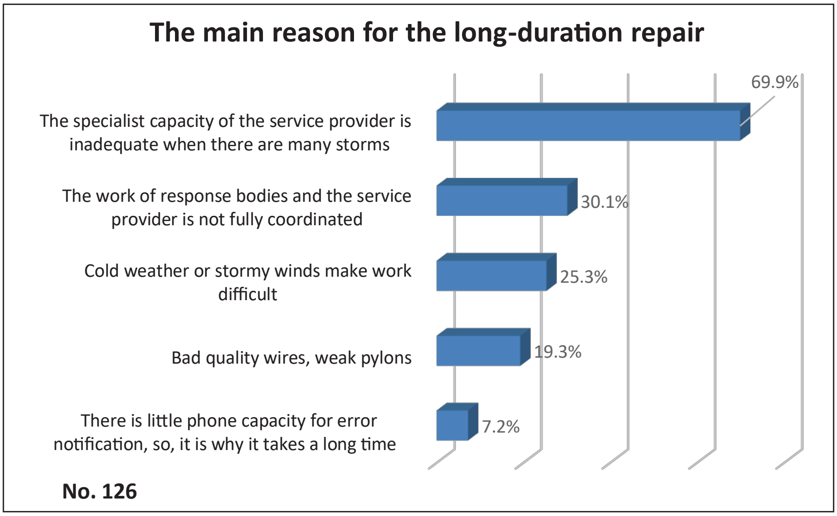

Figure 11.
What do you think was the main reason for the long-duration repair at your place?
Source: Made by the author.

3. How long did it take to restart the power service?

The duration of repair significantly affected the consequences and damages, so, I have asked about the duration. The values of the time unit classification were in a large range, but it can be said that most of them thought it took 3–6 hours (31 persons, 29.8%), 7 to 12 hours (25 persons, 24%) and less than 3 hours (23 persons, 22.1%) to repair, but there were times when it took more than two days to repair (9 persons, 8.7%).

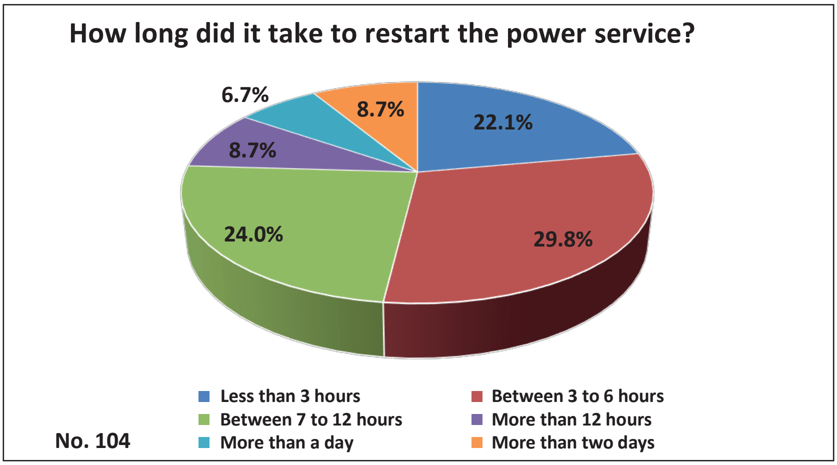

Figure 12.
How long did it take to restart the power service?
Source: Made by the author.

4. How did you first learn of the power outage?

In the event of a power outage, it is important to have everyone know about its cause because thus they can do more for themselves and for their families and also with a greater chance. The responses show that the people concerned are in some degree of uncertainty as they are eventually informed on the causes, mostly through informal channels or not at all.

The majority of people (50 persons, 50.5%) first received information from each other, i.e. their neighbours/relatives. A fairly large number of responders (30 people, 30.3%), a third of the interviewed did not receive any information at all, and if they reported a failure, they were presumably informed by the service provider (18.2%, 18 persons).

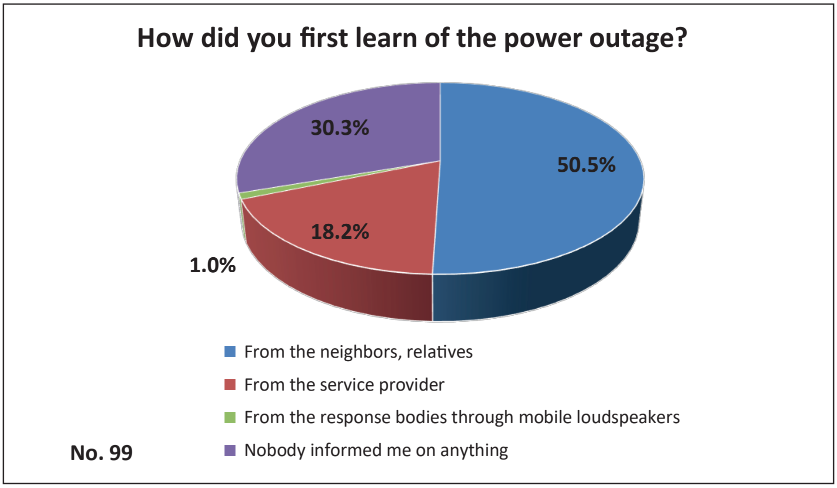

Figure 13.
How did you first learn of the power outage?

Source: Made by the author.

5. Were you informed by the service provider or the authorities on when the power would be restarted?

It is important to know whether service providers, public authorities and protection entities can and do provide information to the public in such cases, in addition to their recovery activities. The replies show that the information does not always reach the public, because 14.3% answered they did, but 86.1% did not receive it.

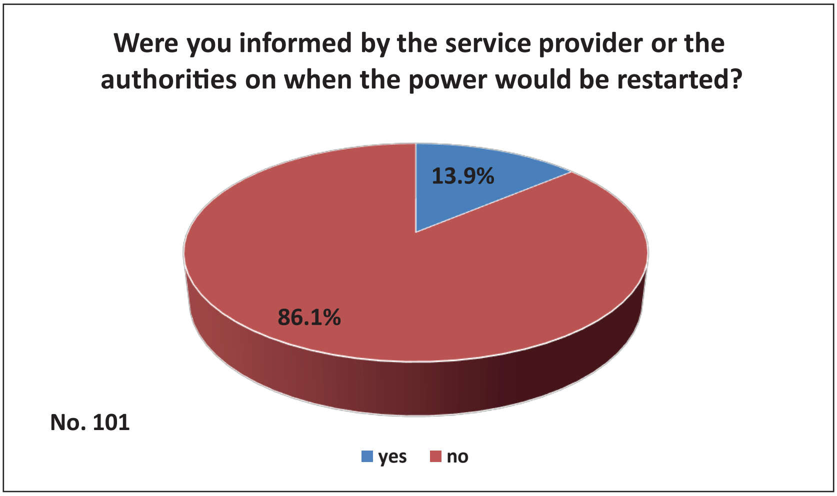

Figure 14.

Were you informed by the service provider or the authorities on when the power would be restarted?

Source: Made by the author.

6. To what extent did the power outage interfere with or disturb your everyday life?

A power outage may disrupt people's lives to varying degrees. The responders could express the magnitude of this disruption on a four-stage scale for the longest power outage they witnessed. To the question of how much a power outage interfered or disturbed their everyday life, the responders had the opportunity to express their disturbance on a four-stage scale. 104 responses were received, of which 36 (34.6%) said very much, 42 (40.4%) said moderately, 24 persons (23.1%) said they were slightly disturbed and only 2 people (1.9%) replied that they were not bothered at all.

It can be said that more than a third of the responders felt that it interfered very much; 40% felt that it was rather disturbing, so, altogether, two-thirds of the responders felt the power outage was disturbing. Only 25% of the responders felt that the phenomenon was only disturbing to a negligible extent or not at all.

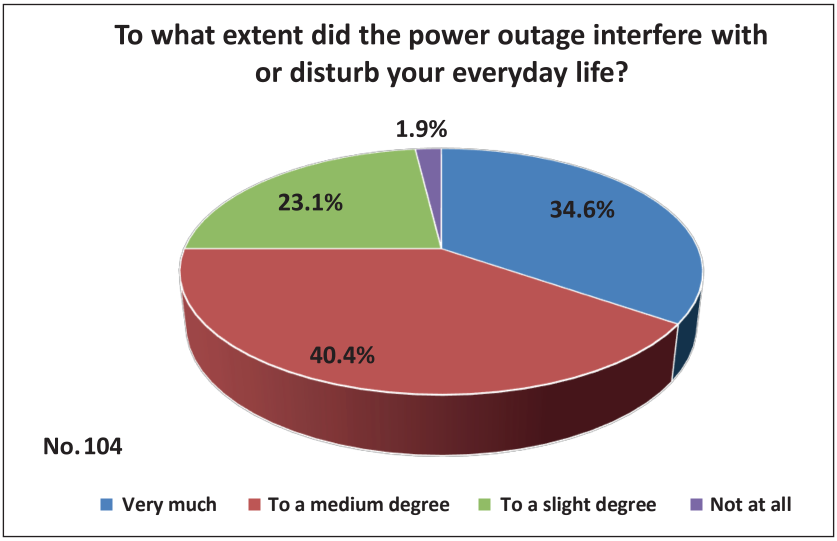

Figure 15.
To what extent did the power outage interfere with or disturb your everyday life?

Source: Made by the author.

7. Please rate from 1 to 5 the degree that the problems at a power outage caused you and your family from the below reasons. (0 = not relevant, 1 = the least, 5 = very much)

A power outage is a big problem, and it is important to know to what extent they have caused problems to the responder. With this question I have measured it. The responders had the opportunity to evaluate each aspect individually on a five-stage scale. The following Figure 16 shows the proportion of those who have listed values 4 and 5 on the five-stage scale, i.e. have assessed the problem as a major one. The largest proportion mentioned the *non-functionality of larger household appliances such as air conditioner, electric heating* (causing a serious concern for 49.5%), and *not being able to use the computer* (41.7%). Out of the problems, one can find in the second group (with values between 30 and 40%), *the deterioration of food* (36.4%) and the *non-functionality of lighting and TV/radio* (39.8%). The disruption of services and anxiety caused by solitude have posed the least problems.

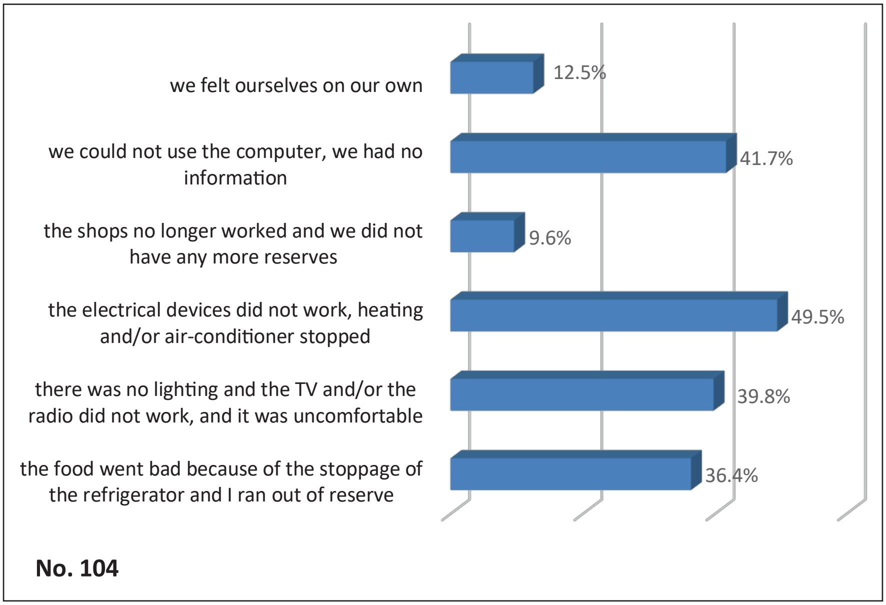

Figure 16.

How big were the problems caused by the below aspects at a power outage (intensity 4 or 5)

Source: Made by the author.

8. What did you and your family experience as the biggest damage?

I have also investigated what the responders regarded as the biggest damage. 30.3% (30 persons) said the foodstuffs went bad, 4% (4 persons) said their health was deteriorated, 26.3% (26 persons) had administration issues, 3% (3 persons) had financial, economic (business) issues, 15.2% (15 persons) were dropped out from work, there were none who suffered an accident due to the dark, however 21.2%, 21 persons thought the supplies were hampered at the given settlement.

So, the biggest problems for the responders were: food turning bad (30%), disruption of daily administration arrangements (26%) and supplies hampered at a settlement (21%).

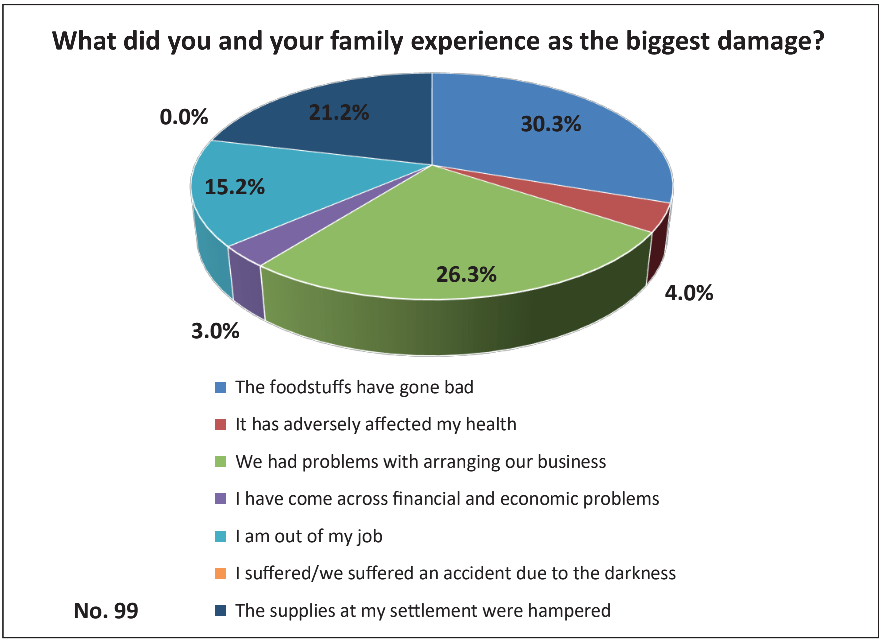

Figure 17.
What did you and your family experience as the biggest damage?

Source: Made by the author.

9. Who helped to resolve the biggest damage?

Fast and effective help can minimize vulnerability. It is important to know whom the affected family can count on, what the tendency in the case of a long-lasting power outage is. Generally speaking, responders could mainly rely on themselves to solve their problems. 77.8% did not receive or use any other external help, but if they did it was granted by their neighbours to the greatest extent (14.1%). The role of protection entities (7.1%) and of municipalities (1%) was negligible. In a next research, it will be worth examining what is the reason that settlements can, in low numbers and efficiency, participate in these cases as assistance. Another question is how can the capacity of settlements be increased in order to assist the population.

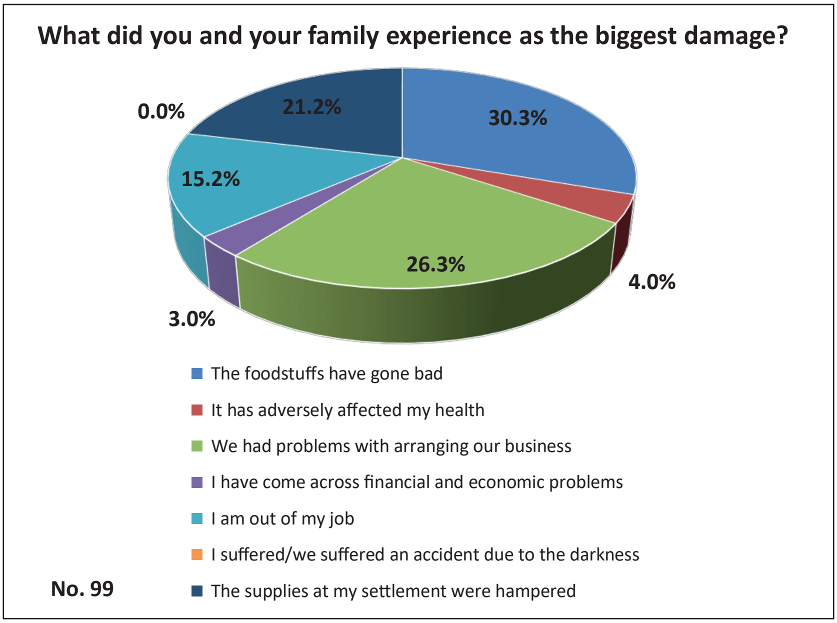

Figure 18.

Who helped to resolve the biggest damage to you?

Source: Made by the author.

With further deeper analysis of data, it would be worth examining what patterns the particular damages and assistance options related to them show, i.e. what problems and from which direction can be resolved more efficiently.

10. From whom did you receive the first backup power source?

A backup power source can easily solve the problem for a short time caused by power outage. With this question I wanted to know if there was any backup at all and, if so, what the responders had. The responses showed that 70.3% did not need it, 26.7% did, but did not receive any. In scarce numbers (3%) the electricity provider helped some families.

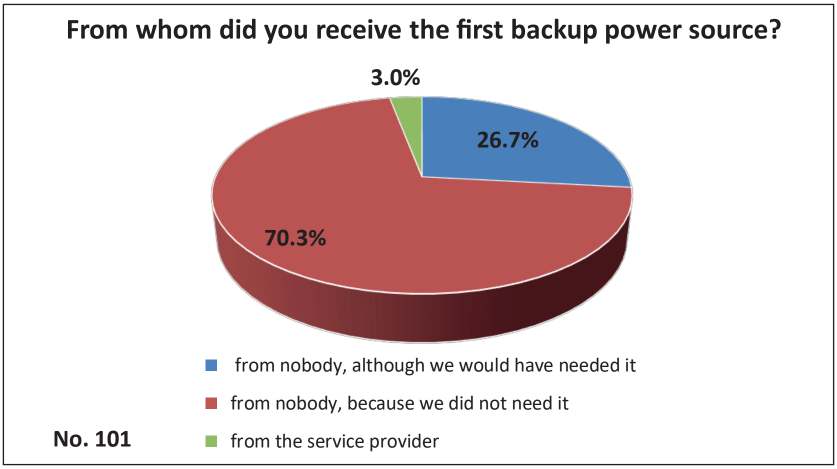

Figure 19.
From whom did you receive the first backup power source?

Source: Made by the author.

4.4. Answers to questions in block 2 of the questionnaire

This block investigated the preparation for emergencies caused by power outages. Questions have been asked that examined general residential attitudes associated with an extraordinary power outage. We were curious about the topics, what characterized preparedness in such situations, which official entities/service providers would have responsibilities and in which (partial) areas during public information or damage mitigation. Basically, we were curious about the impressions and expectations of responders, and because our sample is not representative, the data are rather informative and suitable for presenting opinion streams. There were no significant differences between the dividing variables.

1. Does your family have a backup power source to be used at a power outage?

245 people answered this question, of which 88.2% did not have a backup power source, so the vulnerability rate was high. 4.9% had rechargeable batteries, and power generators were owned by 4.5%. Responses to other categories, such as flashlights, may only serve as an eventual and short-term solution, but even though, only 1.6% of responders had one. It is interesting that only 0.8% have solar cell batteries.

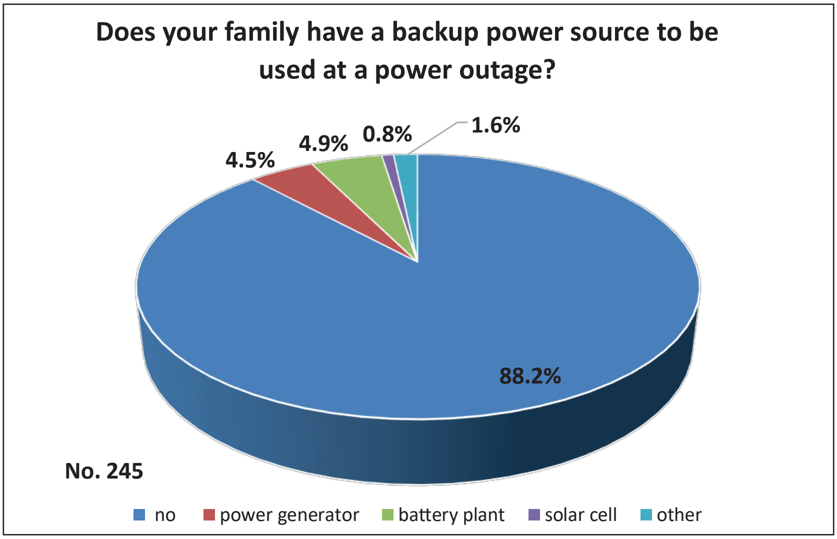

Figure 20.
Does your family have a backup power source to be used at a power outage?

Source: Made by the author.

2. In your opinion, is the electricity supplier well prepared to quickly eliminate the power outage caused by natural disasters?

The population's safety perception is increased if they know that service providers are well-prepared. 59.1% of the responders replied that they did not feel the power supplier was prepared because due to the lack of equipment or expertise, they could not fully perform their duties in emergencies. The proportion of uncertain responders was very high (19.4%). According to 21.5%, service providers are prepared for such unexpected situations and are able to handle them, as it was not up to them that the repair works went on slower, but it was due to the extreme weather. There is an interesting phenomenon that the more unfavourable someone's financial situation is, the more they think the service provider is not prepared to handle such situations.

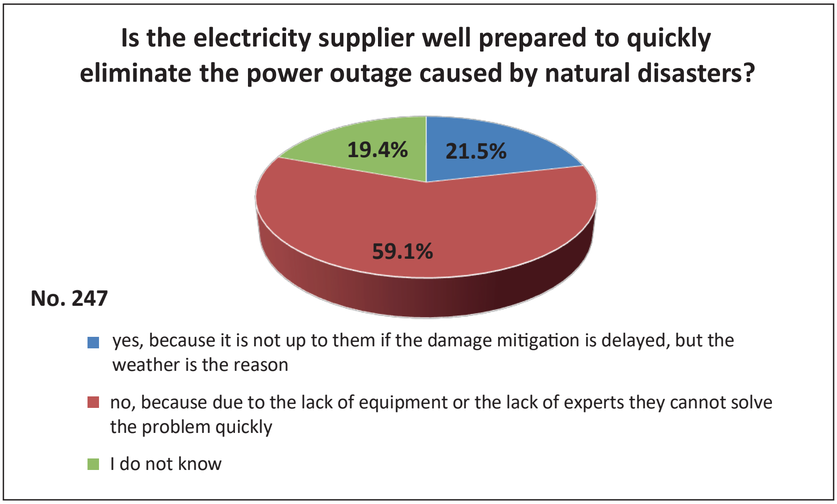

Figure 21.
Is the electricity supplier well prepared to quickly eliminate the power outage caused by natural disasters?

Source: Made by the author.

3. Do your neighbours and relatives from the elder age group have reserves for emergencies like food, medicine, nutrition, etc.?

The preparedness for emergencies is not only the responsibility of a service provider, the population also has a role in it. I was curious about the responders' perceptions when I asked what they were experiencing (their quasi statistical perceptions), how well the elder generation is prepared for emergencies piling up reserves in food, medicine, nutrition, etc. Three quarters of the responders (74.8%) thought that elder people living in their environment do pile up reserves. Those living in a small town and village thought that this attitude is more characteristic of those elderly living with them rather than in cities. The same question has brought opposite results related to young people. According to 94.3%, young people do not pile up reserves, because they do not have the resources, and only 14% think the young are prepared for unexpected situations.

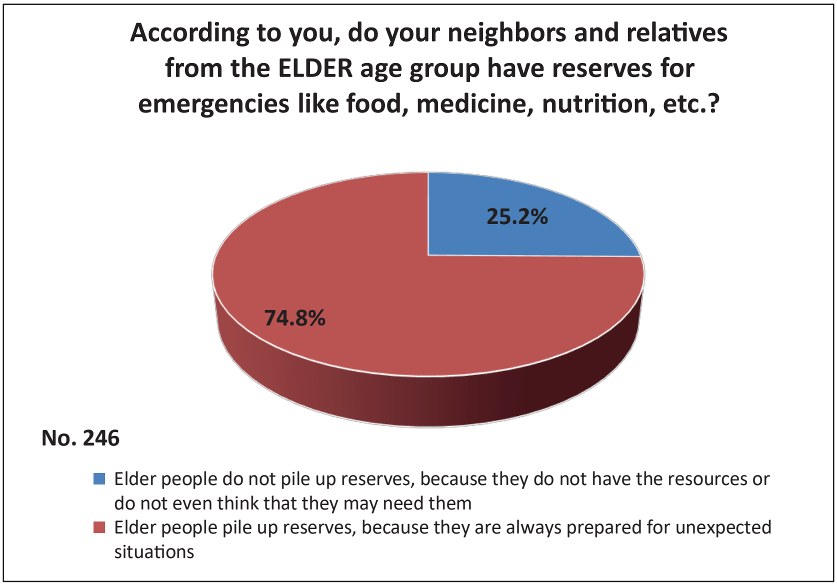

Figure 22.
According to you, do your neighbours and relatives from the elder age group have reserves for emergencies like food, medicine, nutrition, etc.?

Source: Made by the author.

4. Would you be willing to take the time to learn more about the dangers and expected impacts of extreme weather?

One can find more and more information on emergencies.[10] They are usually public information briefings for extreme winter weather situations and they summarize the expected consequences or recommended rules of conduct, etc., but it is difficult to find out how many visitors these sites have. Therefore, I have asked through our questionnaire if the responders were *willing to spend time learning more about the dangers and the expected impacts of extreme weather.*

Nearly three-quarter (171 persons) of the respondents felt that they would spare some time if it gave brief information and practical advice. 15.4% would like to participate without limiting themselves to this condition. Unfortunately, 8.5% would not find the time, and 6.5% would not be interested in the subject. The better the financial situation of a person is, the more they think any kind of information is important.

[10] See the result of the keyword search below: www.google.com/search?q=rendk%C3%ADv%C3%BCli+helyzetekben+t%C3%A1j%C3%A9koztat%C3%A1s&ie=utf-8&oe=utf-8&client=firefox-b (Accessed: 04 July 2018.)

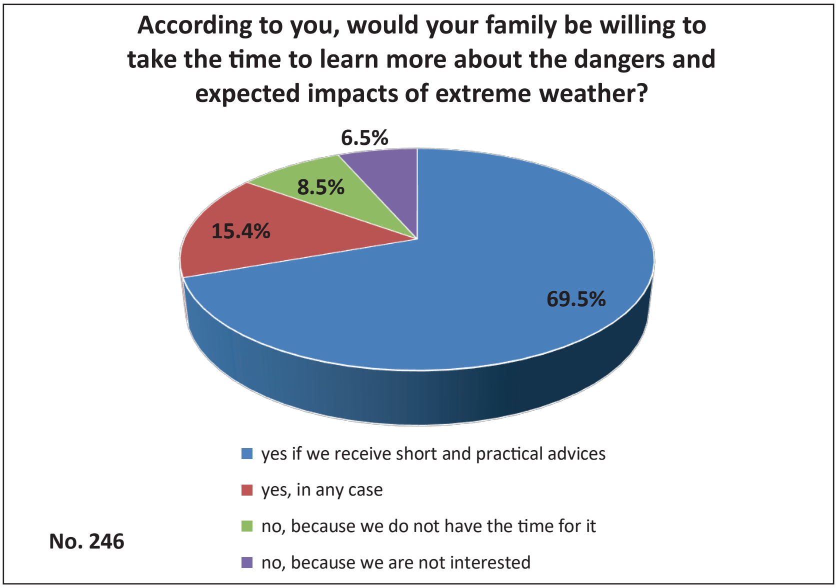

Figure 23.
According to you, would your family be willing to take the time to learn more about the dangers and expected impacts of extreme weather?

Source: Made by the author.

5. From the consequences of extreme weather which one(s) and to what extent would cause problems to your family?

From the following possible consequences of extreme weather, the categories of long-lasting power outages or heating disruptions, supply disruptions, food shortages, disturbances of public safety, temporary evacuation, dropping out of work had to be paired with the response options indicating the impacts on life like below:

a) It would be uncomfortable but would not cause problems.
b) It would cause problems but would not interfere with the normal way of life.
c) It would cause serious problems that would interfere with our normal way of life, but relatively quickly, life would be restored to normal.
d) It would completely disrupt us from the normal way of life, it would take long to restore normal life.

For the responders, the biggest problem (i.e. total and long-term deprivation of normal lifestyle) would be caused by temporary or long-term evacuation, which was followed by dropping out of work. Criteria: disturbance of public safety, service disturbances (e.g. food shortage), long-lasting power outages were reported with close to similar values (around 30%). The slightest problem would be caused by long-lasting loss of heating.

A long-lasting power outage would cause an increasing problem in direct proportion to the *settlement slope,* i.e. the smaller the settlement one lives in, the greater the problem is.

Whichever household size was viewed, most of the answers were about a long-lasting power outage that *would interfere with their normal way of life, but relatively quickly, life would be restored to normal (43.3%),* however, 28.6% would be completely disrupted from the normal way of life.

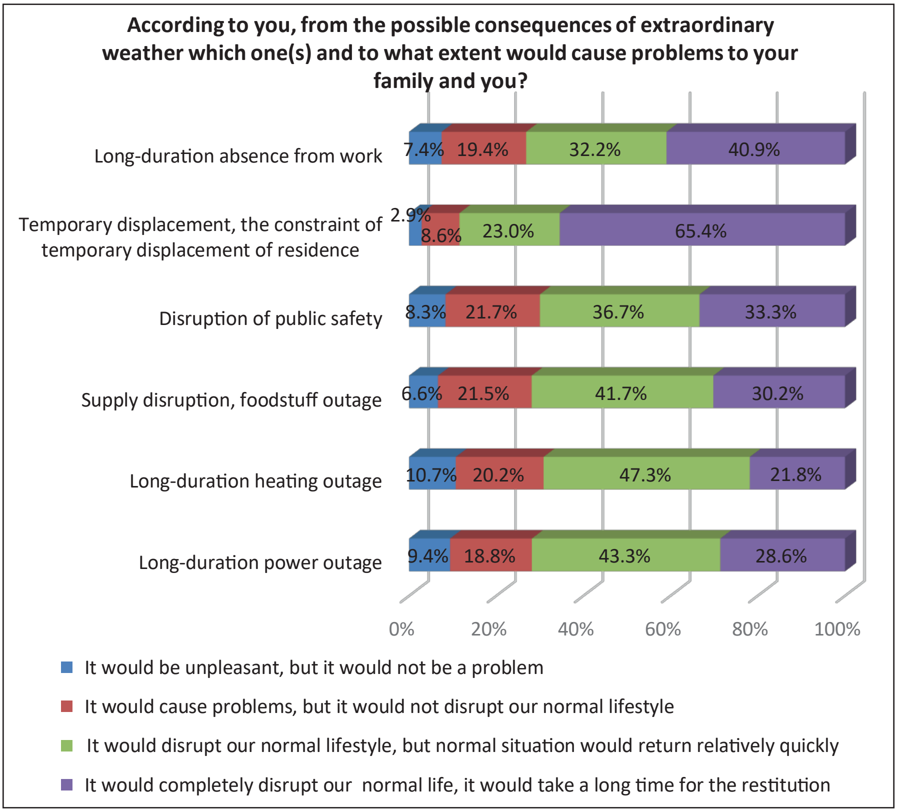

Figure 24.

According to you, from the possible consequences of extreme weather which one(s) and to what extent would cause problems to your family and you?

Source: Made by the author.

In case of a long-lasting heating disruption, most responders said it would interfere with their normal way of life, but relatively quickly, their life would be restored to normal. This is explicitly true for the groups with higher incomes. With regard to supply disruption and food shortage, we found two correlations concerning the size of the household. In households with two or more persons, it would cause more serious problems compared to families with one or with more than five members.

The disruption of public safety would cause more inexorable problems and a more difficult one to restore for the middle-aged group (between 20 and 60), the smaller the settlement they live in, the larger the household is. Temporary evacuation/displacement would cause more of a concern for middle-aged men (between 20 and 60). Dropping out of work would cause more and more problems as the size of the family grows and proportionally with the growth of income.

4.5. Answers to questions in block 3 of the questionnaire

1. Would you agree that each household should have a backup power source and reserve foodstuff?

By asking the question should all households *have backup power sources and reserve foodstuffs* (in such cases, the joint interpretation of the two means protection), I wanted to investigate how the responders are inclined for self-care. 85% of the responders agreed to it. Between the dividing variables, I have not found significant differences. Only 15% disagreed.

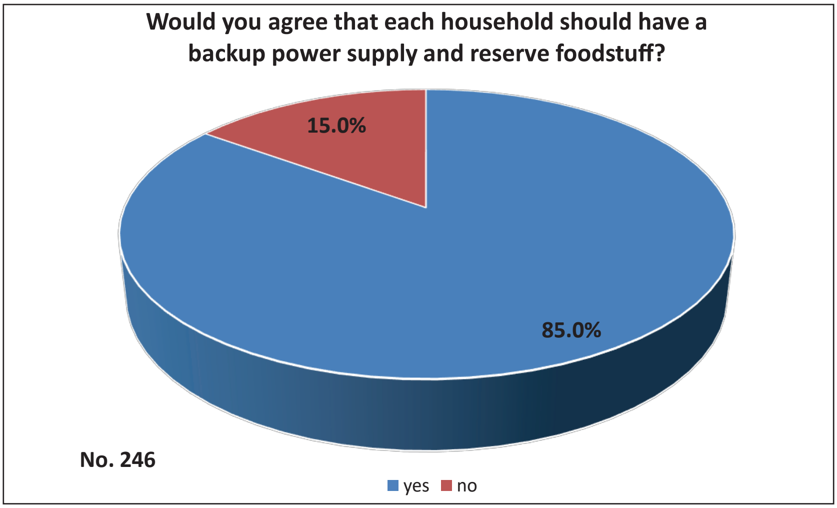

Figure 25.
Would you agree that each household should have a backup power source and reserve foodstuff?

Source: Made by the author.

2. How do you think it would be useful to accomplish it?

In connection with the implementation of backup power sources and reserve food stocks, 40% of the responders thought it *to be solved on their own, but should be deductible from the tax,* 25% believed that *half of it should be self-financed,* the *other half of it should be state-financed,* and 23% thought that a one-off grant should be allocated to families, which would be filled up and replaced later individually. Only 13% of the responders thought it should be solved by everyone at their discretion. The bigger a family size is, the more it has been chosen that it should happen self-financed, but should be deductible from the tax; the same applies to the middle-aged persons (between 21 and 60) and men.

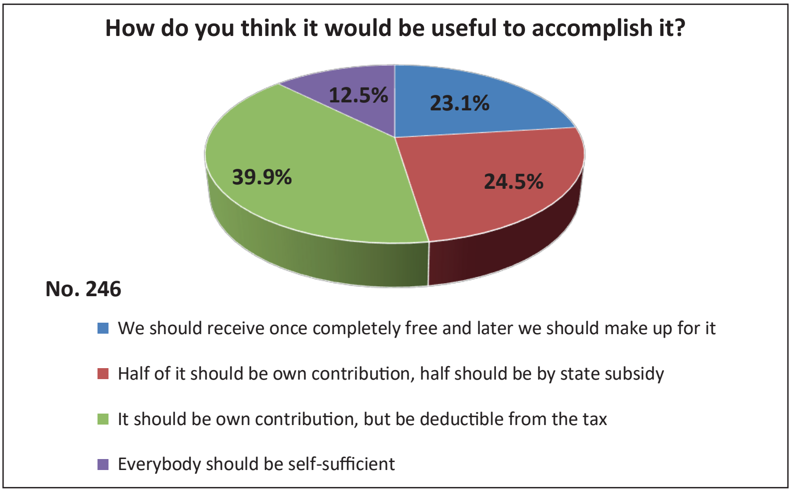

Figure 26.
How do you think it would be useful to accomplish it?

Source: Made by the author.

3. Do you agree that in the event of a long-duration power failure, families should be centrally assisted?

95% of the responders, i.e. 232 persons answered yes to the question should the families be centrally assisted in case of a long-lasting power outage; as it was inevitably necessary, 5% did not agree with it. This means that the answers revealed a strong paternalism; citizens expect central assistance. Between the dividing variables, I have not found significant differences.

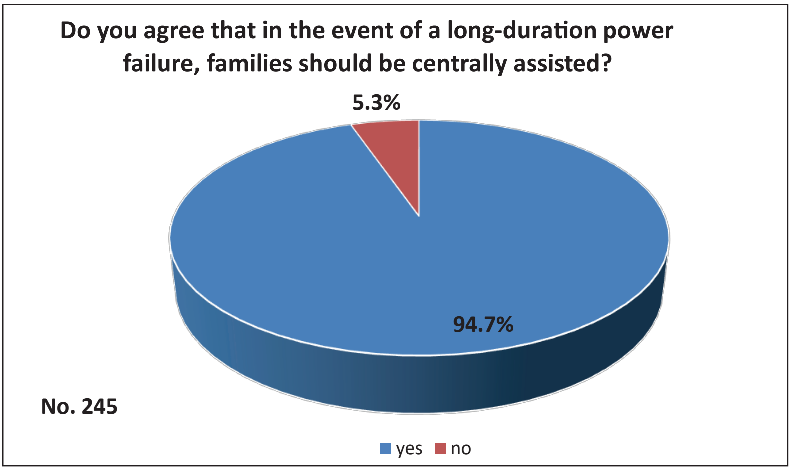

Figure 27.
Do you agree that in the event of a long-duration power failure, families should be centrally assisted?

Source: Made by the author.

4. In your opinion, who should be in charge of helping families in such cases?

I have only evaluated this question among those who answered the above question to agree with the idea of a centralized assistance. The task of the centralised assistance showed a large scattering amongst the responders (in case of each response category, I have measured by the results around 33%), so, it can be clearly stated that self-care is not favoured by the responders, however, regarding the question who should grant assistance, there were big differences in opinions.

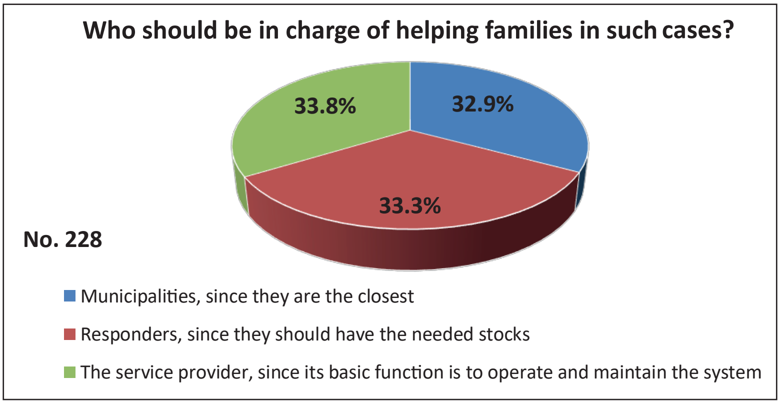

Figure 28.
In your opinion, who should be in charge of helping families in such cases?

Source: Made by the author.

According to people living in villages and large towns and those living in larger families, either the municipalities (because they are the closest), or the protection entities (because they should have the appropriate resources) should assist in such cases. However, in terms of income situation, it can be said that those with higher incomes think assistance should be provided by the service providers themselves (because their functions are to operate the system) or protection entities (because they should have the appropriate resources).

5. Please write down briefly your comments and recommendations related to the topic.

With this essay question, I wanted to measure what suggestions the persons involved have on the protection against power outages or in general about the issue. 80 persons answered this question. The responses received are classified into 5 types: those suggesting technology and engineering solutions (23%), those suggesting improving preparation and information flow (7%), those suggesting motivation of higher level of self-care (26%), those suggesting greater involvement of service providers in population protection (12%) and the responses suggesting a greater contribution by protection entities (17%). 5% did not have any idea.

5. Recommendations and Conclusions on How to Increase Resilience against Power Outages

The answers to the questionnaire point out that extreme weather may cause disturbances in many areas in the life of the population. Power outage is included in these factors. This can have a serious impact on the lives of people, therefore, the protection against it is very important already in the period of prevention but also when power outage occurs and its effects are felt. From the anticipated hypotheses, numbers 2, 3, 5, 8, 9, 11, 16, 17 and 18 were confirmed, the rest were not, but still they may serve as a basis for conclusions. In their view, the activities of service providers and protection agencies are not fully coordinated in such cases. The citizens are not prepared for this situation, they do not have backup power sources and they are most upset by not being able to go to work or by finding foodstuffs turning bad in the melted fridges. Self-care is not typical in either piling up stocks or reserves and the citizens expect help from local governments, service providers and protection. In the opinion of responders, during power outages resulting from extreme weather, the flow of information is weak concerning causes and the expected duration; the population can mainly rely on themselves to solve these problems. Citizens would be willing to dedicate time to acquire relevant knowledge. It is also clear from the questionnaire survey that the population is not satisfied by the level of activity of the authorities to protect the citizens; so this role needs to be enhanced. The question to what extent and in which direction settlement-level protection capabilities should be increased in order to raise the protection of the population against the impacts of disasters due to climate change and extreme weather like long-lasting power outage, should be a subject of further researches.

5.1. Recommendations on how to increase resilience against power outage

To eliminate the above-mentioned problems, it is a must to increase the protection of the population. A special form of protection against the consequences of extreme weather is resilience. When interpreting the concept, we come across several definitions. From the perspective of our topic, the most acceptable one is provided by IFRC (International Federation of Red Cross and Red Crescent Societies), according to which resilience is "the ability of individuals, communities, organizations or countries exposed to disasters, crises and underlying vulnerabilities to anticipate, prepare for, reduce the impact of, cope with and recover from the effects of shocks and stresses without compromising their long-term prospects". (IFCR 2015) This definition suits resilience against extreme weather and long-lasting power outages due to it.

At national level, the tasks of protection against the impacts of climate change and their prevention are stipulated by the Second National Strategy Against Climate Change (NÉS-2), in which energy supply is featured as a priority component of the critical infrastructure elements, including the issue of electricity supply. NCCS calls the attention to the importance of preparing for hazard factors and creating the conditions of adaptation in the future. (NÉS-2 2017) One of the duties of a state is to provide legislation with which these objectives may be accomplished both in branches and in entirety. In the field of energy policy, advocating for the development of alternative energy sources can bring a good solution for settlements and small communities and it may be stimulated by different methods. The task of electricity producers and service providers is to make electric energy available and deliver it to the consumers. In case power supply is interrupted due to some disasters or extreme weather phenomena, the task of service providers is to restore the damaged systems. Service providers should be prepared for this more and more due to the increase of extreme weather phenomena, therefore, it is advisable to improve the durability and stability of the network components. There is also a need to increase emergency reserves in both technology and human resources. When upgrading and creating new networks, it is advisable to position the electricity lines under the ground or to seek for technologies that would lower the cost of using ground cables.

Protection entities and leaders of settlements responsible for safety and security, i.e. mayors are also obliged to deal with such issues. In such cases, they must activate their emergency plan and, depending on the situation, execute their plans. First of all, they have to consider their actions related to the protection and supply of the population, but they also should have a role to play in mitigating damages.

By increasing the protection capability of a settlement, capacities should also be increased in order to reduce the consequences of a power outage. Also, population motivation can bring good results, as well as supporting the installation of solar panels and wind wheels, and exploiting the opportunities of river barrages, too. The introduction of the following good practice should also be considered: to elaborate the war experience of a given region, where power supply was completely lost; certain lessons learnt from the contemporary solutions, e.g. concerning rehabilitation.

The population and local governments still have additional tasks to increase protection and to reduce vulnerability. Settlements should include this event in a more emphasized way in their emergency response plans. They must map the available tools and materials and explore the potential for capacity increase in case of a long-term power outage. Food reserves would also be needed, as well as backup power sources to provide a temporary replacement for the lost power supply. Amongst the new challenges of today, long-lasting power outages due to extreme weather are not negligible problems, therefore, adaptation researches related to climate change should also cover it in the future.

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Rajmund Kuti

On-site Disaster Response for Damage Caused by Extreme Weather Phenomena

1. Introduction

More scientific research has proved that the Earth's climate continues to change. This change has been noticeably accelerated over the past decades on terrestrial scale, and extreme weather phenomena affect Hungary, as well. (Padányi 2013) The media has been reporting more and more about never-experienced catastrophes, damage caused by extreme weather events. In some areas, a large amount of rainfall (60–120 mm) falls down in a short time, flooding residential homes, cellars and road networks. More and more intense wind storms run rampant across the country, ruthless hails cause enormous material damage to agriculture and the built environment. A snowfall for several days keeps the settlements cut off from the outside world. Longer and warmer hot flashes blaze everywhere, cruel drought periods follow each other. Hungary is one of the most affected countries by climate change impacts, extreme weather events become more frequent in our country. Unfortunately, these sudden weather changes cannot be predicted in all cases, so it is difficult to prepare for the control of their harmful effects. In recent times, these phenomena have caused serious damage in our country, and the elimination of consequences included difficult and complex technical rescue tasks. From the point of view of damage elimination, great emphasis should be placed on prevention, but it can be stated that disaster situations caused by extreme weather events cannot be prevented, nevertheless it is possible to be prepared for quick and efficient damage elimination or compensation. (Kuti–Földi 2012) The effectiveness of damage elimination processes can be enhanced by using appropriate disaster response tactics and algorithms, which can also be time-consuming for the complex damage elimination process. An important task is, therefore, to investigate the tactics of damage prevention, as well as to make modifications and additions in order to increase efficiency.

My aim is to investigate disaster relief tasks applicable in Hungary, furthermore with my experience and suggestions, to supplement certain algorithms, this way to help organizations and personnel involved in damage elimination, as well as to highlight the importance of continuous review of disaster management activities.

2. Disaster Situations Caused by Weather Extremities in Hungary

As a result of global climate change, extreme weather events occur in Hungary, its positive consequences are not significant, as mostly the negative effects dominate. (Padányi–Földi 2016) Due to the geographic location and terrain of our country, the followings are the most common forms of appearance which seriously challenge the population and organizations dealing with damage elimination:

- windstorm
- flood-like rainfall
- snowstorm
- extreme temperature fluctuations

In recent years, climatic extremities occur more frequently and with greater intensity in Hungary, therefore extensive experience could be gained during managing disasters and eliminating its consequences, which help in improving damage eliminations methods and tactical steps. At the same time, during elaborating algorithms, it should also be taken into account that the task of clearing and disinfection of a particular eventuality can be clearly and easily accomplished. In the followings, tactics applicable in the above-mentioned damages are presented in detail.

3. Disaster Relief Tactics Applicable during the Elimination of Damage Caused by Climatic Extremities

In most cases, disasters caused by extreme weather cannot be prevented, even if thorough preparation was performed, therefore, the elimination of the consequences and recovery after damage control will be a crucial, central issue of disaster protection. (Papp 2018) Primary intervention tasks are carried out by the professional firefighting units of the professional disaster management organization, in special cases in co-operation with its partner organizations – the Hungarian Defence Forces and the Police. If the damage occurs in large areas, the protection is prolonged, or at the same time a high number of sites have to be handled simultaneously; local authorities, municipalities, voluntary rescue organizations and the active correspondence of the citizens are required to perform the necessary tasks. (Papp 2017) In connection with the new challenges in Hungary, the disaster management system was re-established in 2012. The National Assembly voted Act No. CXXVIII of 2011 on disaster management and the amendment of certain laws related thereto (hereinafter DIS), which provides legal foundations for disaster risk management. During the elimination of various disasters, the professional units perform their technical rescue tasks in pursuance of the NDGDM[1] instruction no. 6/2016. (VI. 24.); its Annex 2 contains the Technical Rescue Regulations. At Chapter V of the Code, rules for interventions in natural disasters can be found. It should be noted that this policy has been enacted, taking into account the management system, the tactics and the systematic tools of the professional units, although not all the elements can be applied in cases where local governmental

[1] National Directorate General for Disaster Management, Ministry of the Interior.

organizations or volunteers carry out damage remediation tasks. I have outlined the rules that should be taken into consideration in line with the remedial work carried out by local governments and citizens.

As a result of a natural disaster, in case of mass rescue missions, the following management, organizational principles shall be applied:

- The location of the intervention should be interpreted in relation to the area affected by the natural disaster.
- The operational area, which is partly or wholly affected by a natural disaster, should be divided into sub-areas, sectors and districts.
- The management mode shall be chosen in accordance with this extended location.
- Depending on the nature of the natural disaster, the rescue manager performs the duties of managing director, in the course of continuous reconnaissance, mainly from a moving operation centre (fire-management vehicle) and, where necessary, from the operation centre built at his post.

Reconnaissance should include:

- The basic tasks of reconnaissance of the area affected by the natural disaster are implemented primarily by the rescue manager.
- Based on the decision of the rescue manager, further reconnaissance groups can be established.
- During the reconnaissance, all reconnaissance of task or damage caused by natural disaster must be carried out.
- As appropriate, it is necessary to arrange for the involvement of other competent bodies in the reconnaissance and for the provision of reconnaissance data.

In the course of an intervention, attention should be paid to:

- During natural disasters, the design of the intervention order should take into account the vulnerability of nationally and economically important installations and essential constituents.
- During inland water discharging, such solutions must always be performed which ensure the natural, gravitational drainage of water.
- In case of natural and artificial drainage, it is advisable, if possible, to seek the opinion of the technicians responsible for the remediation in order to avoid causing damage to the drained water in another place.
- Soil, technical or dismantling of landmarks can only be ordered by the organization responsible for the correction by prior assessment of utilities.
- In case of water removal works carried out in the vicinity of buildings constructed of water-sensitive material (loam), static technicians should be informed, if necessary, for the purpose of inspecting the building.
- Before removing inland water or groundwater from the room below the ground, it is advisable to have an expert's opinion as far as possible. In the absence of this, the water may only be removed for life saving or, if justified, at the written request of the owner.
- During work in the night or in the dark, the illumination of damage must be ensured.

Safety rules

- Extreme weather conditions – heavy rainfall, snow storms, drizzle, hail, fog, heavy crunching, wind storms, thunderstorms and lightning during interventions to account for the severity of the event must be carried out without endangering the intervening staff.
- In the event of a natural disaster, the staff must be provided with weather protection and protective equipment and clothing, appropriate to the nature of the intervention.
- In case of a natural disaster that is hazardous to health, and the risk of infection and poisoning persists, the professionals of the occupational health service and the competent Institute for Public Health should be involved. If necessary, mandatory vaccination should be provided.
- During high-performance damage elimination, anti-fall protection must be continuously ensured.
- The rescue manager must arrange for the disassembly of the structures, electrical installations and networks affected by the natural disaster before starting the repair work. The voltage-free state must be checked by a voltage detector.
- In post-processing, efforts should be made to prevent further damage.
- The forces that do not perform the actual damage elimination task must be continuously withdrawn from that area.
- Cleaning, maintenance and disinfection of tools, equipment must be carried out as soon as possible to ensure their preparedness (NDGDM instruction no. 6/2016. [VI. 24.]).

During the compilation of the DIS and its implementing regulations, legislators placed great emphasis on the involvement of volunteers in disaster management. Volunteering contributions greatly enhance the success of disaster management activities. The appropriate hazard education of volunteers, and their contribution is important for any damage elimination task, so NDGDM and its territorial bodies also put great emphasis on the proper hazard education of the citizens. Based on the above, it may be clearly stated, that certain tasks related to emergency response tactics must be compiled so that voluntary or municipal forces could perform them smoothly.

The remediation tactical algorithms described below have been compiled for disaster preparedness, damage elimination and recovery tasks.

3.1. General damage elimination tasks

Our planet surrounding us is constantly evolving, and the damage elimination of disaster management units is becoming continuously more difficult and complex. By the preparedness of managers and their decisions, the efficiency of damage elimination is greatly influenced. Training for disaster management is also changing continuously, together with its recently-created legal background. As far as possible, trainings and vocational trainings should be constantly broadened with the knowledge based on precedents and previous conscious and environmentally-friendly professional interventions related to the management system. In our social-economic development, the increase in the requirements for decision-makers is also inherent. Today, there is a wealth of theoretical knowledge and a concrete practical knowledge, usage of which are key to effective management in disaster relief. (Kuti–Papp 2018)

3.1.1. Reporting damage

The first step of protection is reporting, which can occur in the event of a disaster directly by the public or by an organization. Most frequently, notifications come to the Integrated Emergency Call Centre or to the disaster management directorate where professionals take the appropriate measures according to the nature of the event and carry out the necessary notification tasks towards the affected settlements. In case of local disasters, the notification can also be sent directly to the local government. It is very important for municipalities to have a list which includes the accessibility of professional damage elimination bodies and LDC[2] members. Upon notification, the person who received the report must inform the professional damage elimination organizations and the chairman of the LDC (mayor) or the person replacing him. If the notification comes to the disaster management body and receives the notification from the local government, and if the magnitude of the damage or the expected consequences justify it, the mayor must be notified. Through local authorities, the population should be informed in order to take the necessary precautionary measures.

3.1.2. Preliminary determination of positioning and protection tasks

Effective protection is based on a rapid and comprehensive survey, the extent of the actions and the order of measures for effective damage elimination. If the professional fire departments of disaster management are not able to arrive at the site in a short time, because they got a lot of calls and also perform at several other locations, the mayor (chairman of LDC), or his deputy person must always go and do an on-site damage assessment and reconnaissance.

They should contact the emergency service on duty, moreover, when the units arrive at the site, consult on further steps with the rescue manager. If necessary, the establishment of the LDC should be provided for, as well as the tools, devices and forces applicable by the mayor's office, the municipal business organizations or the population. If the professional units are overwhelmed and have not yet arrived at the settlement affected, the mayor (chairman of the LDC) gets immediately into a position of decision because he/she has to determine whether or not they have sufficient time to wait for the professional units or to take action immediately. In some obvious cases where the rapid intervention seems inevitable (large area, several parts of the city affected by the disaster, professional units cannot start damage elimination within a short period of time), the winding-up process must be started and action must be taken on commissioning of available forces, on equipment and on the establishment of the LDC.

The on-site protection manager may be the chairman of the LDC or the person responsible for the protection. In all cases, an on-the-spot investigation, fact finding and a survey shall be

[2] Local Defence Committee.

carried out. This can be done by the chairman of the LDC, or by the person on duty. Successful on-site work is assisted by written documentation of the surveyor's experience, which can be done with a pre-made data sheet. The datasheet lists the issues that are most important to the damage assessment. It is recommended to fill out the data, crossing out the excess cells. The questionnaire can be expanded according to the situation. Transmission of information can be done by telephone, by person, or by *courier* interposition. (KUTI–CSEPI 2004)

3.1.3. Launching the damage elimination process

The mayor's decision may be supported if the information on the use of forces required to eliminate the disasters caused by certain disaster types has been previously registered at the local government, so that the appropriate forces and assets can be collected from the list in a case of possible damage elimination. Civilians, the manual labour force is practical to be moved in sections, or in a team unit. It is also necessary to determine whether a shift is expected to be sufficient or continuous work will be required. If damage elimination is carried out by units of professional damage elimination bodies, and their own forces are not sufficient for liquidation, but assistance can only be expected later, they should also be involved in the protection of the local forces.

The goal is to react as fast as possible, because speed reduces injury and can save lives. However, it is very important that only one person from the mayor's office should keep contact with the relief organizations, because taking *cross-action* can cause chaos. As a first step, the professional disaster relief units of disaster management should be contacted.

If they already know about the event, they must be informed about the actions taken so far, unless the following factors have to be communicated to them:

1. location of the damage
2. magnitude, extent
3. nature of the task
4. designated meeting point (this can be a well-known point nearby)
5. the measures taken so far, the number of instruments available and the estimated implementation time of the intervention should also be communicated so that their preparation can be appropriate for the task

In case of a long-lasting task, a duty office has to be established at the local government which has to be operated for 0 to 24 hours. The forces and equipment deployed in local civil protection organizations need to be alerted. Informing and alerting the citizens should also be organized. For backup work, it is advisable to have a backup alarm, as it is always necessary to calculate the number of redundancies due to various reasons. In all cases, for alerted forces and equipment, a meeting point has to be assigned, preferably near the actual work site.

They will need to be briefed on the implementation, nature and expected duration of the tasks, and the on-site manager, whose name, telephone number must be recorded and the relevant addresses of the mayor and the LDC have to be appointed for continuous contact. If necessary, institutions and self-governments involved in the deployment have to be included and contacted. Medical staff should be counted on for permanent medical care, and transport has to be provided to them. Public service providers should be informed of possible public service obstructions. The mayor, if not on the spot, must be informed about everything. (Kuti–Csepi 2004)

3.1.4. Managing events at the damage site

For effective damage elimination, it is essential to have a sufficient number of staff in each work area appropriate the size of the task. For physical work, a section with a protection sub-task is needed, with a team action capacity of at least 6 to 10 people, with only one manager. This is the minimum, in less than one area fewer people should be deployed, because no real progress can be achieved otherwise, and the existing staff can be endangered by imposing on them more than their capability. The forces should be employed step by step,[3] to be provided for their change and care. For sections or work teams – if they do not have tools for protection, hand tools, rubber boots, etc. – the necessary tools and equipment should be provided from the local government inventories, which have been pre-loaded. The tools need to be looked up on brochures with the managers because there are some devices which do not serve only one person. Time should be taken for documentation of transmitting, because later serious damage can occur. It should also be considered that the working conditions of some devices (e.g. generator) must be checked and the material conditions of operation must be ensured. It is very important for an on-site manager to be assigned to each defensive site, the designation being made by the protection manager from the disaster management or, if he/she is not on site, by the mayor. The manager's person must be disclosed to each unit carrying out the task and communicated that he/she is the manager at the site, and everyone must act as his/her subordinate. If this designation is missed by the protection manager, in case of a longer protection, an unprotected state is going to occur. Any defective decisions of the local manager may be screened by the defender's recurring checks. It is also an important requirement to be on site at all locations, even if the protection is done in adjacent areas but in the same process. The best decision would be to entrust people with management who possess the necessary professional skills. Employees should be warned to keep an eye on each other, and no one should go anywhere. This is especially important at night. Where machines or tracked vehicles operate on several locations close to each other, the on-site manager, who keeps contact with other task managers, must be identified. Thus, the supply of materials and continuous protection and damage elimination are ensured. Protection can be carried out simultaneously in work areas, not having to go through every step one by one. This is on the condition that everyone has a definite task and has fulfilled them on proper terms. The on-site manager, however, has to set up a sequence of measures that should be followed in general terms during the work. Without this line of action, important units can be left out. (Kuti–Csepi 2004)

[3] Depending on the nature of the task, the participants in defence must be rested at specified intervals. As long as the first unit rests, the unit in the reserve works and then switch again.

3.1.5. On-site tasks, life-saving, public hazard communication

In the order of damage elimination tasks, saving lives and people's safety should be considered a priority. In the affected area, all public utilities (electricity, gas, and fresh water pipes) must be connected, as their damage could pose a further threat to both citizens and rescuers. During on-the-spot reconnaissance, it has to be determined whether there are people in danger and whether action has to be taken as soon as possible. Complex life-saving tasks should be entrusted to firefighters and ambulances. During surrendering, more serious cases should be anticipated and should not be *buried* on a site until the entire vulnerability is specified, as the correct order can only be established at that time. If displacement is to be ordered, the number and composition of the displaced persons (children, adults, patients, etc.) must be immediately reported to the protection manager or to the person in charge of collecting the data. It is also important to note whether the transportation of persons can be solved by means of simple passenger transport vehicles, or if an ambulance or an off-road vehicle is required. It should be mentioned if a rescue physician is also required. It is very important in this process that the number of people living in vulnerable buildings can be established because they cannot be forgotten. A register of the deceased shall be prepared. The embedded part of the town must be guarded by the police and civil guard. (Kuti–Csepi 2004)

Crisis communication is the process where the protection manager, mayor, or person assigned to the task informs the target group in a timely, factual and appropriate manner. Communication can take place in the form of written and personal speech. It can be a statement, press conference, communication, briefing and interactive communication.

The essence of the communication should:

- be authentic
- built on professionalism
- on trust
- contain relevant information
- not cause panic
- not generate tension

An important task is managing the media. The media distorts events. It is important to counteract distortion with relevant data and real, fact-based information. (Benye 2018) A person needs to be assigned to communicating with the public, providing information and collecting data, otherwise the duties related to citizens will take all the time of the local manager (or protection manager). For this purpose, a persuasive man of good communication skills must be found, either from the protective staff or by the involvement of external persons. The information should be calm, aimed at reassuring the population and preventing panic.

3.1.6. General damage elimination tasks

The general protection process can proceed essentially in parallel with the expense release and is therefore presented in the following table:

Table 1.
Parallel tasks for damage elimination

Reducing the degree of danger, or eliminating it.	**Mitigating material damage, saving and securing values.**
• The protection, rescue locations and sections must be specifically identified, and then the forces necessary for damage elimination must be determined on a given stage. • In case of residential area, the situation of utilities has to be reviewed prior to the commencement of damage elimination. The traces of underground utilities must be marked in the disaster area. The trails must be shown to the operators and to the farmers. Estimation of required materials and the number of equipment to be used and their territorial distribution, temporary or final placement points has to be carried out. These should be shown to local managers and communicated to the vendors (preferably via the protection manager). • The result of the work already carried out (e.g. drainage functionality) should be monitored, any unfavourable changes occurring in the meantime have to be resolved. Where the intervention was not quite effective, new solutions should be sought. • In the event of long-term damage elimination and protection, the logistical background has to be provided for the execution and maintenance of the executives.	• Saving the valuables can only commence if the saving of the people is performed by enough staff. It should not be allowed on a large accident site that rescue forces are retrieving valuables while people are in danger. • The valuables from the houses have to be removed in the order of the building's stability. Firstly, houses with a higher risk have to be addressed, but care should be taken that no one be allowed in already damaged buildings. If there is a suitable person among the occupants, it is advisable to use him/her to assist and control it. • Saved valuables must be delivered to the pre-designated temporary warehouses, preferably stored in a separate building. Distribution is handled by the protection manager or by the person appointed by him. • As far as possible, any unattended building and yard has to be closed or access must be blocked. The attention of the police or civil guard should be drawn to these buildings. • Buildings exposed to the risk of collapse can only be entered if it is considered possible by people familiar with them (fire department or architectural experts). Dangerous buildings must be closed.

Source: Kuti–Csepi 2004

3.1.7. Post-work protection and recovery

Protective work and damage elimination should be continued as long as disaster consequences are significantly impeding proper use. When damage elimination is completed, recovery work is required to restore the original state. If necessary, provision should be made for discharge, disinfection and recultivation. In addition to disaster relief, the Professional Environment Protection Authority or the National Public Health and Medical Officer Service should be involved in professional management of the works. Disinfection is also required after water enters into buildings (regarding the disinfectant, it is also possible to ask for assistance from NPHMOS) but in this case the risk of access to the building must be measured up by a specialist and only those buildings can be accessed, where there is no risk of collapse. Materials that have become redundant must be transported from the areas that have been damaged to the designated storage location. Wood and iron materials still to be used must be cleaned. Tools and equipment should also be cleaned and rusting surfaces must be oiled. The assets issued must be recorded, their condition and their further applicability assessed. Appropriate maintenance of the equipment is essential for further successful protection. The area must be cleaned from all material used during the protection. Waste materials must be handled according to their nature.

3.2. Damage elimination tactics in disaster situations caused by wind storms

In most cases, wind storms can be forecasted, therefore the population has to be informed about preventive measures in order to reduce damage. Because of the serious damage caused by wind storms in Hungary in recent years, the experience, practical knowledge and descriptions gained during the elimination of the damages provide adequate points for defining tasks that can be used during protection. The characteristics of windstorms in Hungary are quite known, their effect is carried to a greater or lesser period of time and intensity, they break trees, tear roofs, damage critical infrastructure, electricity and telephone services, as well as cause accidents both on the road and railways. An important task is providing LDC[4] reports and reports on wind storms. (KUTI–FÖLDI 2012) The following table can be used by the population to identify the types of wind storms. The gusts in the tiled categories can typically cause various damage to our built and natural environment.

Table 2.
Wind and wind speed categories

WILD CATEGORY	WIND SPEED	
	m/s	km/h
Calm	0	0
Light breeze	1–3	4–11
Moderate breeze	4–7	15–25
Fresh breeze	8–11	29–40
High wind	12–16	43–58
Gale, strong gate	17–24	61–86
Violent storm	25–32	90–115
Hurricane force	33–	119–

Source: KUTI–FÖLDI 2012

The hazard levels for wind gusts during wind storms are shown in the following table.

[4] The Hungarian Meteorological Service.

Table 3.
Hazard levels of gangways

Name of extreme weather phenomenon	Sign		Meaning of danger level
Wind gust		1	The expected strongest wind gust exceeds 70 km/h.
		2	The expected strongest wind gust exceeds 90 km/h.
		3	The expected strongest wind gust exceeds 110 km/h.

Source: Compilation of the author based on HMS data.

The most important steps for preparation:

- Cutting the branches of dangerous and damaged trees.
- Control of building windows, shutters, repairing if necessary.
- Monitoring of HMS reports.
- Public hazard communication above the category of *strong wind,* where attention has to be paid to closing doors and windows during a storm, to the importance of a safe place of residence, attention should be called to the danger of leaving home; the participants of any kind of transportation must be urged to take extreme caution.
- Prevention of unwanted conditions.
- The regular monitoring and maintenance of tangible assets required by the local governments and the citizens.

If preparation was prudent and thorough, any damage elimination could be more easily accomplished.

The most important steps of damage elimination are:

- Continuous liaison with the professional damage elimination organizations involved in protection.
- As required, the establishment and operation of the LDC.
- Remediation tasks with the tools available, breaking down broken branches, cleaning up the roads, pavements, collecting fallen building materials.
- Continuous assessment of the situation.
- Creation and continuous provision of a logistic background for technical devices and manpower.

The most important steps of recovery:

- Damage assessment.
- Cleaning the area affected by the disaster (collecting and removing broken branches from the area).

- Reconstruction of damaged buildings.
- Maintenance and replacement of equipment.
- Stock filling.
- Preparing for new protection.

3.3. Damage elimination tactics in a disaster caused by flooding rain

Due to climate change, unfortunately, humanity is experiencing sudden changes in weather patterns during which supercells develop. These phenomena are accompanied by sudden rainfall. Over the past two decades, these increasingly frequent flooding rainfalls have caused serious damage to several settlements in Hungary, and the consequences of eradicating them were difficult, complex and costly. Analysing the effects of rainfall on the natural and artificial environment and the efforts to eradicate their consequences, it can be stated that better knowledge of the effects of the phenomena, preparation for facing the consequences, and work experience of organizations involved in the control of their harmful effects can provide useful basic information. Prediction of weather changes, due to the development of meteorology is getting more and more accurate, but to exactly predetermine precipitation levels is still not easy, so preparing for protection is also difficult. Floods, like rain are characterized by the fact that in a short period of time a large amount of precipitation falls, which canal systems cannot deal with, so in many parts of the settlements rainfall occurs as inland water, flooding cellars, underpasses, underground parking lots and other low lying areas. (KUTI–NAGY 2015) The following table contains the explanations of extreme rain levels.

Table 4.
Extreme rain levels

Name of extreme weather phenomenon	Sign		Meaning of danger level
Heavy thunderstorm		1	Heavy thunderstorms (with a strong wind or large ice) with small probability.
		2	Heavy thunderstorms (with a strong wind or large ice) with medium probability.
		3	Heavy thunderstorms (with a strong wind or large ice) with high probability.
Flood-like rain		1	In the event of intense rain or rainfall, a precipitation of more than 25–30 mm in the short run can occur.
		2	In the event of intense rain or rainfall, a precipitation of more than 50 mm in the short run can occur.

Source: Compilation of the author based on HMS data.

The flooding caused by rains may be eliminated by drainage and pumping in certain places, but there may be neighbourhoods where sandbagging needs to be applied. In most cases, damage elimination is performed by units of the professional fire brigade, but due to lack of equipment and capacity, the local governments and the population have to be involved in protection, as well.

The most important steps to prepare:

- Regular maintenance of rainwater drainage trenches and channels.
- The regular monitoring, maintenance of tools needed for protection.
- Providing sandbags for protection, checking of stocks.
- Providing sand for protection.
- Checking the registration of transport vehicles, devices, keeping vehicles in readiness.
- Keeping pumps and hoses ready.
- Checking, clarifying the records of local civil protection organizations.

If the preparation is done well, taking into account the experience of previous similar damage eliminations, any damage elimination will be more effective.

The most important steps of damage elimination are:

- Continuous liaison with the professional damage elimination organizations involved in protection.
- Shutting down public utilities if necessary.
- Drainage or sandbagging at the damaged location.
- To reduce the drainage capacity of the drainage system in the built-in areas where watering is not possible, water must be removed by continuous pumping.
- If necessary, establishment and operation of the LDC.
- Water removal from the basement of buildings and underground parking areas.
- Creation and continuous provision of a logistic background for technical devices and manpower.
- If necessary, de-migration is implemented as planned.
- Continuous situation assessment.
- As a result of flooding rainfall, post-protection work after the disappearance of inland water.

The most important steps of recovery are:

- Damage assessment.
- Cleaning the area affected by the disaster, removing mud and sludge deposits.
- Disinfection of buildings and public areas.
- Recovery of damage in buildings.
- Maintenance, replacement of equipment and tools.
- Stock filling.
- Preparing for the new protection.
- In the course of elimination work on the inland waters accumulated in the affected areas, a variety of pathogens can endanger the damage eliminators and the human environment, so handling the risk of infection is an important task. Before the recovery works and before public spaces are used again, biological depletion, also known as disinfection, must be done to neutralize or remove abiotic pollutants.

Disinfection is a very costly, time-consuming process, and requires special equipment, materials, methods and procedures to be effectively implemented. The disinfection tasks are of great importance in terms of remediation. It is important to note that the drainage system caused by the flood-like rainfall, especially in case of previously established drainage networks, where rainwater flows into the sewage drainage channel, rain water mixed with the wastewater is recycled into the environment. As a result, the risk of infection can also be a problem in the affected area, during which sewage-discharged diseases are introduced into the human body by contact with contaminated water. Infection can occur when hands come in contact with water, by drinking it, by washing vegetables and fruits when food is prepared or by bathing. Water-borne diseases can be bacteria, viruses or even parasites. The worst water-borne diseases such as dysentery or cholera, fortunately have a minimal chance of appearing in our country. However, pathogens that are most common to humans include Shigella, Salmonella, Legionella and E. coli bacteria, and highly resistant Hepatitis A viruses. Most water-borne diseases affect the digestive tract, but since the pathogens are manifold, the symptoms can be manifested in a variety of forms. The most common symptoms include abdominal cramps, fatigue, bloating, vomiting, diarrhoea, weight loss, fever and weakness. It may be similar to flu-like symptoms. In general, infections of this nature are not contracted only by one person, many epidemics may develop. Signs indicate that the illnesses coincide with the water supply areas where many people are affected, so water contamination can easily be identified. In all cases, when rainwater is mixed with sewage drains from the drainage network, the affected area must be disinfected after the contaminated water has been disinfected to prevent the spread of ozone in the biological pathway. In the presence of contaminants, and of infectious substances, continuous disinfection should be sought. Creating the conditions and logistical background of effective disinfection requires careful and prudent planning. In order to carry out the correct technological order, the disinfection process must be continuously coordinated. Only if it is possible to prevent further infections and effective disinfection is accomplished may they cease such practices. The steps for process planning are as follows:

- Determination of infection or infectious substance.
- Determining the exempted persons, devices, vehicles, environment.
- The selection of the disinfection procedure and devices to be applied.
- Determination of disinfectants.
- Designation of the disinfection area.
- Selecting the executing personnel.
- Treatment of contaminated materials, post-work.
- Determine required tasks and order.

If contaminated water has been introduced into the drinking water supply network or into dug wells, until the disinfection works are completed, the water supply is ensured by using tankers in the affected areas or by setting mobile water purification equipment. (KUTI–GRÓSZ 2016)

3.4. Damage elimination tactics in disaster situations caused by snowstorms

Most of the snow storms can be predicted by the Meteorological Service, so the citizens need to be informed of preventive precautions in order to compensate for health and to reduce damage. People should also be prepared for the possibility of roads blocked by snow and cutting off of the supply. Therefore, it is important for people to keep food and drink at their homes enough for several days. Extremely low temperatures have serious threats by themselves and are massively threatening the population, especially the homeless and the poor, whose number has been increasing in Europe in recent years due to the economic crisis. A snowstorm is characterized by its changing intensity when combined with persistent cold, damaging electricity and telephone networks, causing disturbances in district heat and fresh water supply, road and rail interruptions, and also accidents. It is therefore important to understand that citizens should not leave their homes, except in the most urgent cases and even then they should preferably travel by public transport. Snowfall hazard levels are shown in the following table.

Table 5.

Snowfall hazard levels

Name of extreme weather phenomenon	Sign		Meaning of danger level
Snow		1	Over 12 hours fresh snow can exceed 5 cm.
		2	Over 24 hours fresh snow can exceed 20 cm.
		3	Over 24 hours fresh snow can exceed 30 cm.

Source: Compilation of the author based on HMS data.

In most cases, disaster recovery is performed by professional disaster prevention units and units of the defence forces, but due to lack of equipment and capacity, local governments must also be involved in the protection.

The most important steps to prepare:

- Monitoring Meteorological Service reports.
- Public hazard communication which should call attention to the closure of doors; during a snowstorm, the importance of a safe place of residence, the danger of leaving home; those still on the road must be urged to take extreme caution.
- Preparation of heating facilities of settlements, provision of fuel.
- People in need of health care in the area must be registered.
- The winter preparation, regular inspection, maintenance of snow relief equipment needed for protection.
- Stocking anti-slip material.
- The inspection and maintenance of transportation vehicles.

The most important steps of damage elimination are:

- Continuous liaison with professional damage elimination organizations involved in protection.
- It is necessary to organize the supply of those who work or are trapped in the snow.
- The medical care of persons living in cut off areas due to snow, the access of emergency vehicles.
- If necessary, establishment and operation of the LDC.
- Creation and continuous provision of a logistic background for technical devices and manpower.
- Continuous assessment of the situation.
- Involvement of civil protection organizations in protection.

The most important steps of recovery are:

- Correction of damage caused in energy supply systems.
- Recovery of damage in municipal infrastructure.
- Maintenance, replacement of equipment and tools.

In disaster situations caused by snowstorms, it is extremely important to keep in touch with professional damage elimination organizations, since continuous flow of information is essential to make the right decisions.

3.5. Damage elimination tactics in disaster situations caused by extreme temperature fluctuations

3.5.1. Heat

According to data published by IPCC,[5] the mean air temperature at the surface measured between 1905 and 2005 increased by 0.18 ± 0.74°C. According to the panel, the main cause of this continuous rise in temperature are the greenhouse gases emitted into the atmosphere since the middle of the 19th century (The Second Industrial Revolution). Greenhouse gases in the lower atmosphere increase the temperature of the troposphere. There is no complete agreement among researchers investigating the issue of global warming on how much it is caused by natural effects (solar radiation, volcanic activity, changes in the orbit of the Earth) and human activities (industry, transport). According to studies and professional opinions, global climate change can be traced back to human causes. This finding confirms that solar activity and volcanic eruptions, according to the calculations, are currently against global warming. (Kuti–Nagy 2015)

According to the climate models adopted and published by IPCC, the Earth's surface temperature will probably rise by between 1.1 and 6.4°C between 1990 and 2100. Although most studies expect temperature rise only to continue until 2100, warming may continue and sea levels may rise even if no greenhouse gases are emitted any more, since CO_2 has been associated with other greenhouse gases for a long time in the atmosphere. According

[5] Intergovernmental Panel on Climate Change.

to the fourth published assessment report of the IPCC, snow-covered areas of the Northern Hemisphere of the Earth has declined by 10% since the 1960s, and glaciers have significantly retreated in most parts of the world. The Arctic Sea ice has shrunk by 40% in the summers of the past decades and since late summer 1950, the extent of it has declined by 15%. According to recent estimates, sea ice has dropped by only 8% in the past decade. Sea ice melting does not increase sea levels, but the disappearance of the ice cover facilitates the flow of continental ice into the ocean, which in turn contributes to rising sea levels and also modifies the radiation reflectance of the Earth's surface. As long as ice surface reflects about 90% of the rainfall, the oceans' water accounts for just over 10% of it. (Földi 2013)

The Green Paper of the European Commission draws attention to the health-damaging effects of heat, in addition to many other factors. It is therefore important to develop an action plan of extreme importance in the event of a heatwave. Research has shown that in Hungary, both the number of days with different degrees of heatwaves and the prolongation of the period of heatwaves may be expected to increase in the coming decades. The population of Hungary also includes a large number of vulnerable groups, who are permanently or constantly outdoor during heatwaves. Attention should be paid to the health risk management of outdoor sports events and other events held during heatwaves, and employers have to make sure that their employees are protected from the heat, have sufficient fresh water, time to rest in the shade and proper work clothing. (Kohut 2013) For environment and other environmental-health causes, priority is given to public utility and residential services that have a positive or negative impact on the quality of the environment but also on living conditions of the citizens during heatwaves.

Essential components to be protected are drinking water bases, water intake sites, water purification plants, strategic fresh water reservoirs and piping systems. The task of the water supply service providers is to provide adequate water supply for the population of Hungary even if the daily average temperature is high. In case of power supply, on average, a 3–6 hour shutdown can provide service to all consumers. In the event of prolonged heat, average electricity consumption may increase due to the use of air conditioning systems, so priority is given to the energy needs of critical infrastructure elements, which may lead to restrictions, as well. Hungary is a transit country, our larger cities are transport hubs, so we cannot ignore the dangers of transport infrastructure elements during the heat. The continuous operation of the railway is essential for the country. Even minor malfunctions in the railway may lead to serious interruptions. Heavy rainfalls or exreme heat/cold waves may deform the rails, may damage alarm and safety devices, top wirings and support posts. During the temporary cessation of rail transport, passengers on the train are to be taken care of at the railway stations until no travel is provided for them. The operation of the motorways and main traffic routes should also be monitored continuously by the Transport Inspectorate. In case of persistently high daily average temperatures, the number of accidents may increase in the affected sections of the road. Motorways can be accessed through multiple passages, so in the event of an accident, rescue units can access the scene. Accompanying persons who come to the car as a result of an accident must be provided with water. It is also important to operate public transport. The bus lines of transport companies are constantly on the rise during the long-lasting, high daily average temperature. Companies should pay attention to the fact that in case of a heatwave, air-conditioned buses are preferred to be operated. Older models must be provided with continuous ventilation and the operation of fans to protect the passengers against heat. (Kuti–Nagy 2015) In case of a heatwave, an important task is the regular disposal of municipal waste, the required transport capacity should be provided by the waste management companies. In case of persistently high daily average temperatures, the frequency of emptying containers should be increased to avoid infections.

The most important steps of preparations and protection:

Heat is predictable in most cases, so the population needs to be informed of the precautionary measures in order to preserve their health. Communication can take the form of written and oral information-providing. This can be a press conference, communication, briefing, interactive communication, where attention should be called to the health effects of heat, as well as to the necessary preventive measures. Citizens must be informed about the harmful effects of sun exposure, the importance of protection against solar radiation and about the role of adequate hydration, as well. The participants of transport have to be informed about tasks on the occurrence of accidents. The information provided must always be authentic, stress and tensions should be avoided.

Preparation and communication phase:

- It is necessary to monitor the reports of the Meteorological Service, the communication of NPHMOS.
- Informing the general public should draw attention to sufficient hydration; shadowy locations, dangers of leaving home; citizens should be advised to provide fresh water for themselves; the participants of transport must be urged to take extreme caution.
- Serious patients have to be taken into account.
- Fresh water preserves need to be prepared.
- The number of drinking water transport vehicles have to be kept in mind.
- The water caravans must be ready.
- The air-conditioned facilities of the settlement for mass reception have to be taken into account.

Protection phase:

- Keeping contact with NPHMOS's local organization.
- Continuous communication to the citizens.
- Providing air-conditioned facilities.
- If necessary, establishment and operation of the LDC.
- Organizing drinking water distribution in busy places of the city.
- It is necessary to ensure the daily watering of the main routes and spaces.
- Creation and continuous provision of a logistic background for technical devices and manpower.

In the event of prolonged heat, the authorities should be alerted to the heat. Heat alarm is a warning issued by the HMS, which is given due to higher than average temperatures or higher expected daytime average temperatures. The temperatures for a heat alarm may differ from country to country. The following table shows the temperature values applied in Hungary.

Table 6.
Heat hazard levels

Name of extreme weather phenomenon	Sign		Meaning of danger level
Heat		1	Daily average temperature is expected to reach or exceed 25°C.
		2	Daily average temperature is expected to reach or exceed 27°C.
		3	Daily average temperature is expected to exceed 29°C.

Source: Compilation of the author based on HMS data.

In Hungary, taking into account the data of the HMS, the National Medical Officer's Office introduced the heat alarm in 2005, which is part of the meteorological warning and alarm system. (FÖLDI–KUTI 2014)

Grade 1 (Level of public hazard communication): It is required to be ordered when the daily average temperature exceeds 25°C for at least one day based on the forecast. In case of a first-degree heat alarm, NPHMOS sends its own information to its county departments. In this case local and regional authorities can inform the public about the expected weather through their own media channels. (KUTI–NAGY 2015)

Grade 2 (Alarm level 1): It is required to be ordered when the daily average temperature exceeds 25°C for at least three consecutive days. In case of a second grade heat alarm, NPHMOS will notify medical institutions, ambulance services, GPs and local governments about the extent and duration of the heat alarm. Then, the tasks of local governments include warning of the citizens and the preparation of protection against heat damages. (KUTI–NAGY 2015)

Grade 3 (Alarm level 2): It is assumed that the daily average temperature exceeds 27°C for at least three consecutive days. In addition to the tasks to be carried out in the second grade heat alert, the population should be informed about the expected weather extremes through media and about possible ways of preventing heat damage. (KUTI–NAGY 2015)

The adverse effects of extreme heat can affect large areas and large masses of people. It is therefore important to prepare for a long-lasting heartache and to take full advantage of the protection capabilities of local governments.

3.5.2. Extreme cold

Due to the geographical location of Hungary, during winter, especially at night, under favourable weather conditions, air can cool down very quickly. Compared to daylight, air temperature can drop by as much as 15 to 20 degrees Celsius by night, so the thermometer's mercury can drop below –15 to –20 degrees. Temperature sensation is also significantly influenced by the wind's strength. People should not forget about the rules of layered dressing. It is important to move the limbs and fingers when being for a long time outdoors, which stimulates the circulation and increases the body temperature. Particular attention should be paid to elderly people living alone and homeless people during this period. Continuous monitoring of the NPHMOS reports is required. If extreme winds are combined with cold, it is especially advisable to be prepared, in case windy weather and extreme cold weather warning are expected. (FÖLDI–KUTI 2014) The following table contains extreme cold-related hazard levels.

Table 7.
Extreme cold hazard levels

Name of extreme weather phenomenon	Sign		Meaning of danger level
Extreme cold		1	The temperature may drop below 15°C.
		2	The temperature may drop below 20°C.
		3	The temperature may drop below 25°C.

Source: Compilation of the author based on HMS data.

6. Conclusion

With regard to all phenomena, it can be said that for effective prevention it is essential to comply with the official information and announcements. For effective protection and damage elimination active citizen involvement in the work, the support of professional damage elimination bodies and local governments are all important. Another important task is to conduct a continuous assessment of the situation and to analyse the experience, which will greatly contribute to the efficiency of future protection work.

The damage elimination process is influenced by the preparedness and leadership skills of the persons controlling protection processes, and thus their decisions. The experience from previous damage elimination greatly contributes to the skills of those who manage damage remediation operations. Skills, parallel to the point of view, and the manager's personality should be developed during further training. For the purpose of processing and implementing the experience, the development of decision-making capabilities of persons managing damage elimination operations is an important task in the disaster management task system. The main goal of on-the-job training courses and practical courses would be to highlight events, experiences, decisions that could be of great professional interest. In case of special training courses, it is expedient to study foreign methods, development practices, and special forms of education, and to carry out a comparative analysis, then adapting and utilising the experience in domestic practice. In my opinion, one of the biggest risk factors is the outcome of the rescue and on-the-spot management decisions of successful and effective damage elimination. The increase in the requirements for decision-makers is also inherent in our social economic development. Today, there is a wealth of theoretical knowledge and a concrete professional knowledge the usage of which are key to effective management in disaster relief.

The protection of human lives and property, and the urgent need for restorative work, must always be monitored. In the protection against the effects of disasters, local governments also have a major role. Emphasis should be placed on the careful preparation for the protection of the adverse effects of extreme weather events, which is essential for effective elimination.

Prevention is an important element of disaster protection, however, prevention of extreme weather events is impossible. At the same time, it can be said that, based on past damage elimination experience, rapid, efficient and complex damage elimination and mitigation can and should be prepared. Taking into account the experience, it is necessary to continuously review the applied remediation tactics and adapt according to challenges.

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Current Issues in Disaster Management Aspects of Global Climate Change

1. Introduction

The climate of Earth has changed constantly throughout Earth's history, because the warmer (interglacial) and colder (glacial) periods exchanged each other cyclically. (Teknős 2013) According to the report from the Intergovernmental Panel on Climate Change (IPCC), humanity influences this phenomenon. (Solomon et al. 2007; Padányi–Halász 2012) This divides the scientific world but they agree that the environmental changes that can be experienced recently are causing serious national security, home defence, law enforcement, population protection and economic problems. We can observe dangerous global anomalies (extreme weather, direct and indirect health effects, habitat changes, the decrease of ice areas, etc.) that already affect the natural and man-made environment and the security of life and material goods. (Teknős 2015) According to this, it is imperative that the pace of global climate change and the interdisciplinary research of extreme weather anomalies be present in all the national security sector's systems of tasks and in the scientific–research–education activities.

The train of thought from the official disaster recovery organization is essential, stating that in Hungary's weather history, extreme weather events were always present, but the unusual, extreme values of the meteorological anomalies have been more frequent in the last 15 years. (OMSZ 2013) Nowadays, the national effects of global climate change are clearly palpable. With the analysis of the consequences of extreme weather effects, we can track fire and the evolution in trend of different mechanical rescue interventions, and from these it is possible to make a prognosis, conclude, then decide about prevention and defence methods along with the development of assets.

In this publication, the author tries to identify the official disaster recovery organization's tasks regarding the reduction, mitigation, but most importantly, the adaptation of human activities responsible for greenhouse effect; to evaluate the risks of climate change from the angle of disaster recovery; and to analyse the extreme meteorological anomalies taking the inland migration statistics into account.

2. The Introduction of New Challenges and Risk Factors that Imperil Hungary's Safety

The security aspects of the climate change are being analysed in detail by many studies and reports, and they all state that climate change is a serious global threat. Richard Anderson Falk, American Professor Emeritus, says that the faster climate change is, the more difficult it will be to adapt to negative effects which might lead to armed conflict. (Barnett 2001) Jon Barnett analyses the connection between climate change and security including armies in one of his articles from 2001. He writes that armies are affected by climate change in a lot of ways. On the one hand, they contribute to it with carbon-dioxide emissions, while on the other hand, they suffer the consequences (in a physical and psychological context). Because of the increasing security risks (lack of water, migration etc.) some countries might participate in armed conflict or peacekeeping. (Barnett 2001; Padányi–Földi 2016)

Joshua W. Busby says that climate change threatens security and social prosperity in the United States, as well as in other countries. According to the professor, climate change will cause international level humanitarian catastrophes that will lead to the spread of riots which will happen primarily in countries with weaker governments (some African or Asian countries). In the United States the majority of GDP goes for military expenses. Hurricane Katrina in 2005 put the political decision-makers in a discretionary position. Because of the intensity of the hurricane, twenty-two thousand soldiers and fifty thousand National Guard troops participated in disaster recovery and liquidation. At the same time, there were high-cost paramilitary deployments (for example in Iraq and Afghanistan). It made the American missions even more difficult because the hurricane caused an 80 billion-dollar expense and material sources had to be replaced in the disaster area. According to Joshua W. Busby, climate change has and will continue to have effects, in addition to which the recent military expenses cannot be maintained, so the American influence on global security might decrease. (Busby 2007) József Padányi writes in a 2009 article that the European Union has already investigated the security context of climate change in 2003, then in a report in 2008, they state that the most critical areas are the ones with unstable economic, political and social environments. According to all this, we can state that climate change has international effects, which are some of the global challenges and main perils. (Padányi 2009) According to Professor Padányi, climate change affects a country's security, in which case, we have to investigate the following: lack or dearth of energy, food or fresh water, decreasing ability for maintenance, and the availability and location of strategic raw materials, etc. (Padányi 2014)

Referring to the previous opinions, environmental problems are intensifying the probability of civilizational conflicts. Armed conflicts are expected to happen because of the need of water, forests, fishing areas, soil and residential areas less affected by catastrophes. More and more local conflicts are expected to occur. Environmental problems cause insecurities that can develop social, economic and ecological tension, or can amplify existing ones; so for sustainable security, we must synchronise the use of crisis management tools and strengthen international personas' cooperation.

Considering the introduction of the new challenges and risk factors endangering Hungary's security, we must mention the documents about the National Disaster Risk Evaluation and the Report on the national disaster risk evaluating methods and results of Hungary.

The National Disaster Risk Evaluation contains risk information, threats, effects of main national natural disasters, and human-caused (civilization related) catastrophes as requested by the European Commission. According to the evaluation in Hungary's case, we have to take into account the following: flood, inland water, flash flood, *extreme weather,* earthquakes, forest fire, industrial security risks caused by dangerous industrial plants, nuclear threats, and social risks of asylum, massive migration, mass events, terrorism, and *the effect of climate change.*

The *Report on the National Disaster Risk Evaluating Methods and Results of Hungary* (in the following: Report) consists of two parts.

- The first introduces the process, method and data of the first disaster evaluation.
- The second contains the probability- and effect analysis of risk scenarios, the ranking of risks and the results of risk evaluation.

Natural risk	Civilization risk	Intended risk
1. Extreme weather	6. Industrial accidents	9. Terrorism
2. Water damege	7. Traffic-delivery accidents	10. Cyberattacks
3. Geolgical risks	8. Nuclear accidents	11. Security policy crises
4. Epidemics		12. Power supply crises
5. Space weather		

Figure 1.
The 12 main risk areas of the report on the national disaster risk evaluating methods and results of Hungary

Source: Made by the author based on data of the Ex Ante Report 2014.

According to Figure 1, the Report divides the risk areas into three sections. The first five areas are the *Natural risk categories* (natural events), areas from number six to eight are the *Civilization risk categories* (severe accidents), and areas from number nine to twelve are the *Intended risk categories* (intentional events). The twelve risk areas found in Figure 1 can be divided into thirty so-called major scenarios which contain 72 sub-scenarios. In Hungary, according to the Report, the most intense of the identified dangers are *the natural originated* ones, which occur more frequently. As a result of the progressively more extreme weather in connection with climate change, we have to expect these events to be more frequent and have more severe consequences. (Teknős 2017a)

The following risk areas consume the most resources according to their treatment, and they have the most severe consequences compared to the others:

- extreme weather
- water damage
- flu pandemic
- migration
- nuclear accidents

- invasive allergens or poisonous plants
- magnetic storms
- animal- and plant healthcare damages

In 2011 the Intergovernmental Panel on Climate Change (IPCC) published a thematic report on the risks and management of extreme climatic events (SREX) in connection with extreme weather, in which they evaluated the role of climate change in the change of intensity and frequency of the climatic extremities. According to the report, we can observe changes in some climatic extremities. The climatic models show the frequency of high temperature extremities together with the increasing number of high precipitation events. As a result of the general (extending through the Earth), unusual warming and its tracking, the temperature results are more and more extreme, which significantly define the evolution of precipitation. (SREX 2011) A decision-maker report like the SREX and the HREX, introduces the national occurrences of extreme weather. In the HREX report, the National Meteorological Service names the summer days with heatwaves and frosty days as indicators of extremities, undoubtedly proving the increasing nature of high temperature indicators along with the decrease in frosty days. Precipitation is a time- and space-wise volatile national climate parameter. The number of 20 mm rainfall days and the daily intensity are both increasing. (EASAC 2014; BARTHOLY et al. 2012)

The grouping of the 2nd appendix of the 234/2011. (XI. 10.) Government Regulation is the basis of the risk prevention plans that obviously support population and material goods protection, which reveals that although it takes extreme weather risks into account, the risk prevention plans are not dealing with the harmful effects of high temperature (for example, heatwaves). The following documents emphasize and introduce the risks of high temperature in detail: *National Disaster Risk Evaluation* made in 2011, the *Report on the National Disaster Risk Evaluating Methods and Results of Hungary* made in 2014 and in the same year, the *Climate-adaptation and Risk Evaluation Manual,* thanks to the SEERISK project.

3. The Evaluation of the Connection in Climate Change and Extreme Weather with the Analysis of the Weather of the Last Decades

The analysis of the relation of global climate change and extreme weather in Hungary can be tracked with the help of indicators (meteorological, environmental, ecological, healthcare, social and economic). According to the indicators and measurement results, we can state with great certainty that the increase of temperature values in Hungary follows the rise of global average temperature. We can experience a dynamic warming pace from the year 1970, which shows even greater increase in the last 10–15 years. The increasing number of hot days and warm nights that require meteorological alarm in Hungary also follows the warming tendency. The most powerful warming can be detected during the summer.

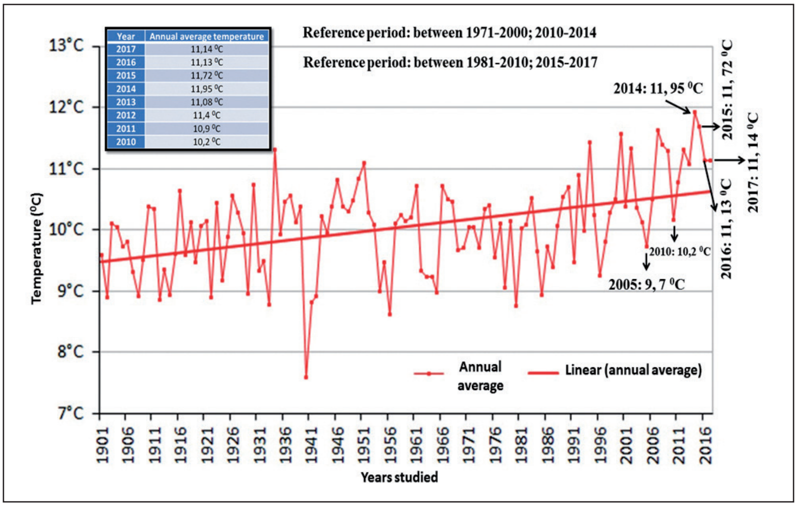

Figure 2.
The national annual average temperature between 1901 and 2017, based on homogenized, interpolated data

Source: Made by the author based on data of the National Meteorological Service.

In Figure 2 you can see the national annual average temperature values between 1970 and 2017. We can observe that after 2012, the average annual values will not fall under 11°C.

Another interesting fact is that some years were colder than usual, but according to the linear trend, the rise of the temperature is obvious. This entails the increasing number and values of high temperature events (proved in the HREX report).

The expected decrease in the frequency of cold winter extremities is smaller than the increase in warm summer extremities. There is a shift compared to centuries of trend regarding precipitation (taking the total rainfall, intensity and dispersion into account). We can observe that there are more anomalies that can be tied to meteorological events in the last couple of years. (KUTI–FÖLDI 2012) This suggests that the circumstances of precipitation are changing. In the area of the Mediterranean Sea the number of high precipitation days decreased while in the northern areas it increased; in the Carpathian Basin there is a negative shift regarding the amount of precipitation and days with high precipitation. This means that the annual precipitation is decreasing constantly and there are fewer days available for it to be dispersed, so there will be days when we can experience more intense (extreme) rainfall. There are already significant changes in the amount of precipitation each season. During the summer, the temperature is constantly high for a longer period of time, which causes aridification; thereby the dispersion and amount of precipitation are less during the summer months. During the winter months we can experience that at drainage basins in Hungary and abroad there is more and more rainfall, but because of the heat, the snow season is getting shorter. There is more rain or sleet, meaning the level of winter runoff is higher (approximately 10–20%) thereby the risk and chance of emergence of floods are higher. (HORVÁTH 2010)

In Transdanubia, increasing number of high precipitation days (more than 20 mm) can be observed. This direction of change in the extreme precipitation index causes serious problems (also) for the national water management.

It can be stated that the current instability of the climate system means a growing level of climate change, so the greater instability entails higher level of change. The answer regarding extremities from the VAHAVA report, one of the greatest research on national climate change, with coverage from a variety of scientific areas, was that we have to expect several extraordinary effects because of heavy warming and the change in temperature and precipitation, which evokes more frequent and more intense meteorology-originated damage. (Földi–Kuti 2014)

4. The Analysis of the Actual Questions of the Aspects of Global Climate Change and Disaster Recovery through Prevention and Protection

The fundamental function of the National Directorate General for Disaster Management (NDGDM) is the protection of the life- and property safety of the Hungarian population along with the safe operation of economy and critical infrastructure elements. Based on this, their main task is to *prevent* the disasters by law enforcement means; execute the rescue in case of occurring emergencies; organise and control *definitions; liquidate* harmful consequences; and implement *restoration* and *reconstruction.* The temporal (analysis method B) and task related (analysis method A) cycles of disaster management are the basis of the interacting process of effective response. To have the effective cooperation of the participants in protection, the opportunities in harm reduction and moderation, and the steps that make the restoration of conditions possible before the damage or catastrophe. At every phase of the management periods, appropriate measurements must be taken in strict order. The separate cycles interact with each other, meaning that vulnerability is increasing with the lack of measurements taken before, during, or after the occurrence of an event, or with inappropriate responses.

The goals of disaster management: (Teknős 2018)

- to avoid or reduce losses and moderate damage as much as possible
- preparation for all dangers
- immediate assistance, providing appropriate protection methods
- quick and effective restoration, reconstruction[1]

[1] Due to extent, the publication does not deal with the disaster liquidation period or the introduction of recovery and restoration.

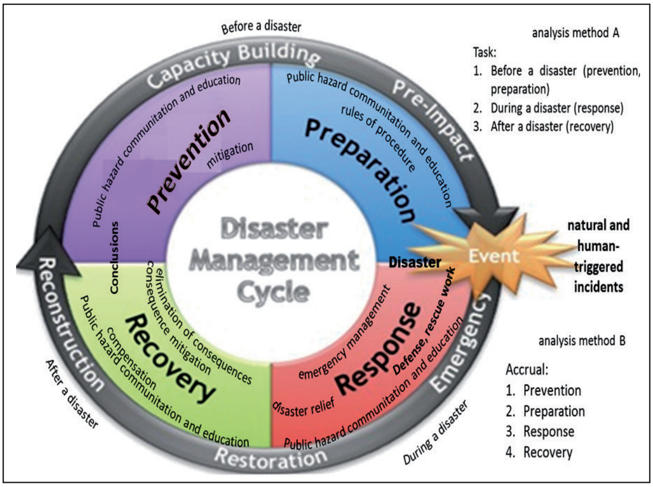

Figure 3.

The separate temporal cycles of disaster management

Source: Made by the author.

The separate temporal and task-related cycles of disaster management can be seen in Figure 3. The process describing the cycle can be divided into four sections. The first part is prevention, which means the reduction of the disaster causes, which is the main period for informing and preparing the population (according to timing). The formation of the requirements for the other periods happens here as well. Since the occurrence of effects, disasters and damages cannot be prevented, the preparation of the population appears as a prevention principle, but also as a separate cycle. This will be the connective transition between the prevention and protection-intervention (response) as a task related cycle. It is important to note that preparation only relates to own staff.

The preparation of population is a complex activity which, on the one hand, is an activity system that contains preparation of the population for emergencies including exemplary rules of behaviour and action. The suitability to save themselves, others and material goods; furthermore, the skills development of this knowledge by appropriate direct practice. On the other hand, raising awareness of self-induced emergencies by negligent behaviour or lack of necessary skills. The goal of this action is the foundation of security culture, formation of self-saving behaviour. The main goal of the disaster recovery preparation of the population is to introduce the behaviour rules to follow in case of specific local dangers or dangerous effects and in case of alerts, as wide as possible. [62/2011. (XII. 29.) Decree of the Minister of the Interior]

5. Defining Hungary's Weather-related Disaster Recovery Threat through the Disaster Recovery Classification of Settlements

The most important fundamental tasks of prevention include the measurement and register of dangers, danger- and risk analysis, making impact assessment, integrated danger assessment, and risk evaluation. The planning regarding all emergencies is the disaster recovery classification of settlements. The closing clause of the disaster recovery law gives authority to the Government to regulate the detailed rules of disaster recovery regulation in a decree, and within that, the rules for disaster recovery classification of settlements and the requirements of protection, along with the content and formal requirements of emergency planning. (Point d of the 81st *Paragraph of the law 128/2011 on Disaster Protection)*)

The 21.§ (1) paragraph of the 234/2011. (XI. 10.) Government Decree being the executor of the disaster recovery regulation, arranges for the disaster recovery classification, so the classification into the three disaster recovery categories covering all settlements happened as a result of risk evaluation process after the real, location specific evaluation of threatening consequences. The hazard level/category of settlements can be found in the 1st appendix of Government Decree 61/2012. (XII. 11.). [61/2012. (XII. 11.) Decree of the Minister of the Interior]

Table 1.

Classification categories of settlements affected by hazard impacts of meteorological origin in Hungary in 2017

Hazard impact	**Number of classified settlements total**	**Number of vulnerable population (persons)**	**Number of Class I settlements**	**Number of Class II settlements**	**Number of Class III settlements**
			Persons affected	**Persons affected**	**Persons affected**
Extreme weather	2,480	6,041,321	6	343	2,131
			145,720	2,619,423	3,276,178
Extreme winter weather	977	4,287,496	14	239	707
			2,446,391	609,528	1,489,722
In 2017, there were 3,177 settlements in Hungary in total			180	1,328	1,669

Source: Made by the author based on NDGDM data.

Table 1 shows the classification categories for settlements affected by meteorological hazards together with the number of the vulnerable population (people). According to paragraph 21 of section V of the 234/2011. (XI. 10.) Government Decree, "The settlements of the country must be classified into disaster recovery categories as the result of risk estimation procedure with respect of the given settlements". [234/2011. (XI. 10.) Government Decree] Within the framework of risk evaluation, we must take hazards into account according to the second appendix. Extreme weather can be found in point a, part 1 of the second appendix of the 234/2011. (XI. 10.) Government Decree amongst elemental disasters and environmental hazards. According to the Government Decree, Table 1 contains the results of annual revision. It can be stated that out of 3,177 Hungarian settlements, 2,480 are affected by extreme weather hazards. There are six settlements in the most hazardous (I) category, 343 in the second (II), and 2,131 in the third (III), which altogether affects six million people. Regarding the winter weather threat, we can state that there is a high risk (affecting 977 settlements) despite the decreasing tendency of the frosty days, because of the rising temperature in Hungary. This data (also) proves that we must deal with hazardous weather phenomena, and the disaster recovery based analysis must continue.

5.1. The analysis and evaluation of challenges in sustainability regarding disaster recovery

The organizational sections of the Home Office and the organizational sections helping the ministry's office activity, together with the individual organizations under the command of the Minister of the Interior (official disaster recovery organization including the police) taking sustainable development into account – in accordance with the principles of the European Union and the National Sustainable Development Strategy – put a great emphasis on a more economical, more environmentally friendly approach and maintenance of the organizational operation; furthermore, it provides the improvement of social conditions. It takes sustainability viewpoints into account and enforces them in its operation as much as possible. [23/2010. (XII. 22.) Order of the Minister of the Interior]

Accordingly, these viewpoints must be fulfilled:

- planning and measuring that serves sustainable development
- preferring products that are more beneficial regarding environmental protection
- reduction of equipment-, energy-, and water usage
- waste management: it must strive to decrease the ratio of all waste generated and increasing the ratio of waste handed in for recycling
- acquisition: bring environment friendly, less energy consuming, recycled products, equipment and solutions into view, make these be priorities
- preferation of alternative transportation to cars
- broadening knowledge regarding personnel sustainability
- health promotion
- improvement of public administration: have colleagues actively take part in developing modern and environmentally aware public administration corresponding with the basic principle of sustainable development

Since the directing body of the Home Office's NDGDM is the Home Office itself, its task system has to contain the viewpoints above.

According to the NDGDM instruction no. 6/2015 on the publication of Sustainable Development Strategy of the NDGDM, the NDGDM is responsible for influencing social and environmental processes. For sustainability, the NDGDM states that it takes sustainability viewpoints into account and enforces them, *the environmental protection strategy of* the NDGDM forms the basis of the Sustainable Development Strategy. The NDGDM follows the basic environmental protection and sustainability principles of the Home Office. Despite the fact that regarding its task system, the official disaster recovery organization is diverse, it pursues more environmentally aware task execution with action plans, keeping the basic purpose in mind.

5.2. Introduction of the population preparation for self-protection skill improvement

The negative effects of climate change can cause problems for the public in two ways. Firstly, directly with physical effects like heat, extreme cold, induced cooling or hypothermia, or storm-caused physical injuries, etc.; secondly, indirectly, for example, because of the damage, loss, or malfunction of material goods.

From the point of view of disaster recovery, on the one hand, this means the preparation and emergency information of the population, the realization of social sense of security (not equal to triggering panic), and the improvement of a prevention mindset. In the struggle against weather and climate effects the goal is to shape self-rescuing skills, execution of appropriate rules of behaviour with trust, and building up active citizen involvement in the liquidation of occurring meteorological and hydrological events. These tasks are not new but with the *change of social habits* and as a result of the education and training of new generations, they will always be actual and obligatory to execute. The goal is to strengthen resilience against the effects of climate change.

The author's opinion is that in the 21st century, modern interpretation of population protection, the self-rescuing equipment and the ability to use them is a field that we must address, and it must appear in the population safety system. Self-rescue supporting equipment is every tool or object with which our own physical integrity can be protected, but strictly from a disaster recovery point of view. This means that self-defence weapons are not – according to disaster recovery viewpoints – self-rescue supporting equipment; they are rather the public equipment used in the fields of fire protection, civil protection, industrial security and healthcare (for example, the usage of a CO metre, fire extinguisher, first aid kit and defibrillator, that ensure the survival of oneself and our partner in case of damage). *Self-rescue supporting skills is knowledge that help the professional use of equipment and the execution of survival knowledge in practice.* In case of the latter, think of simple DIY activities such as board barricading doors and windows, baking bread, making simple food from basic ingredients, the proper removal of ticks from body parts, skill level application of emergency knowledge (at home, in natural and man-made environments), how to change a wheel on a vehicle, basic first aid, how to ask for help, the rules of lighting and extinguishing a fire, etc.

The opportunities helping the improvement of self-defence skills of the population can be divided into three groups. The first group contains the opportunities ensuring the survival of oneself, otherwise known as self-rescue. The second is saving the partner, and the third is the active involvement in the defence against disasters.

Figure 4.
The illustration of self- and partner rescue through some examples
Source: Made by the author.

Self-rescuing skills must have different part elements:

- phone for help
- basic sanitary knowledge (cooling the body, wound treatment, carrying the injured, recovery position)
- making the vehicle and home *survival proof* (the vehicle must be *foolproof,* at home, the storage of equipment that helps survival, like food, blankets, torches, map and if possible, aggregator, etc. have to be accessible)
- recognizing threatening effects (danger labels, storm warnings, being on ice, lighting fire, appropriate behaviour during mass events)
- baking/cooking in the kitchen (cooking pasta, baking bread, making simple dishes from scarce ingredients, knowledge of the fire-safety features of baking/cooking)
- personal protective equipment/making protective equipment
- understanding meteorological predictions
- making a survival pack (mainly for evacuation)

Developing partner saving skills:

- the same as self-rescue with the addition of revitalisation knowledge, proper execution and the usage of defibrillator

Active involvement in the defence against disasters:

- developing safety and health culture and hazard awareness (not equal to triggering panic)
- security awareness: recognizing environmental hazards
- improvement of prevention culture: reducing disaster tourism, capturing disaster recovery knowledge, reducing the chances of damages caused by population
- increasing the will to cooperate in defence against disasters
- recruiting and preparing volunteers

5.3. Evaluation of extreme weather taking firefighting statistics into account

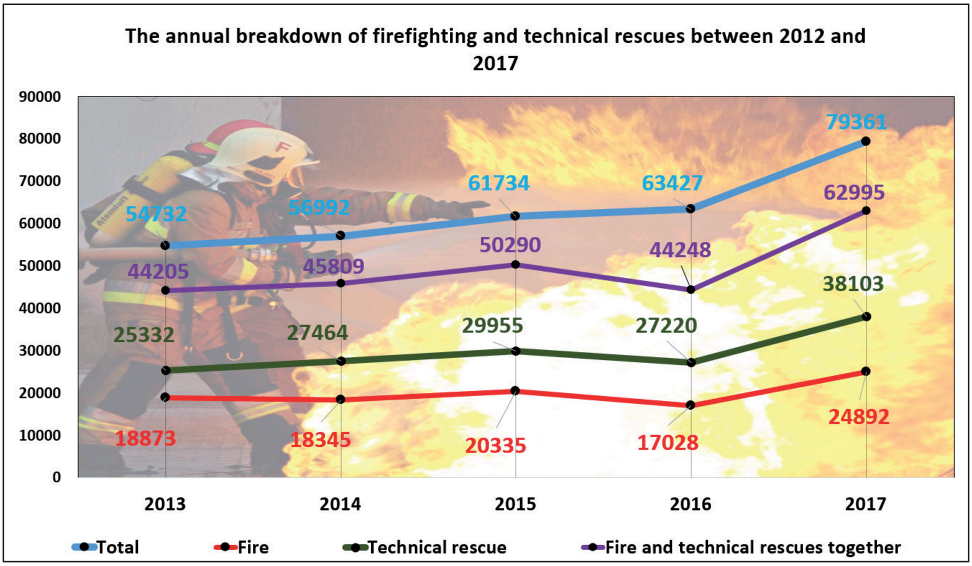

Figure 5.

The annual breakdown of firefighting and technical rescues between 2012 and 2017

Source: Made by the author based on the Daily Reports of the Central Main Duty of Disaster Recovery.

Figure 5 shows the annual breakdown of firefighting and technical rescues between 2012 and 2017. According to Figure 5, the total statistical elements of annual deployment[2] stagnates above sixty thousand since 2015, with the majority of these interventions regarded as technical rescue.[3] The year 2017 shows significantly higher values compared to previous years, where the number of technical rescues are dominating. The reasons for this are the events that occurred in 2017,[4] for example the unusual winter weather on January 13, the cyclone activity on April 19, the flood-like rain as the consequence of the storm cloud system in the athmosphere above Hungary on 23 May, the storm on June 23, the storm striking Lake Balaton on July 10, the intense storm cloud system in Transdanubia at the end of July, the intense thunderstorms on August 10, and the storm on October 29. All together, these increased the number of technical rescue interventions by 13,278. We can see that the year 2012 shows extremely high values regarding annual fires. The reasons for this can (also) be connected to the drier periods during the year and the changes in the periods of structure

[2] The elements making up the deployment statistics: Total number of elements, fire, technical rescue, false alarms, deliberately misleading alarms, deployment not necessary.

[3] Without the need for completeness, like saving lives, animal accidents, elemental disasters-storm damages, fallen trees, water damage, traffic accidents, CO poisoning, rescue from ice, etc.

[4] Without the need for completeness.

and viewpoint of the fire prevention area. In the other years, this aspect is significantly lower, the unusual *additional value* cannot be measured despite the significant number of dry periods. This leads to the conclusion that since 2012, the fire prevention activity of the fire protection area is more effective and the complex measurements and responsibility competences are stricter regarding the protection of the population and material goods.

Table 2.

Annual number of storm triggered incidents, fallen trees, water-triggered incidents that required intervention between 2011 and 31.05.2018.

Number of technical rescue deployments – on national level (based on closed TMMJ datasheets)					
	Incidents requiring response total	**Natural disasters, storm-triggered incidents**	**Fallen trees (incidents)**	**Water-triggered incidents**	**Total (incidents)**
2011	27,344	2,188	5,910	3,033	11,131
2012	20,200	2,116	4,440	883	7,436
2013	23,985	2,146	4,241	2,086	8,470
2014	25,582	3,155	6,441	2,276	11,872
2015	24,846	3,674	5,292	951	9,917
2016	25,015	3,706	5,297	1,538	10,541
2017	33,868	6,642	8,626	1,380	16,648
31.05.2018.	16,322	482	1,223	578	2,283

Source: Made by the author based on data of the Disaster Recovery Data Provider System of NDGDM (KAP-online).

Table 2 shows the total number of technical rescue events that required intervention; from 2011, we can see an increase in case of elemental disasters, storm-triggered incidents and fallen trees. An increase can be noticed in case of natural calamities, storms and treefalls. It can be seen that natural calamities and storms rise compared to the data of 2011, an increase is showed illustrated in linear trend. According to statistics, a higher number of intervention cases has to be calculated which predicts the fact that at a time of extreme intervention, the professional forces become more loaded. Based on KAP-online data, it is expedient to call up volunteers[5] who are qualified in disaster management in order to apply them for managing this type of events. (Teknős 2017b)

[5] Volunteer firefighting associations, rescue organizations, rescue groups.

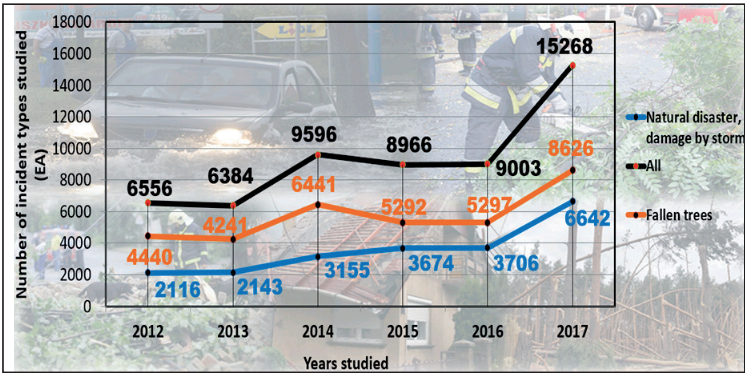

Figure 6.

The occurrence of natural disasters, storm-triggered and fallen trees incidents within the technical rescue category between 2011 and 2017

Source: Made by the author, based on KAP-online data.

Figure 6 is complementary to Table 2. An increase can be noticed regarding natural disasters, storms and fallen trees, which is even more intense from 2013. The content of Figure 6 may as well support the catching up of Hungary to the increasing tendency of meteorological events measured around the world.

6. Summary, Conclusion

6.1. The clarity of climate change

Different analysis and research examinations have stated that the climate of the Earth is changing consistently, which is an obvious, real fact. They also proved that recently there has been a period of warming, therefore *the increase of temperature is part of a natural process.* According to measurement results, warming has been growing fast since the 1970s, and there has been a drastic rise of the amount of so-called greenhouse gases that are emitted into the atmosphere.

6.2. The importance and necessity of self-rescue, partner rescue and the increase of active participation

In addition to the unified state direction of the defence against the consequences of climate change, it is important to reiterate that the active engagement of the public is indispensable. In personal protection, as part of population protection, there is a growing significance and role for self-rescue. The goal is to have more citizens in society who are trained in self-rescue, trained in their security, and are able to cope with these by themselves on a level and method that can be expected from them. Not only can we improve efficiency of part elements of personal protection but also the effectiveness of the partner rescue area. In conclusion, self- and partner rescue skills together provide the self-sustaining operation of the 21st century's modern population protection, forming a community that cooperates with and participates in disaster recovery in a more active, efficient way, representing so-called overall societal values, and fulfilling the expected laws and obligations described in the applicable disaster recovery law.

6.3. The presence of climate change effects in disaster management

This publication introduced the temporal and task cycle of disaster management emphasising the prevention–preparation–protection periods. Taking the national weather hazards into account, it can be stated that self-protection skills and improvement of the recent system of settlements must primarily be put into effect in a normal period of peace, regarding periods of national defence for prevention purposes as a prevention–preparation task. Skills and capacities are used in action during an occurring event, protracted incident, damage, disaster danger, emergency, at the time of response. By then, skills should be used and not established. The effectiveness of the prevention cycle besides the existence of the prerequisites for preparations affects the effectiveness of defensive restoration cycles because the bases of its framework are connected to prevention.

6.4. Unified system of criteria

Data has been analysed and introduced in the publication that clearly backs up the national weather-induced threat, the statements of the national effects of climate change, the meteorological aspects of the increasing disaster recovery operations, and the worldwide increasing amount of environmental hazards and events. The analysis of the researched title was made more difficult by the lack of unified collection of disaster recovery-wise relevant meteorological data. Summarising tables could be made from several disaster recovery operations, but unfortunately, distortion of results regarding data cannot be ruled out. Data can be collected with the help of the unified online Disaster Data Providing System (KAP) of the NDGDM, the HELIOS public security data storage system, disaster recovery yearbooks, based on Daily Reports of the Central Main Duty, then after organising in tables introduce it through figures. Four different data providing possibility with different data collection angles, criteria, and categorization principles clearly make complementing, confirming, and proving by numerical data of theoretical thesis, motifs, and content more difficult.

6.5. Updating meteorological data collection regarding disaster recovery

- There must be more precise, broader data collection (on damage data sheets) and data registration in the HELIOS system, their evident update and actualisation on the basis by which we must establish a meteorological database that adjusts to the needs of disaster recovery.

- The data storage must contain population defence-supply elements such as air-conditioned premises, vapour gates and water provider installations, receptacles, places to get warm, lists of healthcare and social institutions, social, charity bodies that can be involved with contact. They must be shown on maps. A demo version would be necessary to be provided to educational purposes, for example, to the Disaster Management Institute of the National University of Public Service.

6.6. Examination of threats regarding climate change

When categorising settlements, the author suggests to extend the hazardous effects of extreme weather in Government Decree 234/2011. (XI. 10.) with high temperature (extreme heat) and/or heatwaves (unusual warm period, long lasting, unusually warm weather) and forest- or leaf litter fires, because it is justifiable and necessary for the pace of national warming, urban heat islands, the current health level of the Hungarian population, firefighter intervention and establishing self-rescue skills.

6.7. Response and reaction proportional to the effects from climate change and extreme weather

Based on the data and statistics shown in the article, the author's opinion is that the tool- and equipment stocks of disaster recovery and fire brigades have to be expanded. On the one hand this means the necessity for increasing acquisition and setup of forest fire extinguishing agents as a result of the expectedly rising number of forest fires because of the national warming trend. On the other hand, the acquisition of sandbag filler tools for the disaster recovery directorate as a result of the rising number of hydrological events (for example more frequent and devastating floods). The acquisition and optimal allocation of new equipment necessary for damage liquidation, like monitoring devices, the extension of mobile pump capacity, the extension of capacity appropriate for larger scale forest- and area fire extinguishing, more special protective gear, new instruments, dog day-specific first aid kits etc., support the response skills against the negative effects of climate change.

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Hajnalka Hegedűs

Effects and Forecasts of Global Climate Change, Adaptation Strategies in Switzerland

1. The Geopolitical Situation of Switzerland

The Swiss Confederation is a federal republic composed of cantons in Central Europe. It is a landlocked country and more than 60% of its area is occupied by the Alps mountains with peaks rising over 4,000 m a.s.l. Europe's longest glaciers can be found here, as well (e.g. the Aletsch glacier with a length of 24 km). Regarding its hydrology, the spring of numerous great European rivers are located in the country including the Rhine, the Inn and the Aare. Almost 1,500 lakes can also be found in Switzerland. The average annual temperature in the country is 9–10°C. The climate is moderate in the country, however, temperatures fluctuate greatly due to its geographical location. The weather is rather grim in the high mountains while certain southern slopes show Mediterranean climate. The amount of annual precipitation also depends on location. In the Alps and in the northwest part, precipitation is abundant, the average temperature stays below freezing in winter and the frost line is at an altitude of 1,800 m a.s.l. In contrast, a warm, wet climate is dominant in Ticino canton where temperatures hardly fall below freezing. Around one third of Switzerland is covered by forests while meadows and pastoral lands can be found above the treeline. Mountains are covered by permanent snow above an altitude of 3,000 m a.s.l. (Geofakten s. a.)

The state is neutral regarding both political and military affairs thus numerous international organizations hold their seat in Switzerland. Although the country is not a member of the European Union, close co-operation was developed between the Union and Switzerland in most fields of life due to its location, economic and political structure.

2. Switzerland and Environmental Protection

As early as 1876 the first act aimed to protect the environment and natural resources was accepted in Switzerland. The woodland protection act was accepted in 1876 for the area of the Alps, the essence of which was to prohibit clearings in order to prevent landslides and other natural hazards occurring mostly in the mountainous regions. (Seit 2013) Furthermore, the act was not only a pioneer deed but also sustainability appeared in it. Since changes as a result of the act were so much positive, the act was extended over the entire Switzerland in 1898. Following World War II, environmental protection has been part of the constitution of Switzerland. The attitude of the population in Switzerland is also decisive. Everyone feels a personal responsibility for protecting the environment and keeping the surroundings clean and tidy.

Modern environmental protection nowadays is carried out by the Federal Office for the Environment (FOEN/Bundesamt für Umwelt – BAFU). This office is also responsible for the sustainable and environmentally friendly utilisation of natural values, be it water, soil, air or forest. The focus is on resource management policy with the following goals:

- green economy and sustainable exploitation of resources
- regulation and reduction of the effects of climate change
- preservation of biodiversity and
- strengthening the execution of the above

2.1. The relationship between industrial security and environmental protection reflecting the fire at Schweizerhalle

The fire in the chemical factory of Sandoz corporate company at Basel during the night on the 1st of November 1986 has been the greatest industrial catastrophe in Switzerland. In the course of extinguishing the fire, 1,350 tons of very toxic chemicals – mostly agrochemical material, excipients, intermediate products and mercury compounds – were devoured by flames. Due to the formed smoke cloud a curfew was in effect that was withdrawn by next morning. (Giftwolke 2016) However, as a result of chemical material dissolved and washed by water used in the extinguishing process, unpredictable damage occurred in both the soil around Basel and in the River Rhine. Apart from the already mentioned chemicals, almost 3,000 tons of half burnt chemical material was removed from the scene and according to estimations, around 9 tons of pesticides and 150 weight of mercury compounds could have entered the soil out of the above material. (Die Sandoz-Katastrophe 2016) The region experienced enormous fish havoc as mullet and eel populations completely disappeared. Also zander and pike stocks were damaged and the toxic material was detected in rivers all over Germany causing significant environmental damage, fish and bird havoc in many places. (Schweizerhalle-Brand 2016)

Although, according to scientists, groundwater was not affected, waterworks along the Rhine were closed for 3 weeks after the fire thus 20 million people were affected by the catastrophe. The other consequence of the accident was that apart from Sandoz company, authorities also recognised that they need to improve the risk-information basis of chemical factories. As a result, one of the first sustainability control systems was developed called *doCOUNT 2.0 Sustainability Performance Management Suite* (Informationsseite der Nachhaltigkeit s. a.).

Also the states along the River Rhine accepted the so called Rhine action programme in co-operation with the Rhine International Committee (IKSR).[1] This action programme

[1] IKSR – The *Internationale Kommission zum Schutze des Rheins* is an organization with its seat in Koblenz founded by the European Union in co-operation with states along the Rhine – Switzerland, Lichtenstein, Germany, Austria, the Netherlands and Luxembourg with, among others, the following aims: sustainable development of the Rhine ecosystem, utilisation of Rhine water like drinking water, solution of flood protection, easing the burden on the North Sea, etc. (IKSR s. a.)

is a tool for warning the population near the Rhine – *Rheinalarm.* Consequences of the fire were also observed in politics as higher ranked leaders recognised that special policy needs to control chemical industrial risks in a more conscious way and the operation of dangerous factories has to be regulated more seriously. (Hegedűs 2018)

2.2. Other aspects of environmental protection

Considering environmental protection, greatest problems are caused by – apart from global warming – air pollution in Switzerland. Carbon dioxide – emitted mostly by vehicles – load reached 39 million tons by the turn of the millennium. Water pollution also presents a problem primarily due to artificial fertilizers entering water bases. More than 70% of the available amount of water is utilised by the industry in Switzerland. These are completed by the around 3 million m^3 of solid waste produced annually by the population. The list of problems also includes that according to the report of the Swiss Forest Management Office completed at the beginning of the 1990s 36% of forests perished or severely deteriorated as a result of the negative processes of the 20th century, due to air pollution or acid rain. (Gale 2007)

Based on the report of the FOEN and the Swiss Federal Statistical Office (FSO/Bundesamt für Statistik – BFS) published in 2011 (its original title: *Umwelt Schweiz 2011*), they were successful in fighting against environmental load in many fields. It is clear that contamination caused by heavy metals, dioxin compounds, (PCB) and other persistent organic pollutants (POP) was significantly reduced or the reorganisation and rehabilitation of formerly contaminated lands are going on as planned. The report also mentions that the 8% reduction of greenhouse gases accepted in the Kyoto agreement to be achieved by 2012 was not realised. Measures for the protection of biodiversity were not realised completely either, neither in case of plants nor animals. (Umwelt Schweiz 2011)

An interesting element of the report studies the volume of environmental damage outside the country caused by inside consumption. Around 70% of material needs in Switzerland (not only consumption goods and other end products but energy resources as well) are imported and this value is increasing. This also means that environmental contamination associated with production occurs mostly abroad. (Umwelt Schweiz 2011) Related CO_2 emission is discussed later in Section 7.

As a country in the Alps, Switzerland is vastly experienced in precautionary measures against natural hazards. In order to avoid potential damage, it is important to consider the potential dangers when the prevention processed of natural hazards are designed. Such integrated risk management contributes to the establishment of the required precautionary measures and thus the sensibility of both the inhabitants and the affected branches of economy can be increased. Branches where warming due to climate change can be felt, like agriculture, energy production and health care, adaptation measures have to be considered at the design phase.

3. Experienced and Expected Effects of Global Warming

Switzerland also composed its own report and strategy reflecting the changes caused by climate change and the adaptation tasks. The report and strategy were published in March 2007 by the Climate Change Advisory Panel (OcCC – Beratendes Organ für Fragen der Klimaänderungen) composed on commission by the Home Office (EDI) and the Ministry of Environmental Protection, Traffic, Energy and Communication (DETEC). The statements include that although Switzerland reacts very sensitively to the effects of climate change, the rate of warming of the Alpine region is around double than the global average or elsewhere in the country or in Europe. (Later the same conclusion was drawn and further deterioration of the situation was declared by climate researchers in the report entitled *Focus: Climate in Switzerland; Principles, Consequences and Perspectives* that was published by the Forum für Klima und globale Umweltveränderungen under the supervision of ProClim – the Swiss Akademie der Naturwissenschaften [SCNAT] in autumn 2016). The report gives particular solution recommendations illustrated by examples for the population to adapt to climate change. The report also gives recommendations to how and where CO_2 emission could be reduced in Switzerland and also discusses the possibilities of national and global climate policy.

Studying the effects of global warming, the above-mentioned Alpine region is the most affected. Based on the data of the past 100 years, warming in the Alpine region has been 0.6°C more intense than the global value. (Permafrost–Dauerfrost s. a.)

Besides the results of warming, dense built-up conditions due to geographic conditions also present a problem. Several inhabited areas (together with the associated infrastructure) are located very close to glaciers and rivers and also to lakes formed by meltwater from glaciers (see Section 6). Numerous infrastructure elements like ski lifts or avalanche protection equipment are grounded on permafrost ground and could be destabilised by melt as a result of warming. In lower regions the lack of water is pressing. The water demand of irrigation in prolonged dry periods can be solved from various surface waters but water utilisation interest oppositions may cause conflicts.

Inhabited areas are risk factors not only in Alpine regions since load on the built environment like heat islands forming in summer heats also cause problems, just like in other parts of the world. Moreover, most Swiss cities were built beside rivers or lakes and the growing number and prolonged character of floods cause a growing number of problems.

For appropriate risk evaluation not only potential dangers have to be surveyed but considering any related processes as in domino effect is also important. Prolonged heat waves and dry periods wear out people, the flora and the fauna. The disappearance of the Scotch fir, so typical for Swiss woodlands and the basis of forest management can be expected. On the one hand, the trees themselves suffer from dry weather and on the other hand, damage to the trees increases due to the proliferation of pests like bark beetles caused by warmer weather conditions. Warmer weather is also preferred by apple ermel (and other similar pests attacking domesticated plants), they may reach 2–3 reproduction cycles in a year instead of 1–2 that are typical nowadays. With shifting seasons, the co-operation of the flora and fauna may also collapse, e.g. certain insects could be late for blooming and also for pollination. Animals preferring cooler regions will move higher and higher in the mountains facing smaller areas and maybe competence with other species. (Brennpunkt 2017)

There are positive consequences of global warming here, as well, even if in smaller numbers. Due to gradually warmer winters, heating costs become less. However, in summer heat waves cooling requires much more energy, at least renewable energy resources are available for this purpose. Certain domesticated crops (like corn or grape) preferring warmer weather produce higher yields with appropriate precipitation amounts.

4. Weather Anomalies

Weather features in Switzerland follow global tendencies. In the second half of the 19th century an average temperature increase of 1.8°C was experienced. The number of tropical like nights in the Alpine regions (see above) was multiplied by ten while the number of freezing days decreased to half.

For permafrost regions some improvements were brought by the winter of the last two years (2016 and 2017) where significant snow cover developed because this could halt or even reverse surface processes. Significant temperature drop was experienced on surfaces lacking snow cover in January 2017 (the trend continued in the Eastern Alps, as well). Although snow did not cover the area, near surface layers, loose layers and gravel and cliff glaciers could cool down due to prolonged minus temperatures and the negative records of the last quarter century could be broken at permafrost areas in depths of 10 m or in certain cases even 20 m. (Kurze Pause 2018)

In other areas lacking precipitation and also at places where snow is typically small in amount, for example at steep cliffs, the warming trend is continuous.

5. Glaciers

5.1. The problem of permafrost

As a result of warming, glaciers melt and retreat while permafrost also melts. The term permafrost is related to permanent frost and is used in connection with ground that has been frozen for at least two years containing a significant amount of animal and plant remains. It is natural that in the warmer (summer) periods permafrost contains so much heat that its top layer melts. Without global warming, the ground under this top layer would remain frozen preserving the organic material like coal and methane. The arctic permafrost region alone contains 1,700 billion tons of carbon dioxide according to estimates, double the amount contained in the atmosphere. (Shahgedanova 2002) When permafrost melts, huge amount of carbon dioxide and methane or other greenhouse gases are released into the already loaded atmosphere. Scientists currently argue over the speed of permafrost melt and also over the expected amount of potentially released greenhouse gases. Everyone agrees, however, that the process has to be stopped. (Der Permafrost taut 2011) Scientists at Colorado University predict the melt of two third of permafrost ground present at the turn of the millennium by 2200, releasing around 130 and 150 billion tons of carbon dioxide into the atmosphere which equals one fifth of the amount currently present in the atmosphere. (Schaefer 2011)

Permafrost is found in 6% of the Swiss Alps. Permafrost ground may reach as deep as 100 metres. It occurs at an average altitude of 2,400 m a.s.l. in Switzerland. Glaciers are one of the typical features of permafrost. Glaciers form where snow fell in the cold and wet period does not melt completely in the warm and dry period. Thus snow accumulates and due to its own weight it moves from higher areas towards lower ones where it melts again (ablation). Accumulation and ablation areas are separated by a line of equilibrium where the difference between the accumulation and melt of ice is zero. This line is called *Equilibrium Line Altitude* (ELA). In mountain areas glaciers slide along valleys therefore they have an elongated shape. These are typical in Switzerland, as well.

Glaciers in the Alps, for example, lost around half of their volume in the period between the end of the Little Ice Age (1850) and 1975. Another 10% (that is 20–25% of the remaining volume) was lost between 1975 and 2000 while further 2% of the remaining volume was lost each year in the first decade of the 21st century (2000–2009). (HAEBERLI et al. 2013) In case of glaciers, equilibrium with the local climate is reached when the total accumulation of frozen material equals total ablation. If climate did not change in the coming few decades, glaciers still would lose 32% of their area and 38% of their weight causing 163 ± 69 mm sea-level rise (the total weight would cause 430 mm of sea-level rise). Figure 1 shows the retreat of glaciers experienced in the last 100 years. This would result in the saturation of the earth surface and the advancement of marshlands in the area apart from the rise of the water level of surrounding lakes and rivers in the Swiss Alps. Furthermore, the risk of landslides would also multiply in the mountain regions. (MERNILD et al. 2013)

Figure 1.
100 years of glacier change

Source: www.gletscherarchiv.de/fotovergleiche/gletscher_liste_schweiz/

Parallel with the continuous warming of the surface of the earth permafrost also thaws. According to the data of the Swiss Permafrost Monitoring Network (Schweizer Permafrost-messnetzes – PERMOS), the year 2016 brought partial changes in the case as somewhat cooler weather stabilised following the extreme heat of the first half of the 2010s. The relatively late snow in early 2016 had positive effects in the surroundings of Engadin and on the southern slopes of the Alps followed by a cool and wet spring that could protect somewhat the surface of the ground, however, the melting of permafrost was not halted completely. Average temperatures, however, finally showed a decreasing tendency and remained 1°C below the average temperature of 2015 but still stayed above the average of the last 15 years. Warming was not halted, however, in other parts of the Alps and reached peaks in the last 15–25 years regarding the values measured at depths of 10–20 metres. Around Stockhorn Zermatt for example the –2.6°C measured at an altitude of 3,400 m on the 11th of October 2011 increased to –2.0°C by October 2016. (Permafrost wird wärmer 2017)

Permafrost is also important in holding together different materials like putty. This is of primary importance in case of block glaciers that are ice formations embedded in debris or moraine like the peak of the Matterhorn shown in Figure 2.

Figure 2.

The Matterhorn consists partly of ice

Source: https://wetterfroscher.ch/typo3temp/pics/1a3ed64908.jpg

In the framework of the PERMASENSE project sensors were placed on block glacier mountains like the Matterhorn or Jungfrau in order to observe rockfalls triggered by permafrost melt. As a result of warming in the climate, the fracturing and movement of block glaciers intensified, as well. Although this is also a natural process, these block glaciers moved much more metres in the last twenty years than before and the number of rockfalls also increased. Due to measurements it is proved that the frequency and latitude of rockfalls multiplied since 2003 especially in years when warm temperatures were followed by wet periods. (Permasense s. a.) Regarding these, the year 2016 was advantageous since the very dry end of the year and the late snow fall provided conditions appropriate for cooling the ground.

5.2. Solution: snowmaking (?/!)

A relatively simple but effective tool is used for fighting against the effects of global warming regarding glaciers. Using snow guns was tested in the region of Oberengadin on Morterartsch glacier in the summer of 2016. As scientists suggested, a thin snow cover was sprinkled over the glacier in order to halt it melt. Morterartsch glacier is important from not only the point of view of tourism as it has an essential role in the water budget of the entire region. Felix Keller glaciologist planned to use the albedo effect of the snow cover to stop the warming of the surface. (Schneekanonen 2016) Albedo is the volume of reflected radiation arriving from outside the atmosphere. Lighter colours have better reflection potentials than darker ones (see Figure 3). Darker surfaces reflect much less solar radiation, they rather absorb such radiation and become warmer heating their environment, as well. Surfaces covered by ice and snow reflect much more rays than surface covered by other material. Therefore, melting arctic ice sheets and glaciers not only raise water levels but trigger a positive process in temperature rise due to the albedo effect. A continuous snow layer not only insulates the surface but it can hinder or at least slow down the melt of permafrost ground due to its heat reflection capacity, as well.

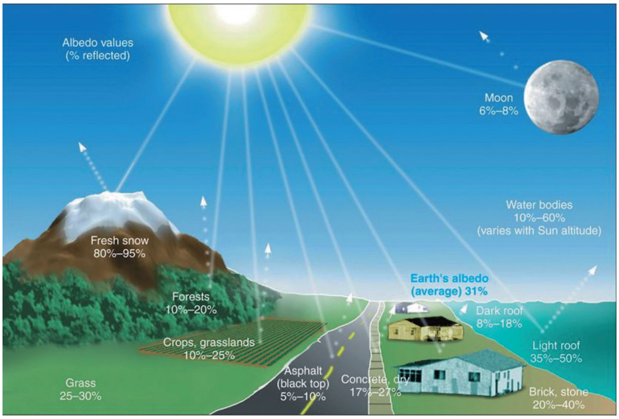

Figure 3.

The Albedo effect with regard to some surface covers

Source: www.improvevia.com/view/n/80

According to Keller's opinion a new snow cover as thin as 20 cm can stop melting. Since meltwater is abundant in the surroundings of the given glacier (even a smaller lake has been formed) it would be beneficial to recycle this water. Furthermore, no high quality snow is required for the appropriate effect like when ski tracks are covered with snow; therefore, the equipment of sprinklers need not be of high quality and costs. (Schneekanonen 2016)

Artificial glacier growing is supported by renowned glaciologists like Professor Eduard Heindl at Furtwangen College who was successful in growing a smaller glacier near Zermatt in 2010, (Gletscherprojekt 2010) or Professor Martin Funk at ETH Zürich even though his and his colleagues' research is based on a snow layer of almost double thickness that would be spread over an area of several square kilometres. They agree that the required amount of water is available, however, the place of this water could present a problem. Glacier lakes are located at their base while artificial snow fall should be started in the vicinity of the equilibrium line in order to stop melting and warming for which serious technical solutions are necessary. They also agree, however, that snow fall over areas at lower altitude could also be useful for smaller superficial treatments and solutions. (Gletscher schmelzen schneller 2017)

6. Damage Caused by Meltwater and Their Risks

6.1. Glacier lakes

In case global warming is not stopped and reversed, 90% of the ice currently present in Switzerland is expected to melt by the end of the 21st century. Hundreds of lakes will form out of the meltwater some of which will disappear shortly but some will remain causing both advantages and potential risks as well. (Stocker 2015) If warming continues at today's rate, then glaciers will totally disappear below 3,000 m a.s.l. changing fundamentally the water budget of the Alps. In the place of the present glaciers high volume of rock debris, sparse vegetation and lakes with fluctuating water level will be typical. Some of these lakes will be filled with debris arriving with meltwater or their water will flow away in the loose ground. Some lakes could also form, however, that could be utilised not only for tourism but may play a role in balancing the water budget of the region or could also be utilised for energy production, as well. Considering this, primarily the Aletsch region is in the focus of climatologists and other professionals.

When lakelets are formed, dangers have to be considered as well. Without the cementing force of ice, the stability of mountain slopes ceases frequently and falls, and landslides may form. Such rock falls resulted in tsunamis in the neighbouring lakes on numerous occasions in the history of Switzerland. (Nicolussi 2011) In case of the Lower Grindelwald Glacier in Bern canton, intervention became necessary in 2009 and measures had to be taken in order to prevent such events (establishing measurement stations, setting up underwater observation points, etc.). Although these measures are expensive, prevention is still more cost effective than paying for eliminating the possible damages and clearing away consequences. (Neues Phänomen 2009)

6.2. Rivers

Sudden downpours with high intensity and snow melt caused an increase in the number of floods, as well. Floods transport greater amounts of debris from melting glaciers increasing also soil erosion. High embankments for flood prevention that are of rock structure and/or have sand-and-gravel cover could become instable and useless as erosion transports their material away and they will be undercut.

6.3. Hydropower generating plants

In contrast to precipitation changes and extremities in the Alps and Jura, on the southern side of the Alps and in Mittelland heat waves and drought occur that influence negatively the operation of hydropower generating plants apart from agriculture and tourism. Nowadays hydropower is a basic pillar in electricity supply in Switzerland and it is regarded to be the most important effectively renewing future energy resource. With glaciers retreating, however, changes in the water regime of rivers supplying the reservoir lakes (a tendency with 30–40 years of history) have to be expected. Depending on the variable climate scenarios, this tendency is likely to continue in the next 10–30 years and water inflow will significantly and irreversibly decrease as a result of the gradual disappearance of glaciers as shown in Figure 4.

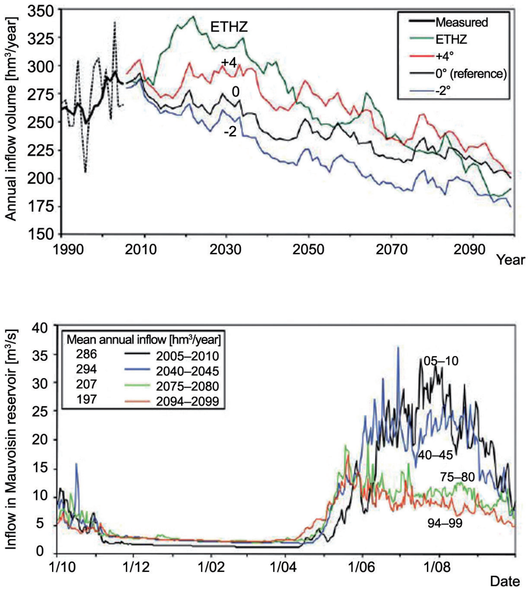

Figure 4.
Five years average annual inflow in Mauvoisin reservoir based on certain climate change scenarios (top) Hydraulic system of five years' average inflow in Mauvoisin according to the scenario of the Zürich Technical College (bottom)

Newly formed lakelets, however, may help to sustain electricity production at today's level as they will be located typically higher than the already existing reservoirs. Furthermore, by building new dams, outflow can be blocked and the amount of water in the natural lakes can be increased. Apart from energy production, the water regime controlling function of the newly formed lakelets would become significant, as well as they could take over the reservoir role of former glaciers after their disappearance. This role is important both in the prolonged periods of drought and in case of flood protection.

6.4. Possibilities of adoption

In the framework of the National Research Programme *Sustainable Water Usage* (Nationales Forschungsprogramm *Nachhaltige Wassernutzung*) abundant research was carried out on the surface of melting glaciers and in their environment to set future prognosis and scenarios to establish protection mechanisms. (Stocker 2015) Regarding both local and regional levels, 50% of ice surfaces and 75% of ice volume in Switzerland were studied and on the basis of obtained data, models were set that include the possible slide movements of glaciers. Ice thickness was measured by in-situ and surface mapping and also by applying helicopter radars.

The SACFLOOD project aims to determine and map the threshold above which a given soil is unable to swallow water (as the higher volume of water is stored or seeped away by the soil, later floods will occur in the area). Since rocky, moraine-debris soils can be found in the vicinity of glaciers their seeping capacity is very high (much higher than expected). They also make difficult, however, the flood prognosis of a given area since the first greater volume of water is driven away relatively easily but rivers supplied by them suddenly swell after the first *moderate* water level increase. If the deep soil is less permeable, floods develop much sooner. The results of the research also revealed that the sloping of the area influences the risk of flood development less than it was previously assumed. (Sacflood s. a.)

Since the established observation network is able to control *outbursts* and rockfalls can be predicted, damage in the newly formed glacial lakes can be prevented or at least reduced by building dams that can take hold of potential floods and drive away spilled water. In this respect the new reservoirs have multiple purposes and could form synergy projects in other areas as well.

The legal background of meltwater lakes has been regulated (although the formation of most of them can be expected only on theoretical bases). As the rock and glacier areas, the newly formed lakes are also *areas unsuitable for cultivation.* They are at the disposal of such cantons and partly local governments where water law establishment permits cannot be given for commercial purposes, they can only be given for other personal utilisation for up to 80 years. (Stocker 2015)

In case of rivers, there are several possibilities for preventive protection. Receiving lakes have a major role even today in retaining water and they still have some more potential. Newly forming lakelets in lower regions could be used for water storage. In the lower and middle section of the rivers damage prevention is the primary target for which several ways are available. For example, widening the river bed or its re-naturalisation reduce potential damage. In case natural or close-to-natural conditions were restored the nearshore, so called *ecological balancing* areas would be flooded. According to the calculations, this would mean the exclusion of 22,000 hectares of riverside areas from cultivation. Regarding local conditions, most lakes and rivers could be re-cultivated and utilised in this way except for Bodensee and Wallensee, of course bearing in mind the protection of fishery and the embankment and limiting nearshore settlement development, growth becoming increasingly typical in Switzerland, as well. (Stocker 2015) Although scenarios applied for each future prognosis are based on careful measurements two things are not considered. First, the self-generating processes due to albedo reduction that can be traced back to snow depleted winters in the past periods. Second, the subglacial ablation. (Haeberli et al. 2012) In case of block glaciers, the movement of debris following the melting of ice will be a factor of uncertainty. Also predicting precipitation and snowing within it is very difficult in which case data collection is not necessarily adequate for eliminating uncertainty factors.

Considering future tasks, it has to be considered what will happen if warming cannot be stopped. Scenarios so far studied the effects of climate change and collected data until the height of around 2,000–2,500 metres in the Alpine region. With extensive warming, however, it could result in similar consequences in the high-altitude regions, as well from the second half of the century. Independent of the efforts made by the world to stop global warming, precautionary measures have to be made today. Design has to be started as early as possible since local planning, organising and building measures take time.

7. Reduction of CO_2 Emission

In order to reduce CO_2 emission numerous recommendations have been identified to achieve the target values. Earlier Switzerland targeted to reduce greenhouse gas emission by 8% by 2012 compared to the values of 1990 in accordance with the Kyoto Protocol. Later when IPCC accepted the anthropogenic causes of climate change and as a result of the 21st Climate Change Conference at Paris international policy accepted the agreement legally binding for every state targeting to keep the global temperature rise under 2°C and thus constrain the effects of climate change, Switzerland also joined the international agreement. On the basis of the targets set by the UN on the 27th of February 2017, Switzerland also targeted the domestic reduction of greenhouse gases by 30% by 2030 and the foreign reduction of greenhouse gases (released during the production and transport of products, raw material and energy resources imported into Switzerland) by 20% compared to the 1990 level ratified also by the Swiss Parliament. It was also agreed that they target the net zero emission for the period after 2030 as a step presenting a real challenge in order to act in accordance with international tendencies. This process has to be designed very early and has to be integrated strategically into the national climate policy to sustain the chance of successful realisation. Figure 5 shows the distribution of CO_2 load among the economic sectors in Switzerland.

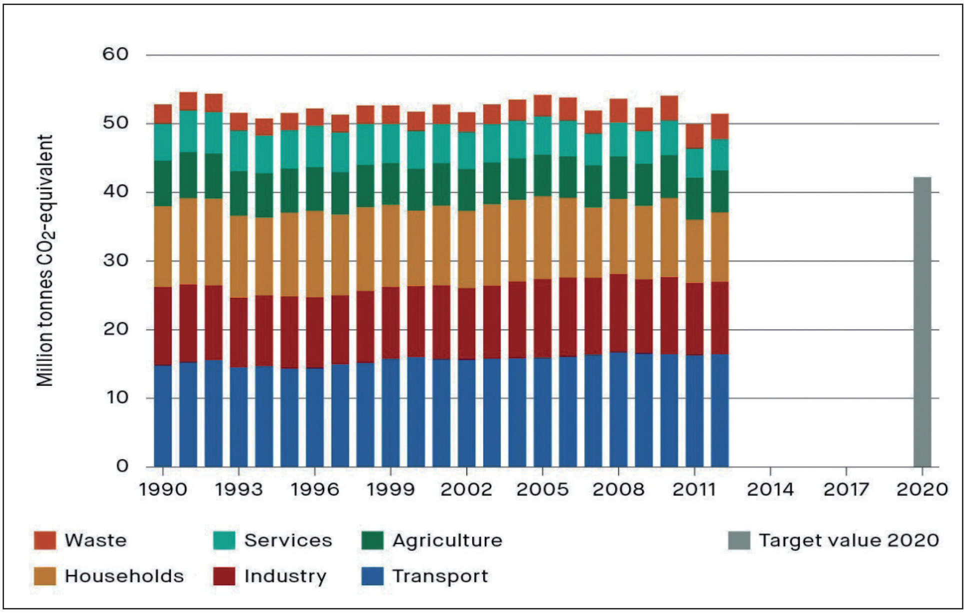

Figure 5.
Greenhouse gas emission by sector in Switzerland

Source: www.eea.europa.eu/soer-2015/countries/switzerland

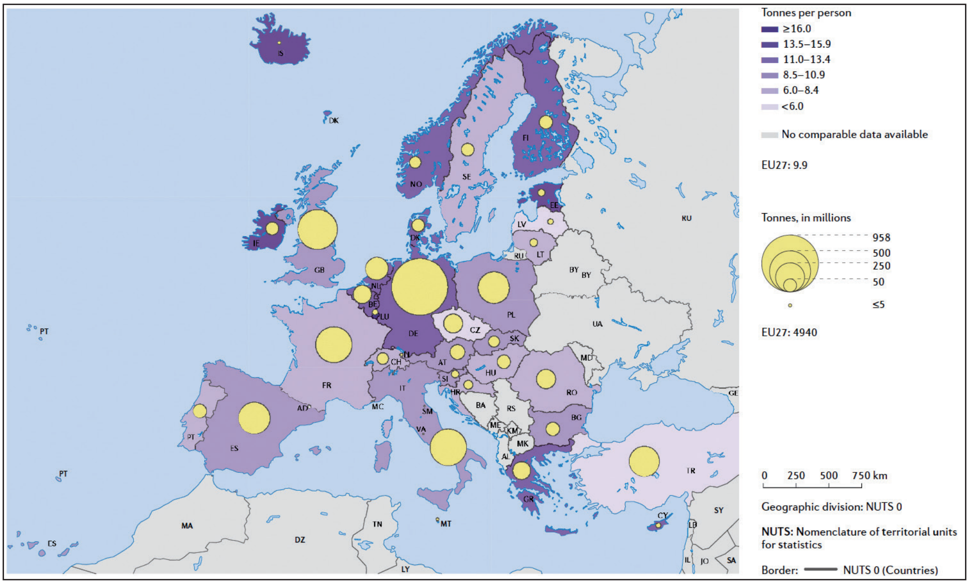

Figure 6.
Greenhouse gas emissions in CO_2 equivalents, 2008

Source: Umwelt Schweiz 2011, 82.

As Figure 6 shows greenhouse gas emission in Switzerland is way below the Western European average due to the less CO_2 intense energy supply forms and to the relatively low level of industrialisation. The so called *grey* emission, i.e. emission occurring outside the country but counted for Switzerland, however, is relatively high. (Umwelt Schweiz 2011)

As stated in the FOEN–FSO report cited earlier, Switzerland did not manage to achieve the emission reduction targets. So that emission values until 2008 and the sold volume of fossil energy resources even increased and not decreased as illustrated by Figure 7.

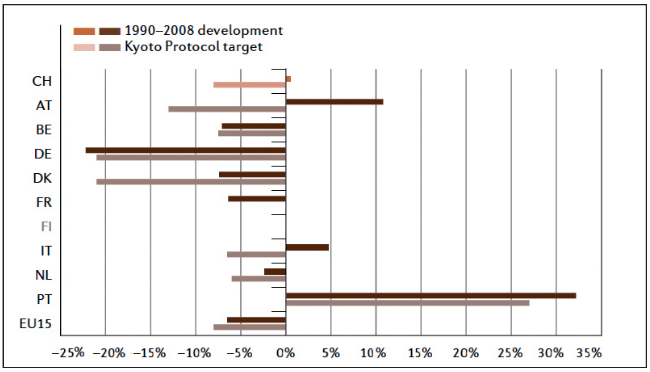

Figure 7.
Development of greenhouse gas emissions between the Kyoto Protocol base year and 2008

Source: Umwelt Schweiz 2011, 82.

The reasons for the above are diverse. For example, petrol prices in Switzerland were very low in the early 2000s compared to the neighbouring countries. Petrol tourism was thriving in settlements along the border. This came to an abrupt end because Switzerland even before the Paris agreement set a CO_2 tax on fossil energy resources – including fuel – integrated in the prices so that the prices were raised. This was aimed to encourage the industry and households to rely increasingly on renewable energy resources. (CO_2-Abgabe 2008) The Swiss Federal Council decided to change the general energy policy, as well. The emphasis was on increasing energy efficiency and on increasing the use of renewable energy resources. In the field of road traffic, the efficiency of fuel had to be proved. The CO_2 tax is an ecological market economy regulation tool, a special tax with which the government tries to achieve a reduction in the use of fossil energy resources by using the price sensitivity of consumers. The primary goal of this tax type is not to increase state income but to include the costs of climate and environmental protection in the price of energy resources. In order to prevent excess costs weaken the spending power of the economy, income from the CO_2 tax is distributed as an eco-bonus among enterprises and individuals who are proved to use less fossil and/or more renewable energy resources. Energy intense enterprises the annual carbon dioxide emission of which is above 100 tons are exempted from paying the tax in case they agree to reduce their CO_2 emission. (CO_2-Gesetz 2011)

Seeing the achieved results, the Consulting Organisation responsible for Climate Change (OcCC) declared in its most recent report that the steps performed so far are not enough to achieve emission reduction, much stronger and more effective measures are required. Primarily because the reductions recommended by certain agreements are based on estimations and their actual effects would be felt only after years or decades. The corporation involved *Ernst Basler and Partners – EBP* in the research in 2016 who have significant international background reports in this field. According to their opinion, personalised CO_2 budget management could be the solution. Currently the main point around which a framework agreement could be formed in order to establish the tools with which personal CO_2 budgets could be integrated is the Swiss common knowledge. (Basler 2017)

7.1. Personal CO_2 budget

In the course of other measure recommendations not only the responsibility and environmental consciousness of the industry and agriculture were increased but that of the individual, as well, considering also emission reduction that can be hardly planned. The personalised CO_2 budget is a new and innovative tool that is in accordance with both global aims and the national climate policy. It is based on the fact that Swiss citizens take part as private individuals in the reduction of CO_2 emission by changing their consumption, mobility and accommodation habits.

What is the method of calculating personal CO_2 budgets? This is based on the emission volume that is enough with 66% probability to achieve the 2°C warming target by 2050 and project this to the Swiss population. By this a number is obtained that equals the allowable emission value per capita (for one or several years). (Calculations consider possible population growth, as well therefore, a certain stock is formed for the growth.) According to plans, a certain *Central CO_2 Bank* will be established for handling CO_2 budgets (and withheld stocks).

Of course certain open questions are raised to which no *objective correct* answers can be given only replies based on social values. These include the following:

- Should difference be made between adults and children in personalised budgets?
- Should poorer households that have to choose solution methods on cost basis rather than environmental consequences have greater CO_2 budgets than richer ones?
- Shall we calculate budgets for foreign visitors and cross-border commuters?
- How will personal CO_2 budgets follow changed emission amounts in time?

7.2. The realisation of the CO_2 budget in practice

All goods and services would have a CO_2 price tag beside its normal price tag (independent of whether it was bought in the country of from abroad). The CO_2 budget would be stored on a kind of electronic payment tool similar to bank cards. In case the CO_2 budget is low and it is not enough for the CO_2 price of the product or service the purchase cannot be made. If the purchase is successful, the person or company selling the product or service has to *report* the CO_2 amount to the state.

Decision-makers hope that this solution will change customers and customer habits and thus production habits as well because if the CO_2 budget is finite then products and services with low CO_2 values will be more popular while products requiring more CO_2will be purchased less frequently. Hopefully producers will try to implement technical developments in order to reduce CO_2 emission. (OcCC 2017)

According to plans, not only products, consumer goods and services would receive CO_2 price tags but any cost would contain this extra charge in the fields of accommodation and mobility where greenhouse gas emission is typical. Furthermore, since emissions per unit are rather difficult to calculate in case of products and services, the practice of CO_2 extra charges would be introduced first in relation to accommodation and mobility. Emissions related to heating, cooling and electricity supply for flats and houses can be calculated relatively easily just as that related to mass and individual transport and freight. In the introductory phase this CO_2 budget would be a complementary solution in association with other emission reduction measures; however, if it was successful it would stand alone due to self-generating mechanisms in emission reduction. Naturally the institutional background of its execution has to be organised as well, the system of punishment measures has to be established, and an institutional framework has to be created for the reliable distribution of the total CO_2 budget for individuals ensuring also the reasonable handling of excess or missing emission rights. (OcCC 2017)

The idea was accepted well by experts; however, its realisation in practice in the country requires a longer process and therefore, it is not listed among short-term solutions. Since emission reduction targets set for 2012 were not achieved, the introduction of the CO_2 budget is becoming more urgent, at least initially, in the form of pilot projects. Until individual CO_2 budgets are introduced, the attention of the population is drawn to the necessity that anyone has to change behaviour and attitude, for example:

- use bicycles or go on foot to work instead of cars as this not only reduces emission but it is healthy as well

- using modern telecommunication possibilities (Internet, video conferences) save unnecessary travel to work or travel elsewhere, work from home
- re-think summer breaks (spend longer time continuously somewhere, domestic tourism – less flight) to reduce emission
- stop wasting food
- use energy effective (A and + energy classes) equipment
- unplug devices when not in use
- treat heat adequately instead of using air conditioning
- compact lifestyle: shop and go out locally
- choose hybrid models and avoid excessively high power engines when buying a car (OcCC 2017)

8. Emission Trade

Simultaneously with other measures, Switzerland introduced the so called *Swiss emission trade* (Emmissionshandelssystem der Schweiz – CH-EHS) in order to achieve climate targets and to reduce greenhouse gas emission. Every plant that has especially high emission (in general factories that have an energy demand of at least 20 MW) is bound to take part in the trade. Companies with moderate energy demand are free to join the system. In return, all participants are exempted from CO_2 tax. Emission rights are distributed by the state for free and a part of the rights are sold in auctions. The number and volume of the rights are limited and are reconsidered annually on the basis of real emission values. Companies achieving smaller emission than that provided by their rights can sell their excess rights. Companies emitting more than the limit of their rights are encouraged to reduce their emission by the costs of purchasing further emission rights. Thus the trade of emission units with state controlled prices helps to save emission at the lowest possible price and to accomplish permitted volume limits in a cost effective way. (Emissionshandel 2014)

Initially, as a test, emission trade introduced for the period between 2008 and 2012 together with CO_2 tax was a free alternative to choose for companies. Since Switzerland was unable to meet the Kyoto obligations this method was restructured in 2013 and was made obligatory for certain companies detailed above. In the second trade period between 2013 and 2020, a part of the Swiss emission (33% of carbon dioxide emission or 10% of the total Swiss emission of greenhouse gases) is planned to be reduced by this system.

At the start of the second, partly compulsory, trade period in 2013 more than 50 production units of 37 companies took part obligatorily in the CH-EHS list mostly from the fields of cement production, oil refinery, chemical and pharmaceutical, paper and steel industry and district heating. In total 5.6 million tons of CO_2 equivalent (global warming potential or greenhouse warming potential, GWP) was calculated for the trade system the amount of which is decreased annually by 1.74%. The price of the right for the emission of one ton was 40 CHF in 2013 increasing to 47 CHF by 2017 which is near the average in the Union. The amount of free distributed emission rights and the initially low prices were heavily criticised (from both the EU and environmental protection professionals) because those together were proved to be much cheaper than any technical change to reduce emission. (Häne–Reichen 2017) Furthermore, companies exempted from CO_2 tax by purchasing emission rights received shares from the distribution of the income from CO_2 tax. As a result, the BAFU executed the recommendations of the Swiss Taxation Authority in early 2017 by removing the companies in question from the distribution of CO_2 tax income. Moreover, also due to pressure from the Taxation Authority, the CH-EHS was restructured so that it was harmonized with the *European Union Emissions Trading System* (EU ETS). Finally, after several years of negotiations Switzerland and the EU agreed to connect their emission trading systems so that emission benefits in one system are acknowledged in the other and emission rights in both systems are mutually purchasable in the two systems and finally the Swiss regulation can fill its role. Furthermore, since the majority of Swiss emissions are not realised in the country certain emission reducing factors remained eligible in Switzerland, as well according to the Clean Development Mechanism (CDM) or by the Joint Implementation regulated by the Kyoto Protocol. In contrast, the Swiss law tries to regulate the framework to hinder companies selling Swiss emission rights abroad.

9. Summary

In general, Switzerland is no exception to the effects of global warming. Due to its topographic location, some effects are stronger while others are weak or have no effects at all. Warming and the melting of permafrost and glaciers impose much higher risk than changes in the average precipitation for example (even though both the distribution and intensity of precipitation change). Changes in the cryosphere and sea levels have a global effect on the country via possible migration processes.

Reflecting changes that cannot be prognosed, that are partly the result of the natural variability of weather and the atmosphere and partly caused by human activities, the Swiss leadership places the emphasis on changing human activities and attitude in order to achieve the set targets. In realising the aims increasing the sensibility of the population and the financial conditions of individuals and families to accept measures have a special role. To know such conditions is also important in order to choose the appropriate tools for achieving emission reduction targets.

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Tamás Berek

Tasks of the Implementation of Physical Security of the Water Supply System in the Light of Climate Change

1. Introduction

At the moment 54% of fresh water is used by the human population, by 2025 this number will be 70%. 18% of the population does not have access to healthy water. (Bulla et al. 2008)

Lack of potable water and the consequent health problems still pose a serious danger in several regions of the world.

Unfortunately, several signs point to an unwanted direction that causes the drastic rise in the water need of mankind. The significant growth of the population in the world is only one of the factors, and consequently, more people need more water. Parallelly, it is a fact that in modern consumer societies the *water footprint* of individuals, in other words, the water use per person is multifold of that in the less developed countries. So, the aim and example for the population of developing countries arising from those of the rich countries mean a way of life where there is much waste. In addition to the growing needs, the limitation of water supplies is expected. It is obvious that the protection of depleting water supplies, getting control over their acquisition and keeping them will be a serious issue in the future. Depending on economic, social and political tensions in a given area conflict situation due to the lack of water will likely escalate. (Földi 2015)

The size of water areas, also due to climate change became half the size in the previous decades; however, the need for water will grow by 50%. The undesirable rate of these two processes will continue growing. Presumably the population will move towards water and this migration will be causing additional burden for the coastal areas. (Bulla et al. 2008)

It will be more and more difficult to access clean water all over the world in the future and it seems that without the establishment of the conditions for sustainable water management and with this amount of wasting water, the security of water provision may become endangered even in those areas where there has been no problem so far.

Because of the geographic position of our country, it is very vulnerable to freshwater supplies. Most of our rivers originate outside the border, so the quantity and quality of water are determined primarily by foreign circumstances, depending on the benevolence of others in a crisis situation. (Padányi 2015)

Water is a natural source used in many ways and its evaluation cannot be approached from one direction only since the use of water as an environmental element is manifold; it is used for energy, tourist and recreational purposes, etc., nevertheless, its use for consumption is still the most important. The security of water supply cannot be discussed without the physical protection of water provision facilities. In addition to the decreasing of clean water sources and the burden on water, the need for clean water has been continuously increasing. This double directional process proves that the planning and application of the security of facilities providing drinking water should be controlled continuously. Impacts due to climate change are of direct consequence to the quality and quantity of ground and underground water, and at the same time the impact on weather influences the operation of the system providing physical security of water supply.

2. The Impacts of Climate Change, Risks and Prognosis for the Future

In Hungary the most precipitation is in May and June, the least is in January and February. The amount of precipitation changes from year to year, in years of most precipitation the amount can be three times more than in dry years. (Indicator 2015))

Because of the uneven distribution of precipitation, water management will become more important in the future, especially taking into account the need for water in agriculture. In the following times the factor influencing the quantity of usable water supply will be the changeability of the pour down. In the long run, drought will pose a serious problem. Due to climate change, it will happen more and more often both internationally and in our country. The impact of droughts and the lack of watering in agriculture are clearly visible.

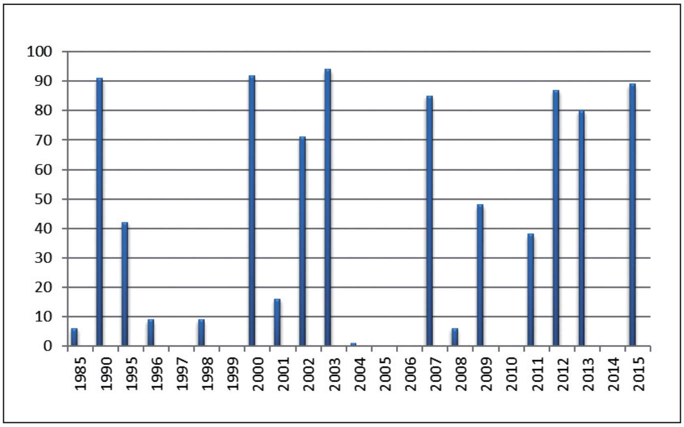

Figure 1.

The rate of territories influenced by droughts

Source: KSH 2014

On the one hand, droughts increase the need for water, on the other hand, since water users are limited in usage, the main impact is in watering, but there is an impact on water supply too. (SOMLYÓDY 2008)

Talking about the situation in the world, factors such as the growth of population, urbanization, conditions of the economy and social aspects are likely to influence the water accessibility more than climate change. In economically developed regions where the number of population and the water use per person is comparatively permanent, climate change will influence problems connected to water supply. Besides the changes in territorial and timely needs in ware supply, both quantitative and qualitative timely changes may influence the satisfaction of the need for water. (Papp et al. 2007)

So the impacts of climate change will manifest in the future in the needs for water and also in the characteristics of their supplies. In spite of the fact that the majority of water is on the ground, the underground amount is also significant. In certain regions of Hungary underground water does not exceed the quantity of the renewable amount. The result is the continuous decrease in the level of ground water and that in wells.

The supply of water in the Alföld is based on underground water the usage of which is already 100%. Because of climate change, by 2050 the usable water in certain parts of the Alföld can diminish by 50% which means it will be barely enough for providing drinking water. (Somlyódy 2011)

The examination of the intensity of water use in the Alföld proved that there is an overpass between the water provision layers and the tests showed a lessening of the underground water which has an impact on the ecosystem. (Szanyi 2004)

To take into consideration the impact of climate change on ground water, as well as the water need for agriculture, it can be said that in the future there will be territories where the sustainability of vegetation will be impossible without watering.

The result of the impact of climate change on underground water can be the lessening quantity of the water leaking in, which can decrease by 70% and can pose a serious threat for the water provision in the Alföld. (Somlyódy 2011)

The territorial accessibility to underwater supplies and the difficulty of the artificial transportation of water result that in agricultural areas with lacking water there may be a possibility to use underground water that is financially understandable, especially if we consider that in different regions of our country this may be the only possibility.

Our waters are burdened more and more, at the same time there is a continuous increase in all areas of usage for good quality potable water. The impact of climate change has a negative influence on both the quality and the quantity of underground and ground water. It indicates a future danger that, an incident in the process of water supply can lead to water pollution; the solution of which with an alternative water source would be more and more difficult. As a result, the role of all security measures connected with the security of potable water supply will be more and more valuable.

Besides creating a comprehensive program for the handling of situations endangering security, it is necessary, for the security of water supply of the population, for the protection of water bases and water management facilities to plan and create a systematic approach.

From the point of view of the establishment of security, it is necessary to determine the types of possible risks. It is necessary to account for the following:

- natural risks that are independent from human activities and which occur as natural disasters
- risks of civilization, technology that are connected to human activities, due to improper human intervention, carelessness or because of technical or planning errors
- danger resulting from deliberate or harmful activities

Water supply facilities are critical infrastructure, the operator must work out an operational security plan that is established by the branch authorities including both content and formal requirements and where he/she has to determine the organization and means that provide the security aspects. (Act CLXVI 2012)

The operational regulations of the water supply system have to include technical, technological, health directives connected with the proper and secure operation of the establishment, including security technology and personnel provisions.

The integrated physical protection of water provision facilities needs to ensure that the protection of production processes, through the means and materials used, would be achieved.

When establishing the physical water production facility protecting system, it is necessary to identify the inner and outer factors that endanger security, to map their characteristics and after their assessment to plan the establishment of defence.

An exceptionally important element of the limitation of security risks should be the physical defence of operational protection facilities.

Activities performed during water production, from removal of the water to filling it into the network, the amount of the used materials, their value and dangerousness can be relatively well identified. During the establishment of water supply facilities, it is necessary to consider some specifications.

3. Risk Analysis and the Establishment of the Defence Concept

A production facility is a well-rounded area. The measure of its endangerment is characterized by the security of operation, the different materials used in production, tools, information search and its conversion, the criminality of the area, the reliability of the applied security system, intervention and the swiftness of the repair. (Lukács 2002)

During the analysis, it is necessary to examine the possibility of risk occurrence, how to avoid the possibility of danger, the measures taken to avoid these risks, and taking into consideration their possible effects, to work out alternative solutions and suggestions. (Utassy 2007)

During the analysis, it is necessary to deal with the following factors:

- environmental features of the facility, its criminal statistics
- architectural, energetic, electronic and informatics subsystems of the facility
- operational systems of the facility, regulations, authority procedures
- basic functions of the facility, temporary, additional functions
- the comprise of the personnel working in and visiting the facility
- insurance contracts, conditions (Utassy 2009)

Prior to working out the defence concept, it is important to check the vulnerability of the water supply system.

The knowledge of environmental features of the protected facility is important for planning defence.

The area's coverage, integrity and terrain characteristics can be well analysed and simulated using CFD, (Csurgai et al. 2005) digital mapping database and digital terrain model. (Csurgai et al. 2006) In the mid-2000s, numerous and successful researches were conducted in this direction.

The vulnerability test should be extended to the full spectra of water supply including the facilities of the settlement of the transportation network and other transportation devices, the water reservoir, pre-treatment, treatment and distribution network, the components of the automated production direction systems. It is necessary to pay special attention to the escape of dangerous materials in the area of water management.

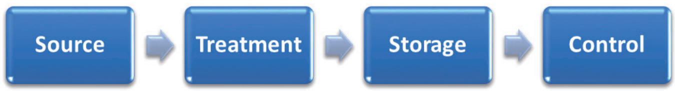

Figure 2.
The main facilities of water supply

Source: Edited by the author.

As the basis of the defence philosophy or the establishment of the security system, the security analysis has to deal with the damage of essential service, as well as with the dangerous materials used in the labs during water treatment that are getting out as a result of criminal intent, carelessness or technological error.

One of the characteristics of water production facilities that need to be taken into consideration for protection is that water removal facilities, together with the water base and the water source, are usually situated outside the production site, quite often being far from it. These facilities are supervised by personnel only periodically, in these areas electronic protection devices are of outmost importance. Taking into consideration their vulnerability, physical protection is very important, which is a big task due to the size of the territory. When establishing the defence concept, this factor has to be considered. It is necessary to define those procedures and equipment which are critical to protect. It is necessary to evaluate incidents that are threatening security taking into consideration the abilities and the applied methods of the perpetrator and it is necessary to assess the abilities and the reaction time of the security services and of public defence.

In case of water production facilities, it is necessary to take into consideration the presence of dangerous materials as a specification of the branch. During water management and water quality tests, it is important to pre-examine the site where dangerous materials are used, for the planning of the property protection system. The complete assessment of the examined parameters has to be conducted. The size and the place of the chlorine facility is of critical importance, it also needs to be pre-assessed and it is necessary to identify those elements of the building that can be easily attacked in case of lack of protection. So, it is necessary to establish the target of the protection, the sources of danger and consequently, to establish the defence concept.

The defence concept describes the functions, relationship and mode of operation of the property protection system. It defines the necessary mechanical, electronic and information technology parameters of defence subsystems, their interconnectedness, the methods of their management and service. (Utassy 2009)

For the protection of public water facilities, there needs to be a defence area which needs to be enclosed and in case of necessity, to be protected. To define who can enter, authorities need to be worked out, so that only those who work there or are authorised to enter should stay in the establishment. (Berek–Rácz 2013)

4. The Components of the Physical Defence

During the establishment of the integrated physical defence, there is a need for a protection system where the conditions of the independent operation of the subsystems are provided by an algorithm that coordinates their communication and at the same time provides the possibility of intervention for the personnel according to the levels of responsibility. (Berek 2011)

The complex property protection is comprised of elements built on each other and their aim is to limit as much as possible the possibility of risks and should they still occur, to diminish their dangerous impact.

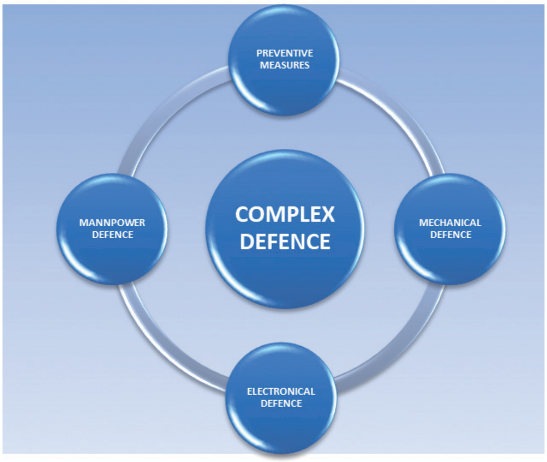

Figure 3.
The components of the complex property protection

Source: Edited by the author.

The above displayed subcategories can be applied either one by one or alltogether at the same time but the high level of security can be reached by their coordinated optimal and proportional application; this is the complex guarding-protection or the complexity of the guarding-protection. (Berek–Vass 2014)

4.1. Mechanical defence

The mechanical protection as one of the significant elements of the complex personal and property protection is the totality of all architectural and mechanical procedures, means and technologies that impedes, obstructs or possibly prevents a criminal act and provides the security of a person or property. (Berek 2014)

The main areas of the mechanical defence:

- protection of the outer area (gates, fences, mounds, ditches, hangers, etc.)
- building protection (walls, floors, benches, roofs, doors, windows, bars, shutters, foils, etc.)
- mechanical object protection (plates and safes, tresors, lockable furniture, chests, etc.)

During the establishment of the mechanical defence of water supply facilities, the application of the above-mentioned elements is strongly influenced by the characteristics of the establishment.

4.1.1. Water acquisition

The facilities of intake structures are usually wells and well groups on water bases. It often happens that some or all the wells established and operated by the water works can be outside the water works and they are connected to the collection pipes of the water works by tubes. It is also frequent that these groups of tap wells are dispersed on large areas and this fact needs to be considered. In case of river bank filtration, the protection of the wells built on the flood area of the rivers can pose a problem. In addition to the upkeep of the operability of the wells, the important accessories providing their operability are: electric switches, diver pumps, water level measuring gauge, quantity measurement gauge, etc. It is also important to protect them due to their high value.

The exterior mechanical devices have to impede or obstruct an unauthorized entrance but it is very difficult to enclose the above-mentioned area of several hectares in size with a fence of 2.5–2.8 metres height that would prevent climbing over. It is also very expensive and difficult to protect. A cheaper barbed wire fence can be used, but in this case it is necessary to supplement it with different types of electronic tools, intrusion detection sensors. Nevertheless, it is necessary to consider the financial aspects of the electronic protection device and its outdoor functions, such as movement, oscillation, change in the pressure, change in the electric lines and other devices that work on movement detection.

4.1.2. Water management

It can be established in connection with the mechanical protection of water management and water storage that the area of protection is smaller but values on these areas are more concentrated and they are more valuable. Damage in the water management devices can have a bigger impact on the water management operation. These two aspects provide not only an opportunity but also require a higher level of mechanical protection. Concrete based and of proper height fence that provides mechanical firmness made of concrete, bricks, stone, metal and is combined with electronic warning system is necessary here. Besides, this area is frequented by persons and goods traffic which need gates and due to the heightened traffic, it is necessary to employ personnel for the regulation of their entrance. The mechanical protection of buildings of different function, workshops and stores also needs to be established by the above-mentioned building protection devices. It is also necessary to protect important production documentation and high value devices which can be easily stolen. At the sizing of the mechanical protection of water management facilities that store dangerous materials it has to be considered to prevent the unauthorized entrance connected to the security of dangerous materials.

Dangerous industrial facilities always pose a risk for the environment, for troops stationed there and for the civilian population due to the nature of their functioning. (Kátai et al. 2015)

The Hungarian Insurance Association makes offers in connection with the material and assembly of the bars. There are three steps associated with protection: full, partial and minimal mechanical protection. Doors and windows that are lower than 3 metres should be protected by metal bars. According to the regulations, they are considered safe if their material is 12 mm diameter of circular steel or different type of steel accordingly. In case of banks, this size is 16 mm. The openings of the bar system cannot be more than 100 x 300 mm. The bars need to be fixed into the walls by wall nails that correspond to the cross section of the bars in the depth of at least 150 mm following each 300 mm. The bars have to be fixed at 4 places at each side. The bars can be fixed to the case of the window so that it cannot be disassembled from outside. Shutters, as well as breakage preventive plastic foils provide certain security for the windows. The basic requirement in connection with the building and structure of the outer doors is that it needs to be as firm as the surrounding walls. The door is secure if its material is 40 mm firm wood and it is supplied with a secure lock and the door casing is fixed to at least three sides of the walls by wall nails. The security of the door is enhanced if it is made of hard wood or metal or if it is supplied with a lock made of metal plate or metal bars or with a lock fixed to several points, for example a band lock. It is a requirement that the pert of the lock needs to enter the case for 20mm. The main entrance points of buildings are usually the doors and the windows that are partially or fully glassed. The security foils can be applied for the protection of these glass surfaces. These are multi-layered, laminated plastic based protection elements that can be applied or stuck on to the surface of the glass. This way they prevent the immediate breakage of the glass in case of intrusion. The protective foils can be combined with metal fibres. When they are connected to the alarm system they generate a warning. (Berek 2014)

4.1.3. Water storage

The main task of the water supply is the operation of a properly established reservoir. The supply of nearby settlements and industrial facilities is based on hydraulic sizing. The continuous supply is provided by different structure reservoirs. When they are established it is important to preserve the quality of water.

The main aim of the mechanical defence of water storage is the physical protection of the stored water from pollution (environmental, animal), careless and intentional pollution that can be prevented by the obstruction of physical intrusion. Biological pollution goes together with serious public health consequences.

4.1.4. Control technology and energy supply facilities

When we establish the control technology and energy supply, the aim is not only the protection of operation security (water supply) and that of the different equipment but in certain cases (e.g. transformation building, electricity dispenser, etc.) the building protection devices of a building serve as aims for life protection security.

The devices of mechanical protection mean the first line of protection; their task, in addition to protection against intrusion, is to detain the intruder until the security services arrive.

The level of protection can be highly increased with exterior mechanical protection, with building protection on the territories of the above-mentioned water production facilities and with the combination of the devices of mechanical object protection having electronic protection sensors and with the application of personnel who operate and supervise the system.

4.2. Electronic defence

Electronic protection is a complex system; it consists of several independently deployable, independently functioning security technology subsystems.

In water production facilities, the application of the following electronic protection subsystems is possible:

- intrusion detection system
- video surveillance and recording system
- patrol following system
- access control system
- electronic fire alarm system
- systems monitoring the presence of dangerous materials

The use of electronic protection on the territories of water production may generally prove to be necessary in all production areas but there are plant areas where during the establishment of their protection, due to their nature, several electronic protection devices are necessary for efficient protection.

At the protection of the endangered areas of water removal there are not many possibilities for human protection, consequently it is necessary to enhance the rate of electronic protection devices. Because of the use of dangerous materials, it is an important requirement, besides the above-mentioned, to install a subsystem monitoring the presence of dangerous materials and the integration of this system into the electronic component of the complex property protection system.

The majority of water bases can be found in scarcely populated areas. These areas are less controlled from the property protection point of view. On the protection territories of the wells chosen for lengthy operation, reserve and observation it is necessary to establish electronic protection systems. We must also not forget about non-operational wells. In case of a possible sabotage, it is easy to cause pollution. (Davidovits–Berek 2011)

Special attention has to be paid to intrusion protection and the control of protected areas.

4.2.1. Intrusion detection system

The aim of the intrusion detection subsystems is to provide information to the personnel about an unauthorized intrusion or its attempt. A properly planned and settled system with the help of detectors mounted directly on the devices of the mechanical protection are – already at the beginning of the infringement of the mechanical protection – able to inform the personnel with sound and light warning or with distance warning through the distance supervision centre. (UTASSY 2009)

4.2.2. Exterior intrusion detection application

Sensing of an intrusion has to be started at the edge of the object and the process of intrusion must be observed. For this purpose, security circles must be established. The perimeter security can be found outside the protected building. In the outdoor protection fixed settled perimeter devices, as well as fence mounted protection devices can be used. The main types of fixed settlement perimeter devices are: buried-line sensors, magnetic area sensors, seismic, seismic/magnetic, magnetic and balanced pressure sensors microwave devices and infrared ray based devices like exterior passive infrared sensors. Devices of fence sensors are: strain-sensitive cables, taut-wire sensors, fibre-optic cable sensors, capacitance proximity sensors, vibration sensors. (BEREK–BEREK–BEREK 2016)

The sensors of exterior intrusion detection can sense movement, oscillation, change in pressure or change of the electric field. At the establishment of the exterior intrusion system of the water supply facilities, when the applied technology is chosen, we need to assess the environmental characteristics of the facility, the conditions of environmental temperature and climate and the peculiar criminal methods used to that area.

Taking into consideration that the exterior intrusion detection devices are especially sensitive to the environmental influences, including meteorological features, together with their drastic changes, their planning and establishment have to be done very carefully.

Climate change can also be observed in the Carpathian Basin. When planning the exterior intrusion detection system, it is important to consider that the number and intensity of unexpected meteorological situations is on the rise. Intensive weather conditions such as intensive raining, snowing and hurricane force winds, swift warming or cooling, long periods of heat can also influence the number of warning errors.

The provision of proper temperature with heating and cooling for the proper IP[2] protection and the operational optimum is of primary importance for the proper technical reliability of the exterior intrusion alarm systems. In addition to the sensitivity provided by the characteristics of the sensors, the rate of mistaken warnings is also an important factor.

The infrared sensor consists of two units facing each other, they are the transmitter and a sensor, the transmitter lets out an impulse module infrared beam that gets into the receiving unit. If this ray is interrupted, the receiving unit sends a signal to the centre. The microwave intrusion indicator contains a transmission and receiver unit. The transmitter lets out a guided microwave signal; the antenna senses it and gives a permanent indication.

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[2] International Protection Marking.

This ray is stopped by the body of the intruder which is sensed by the transmission unit and it warns. (Berek–Berek–Berek 2016)

When using the infrared light sensors, it is necessary to provide full visibility of the transmitter for the reception unit because hanging plants and tree branches could generate a mistaken warning. The travel of the sign can be obstructed by strong rain or snowing, remains of plants and rubbish moved by the wind. The transmitter and the receiver have to be settled in an area where there is no ground movement that can result in the movement of the transmitter and the receiver away from each other. When using the microwave intrusion–detection sensors, the requirement is that in the middle line between the transmitter and the receiver the area of ground plantation needs to be removed and the difference in the level between them cannot be significant. The water surface, including bigger puddles, near the sensor area, especially water flow can also generate mistaken warnings. The establishment and covering of dead zones of the microwave sensors also need to be considered. (Guidelines 2006)

Especially in the mountain area wind, air pressure, precipitation, fog, the surface, and in case of karst area under the surface, state of waters can become determinant. The movement of karst waters is characteristic for the mountain areas. The channels inside the mountains get filled with water in case of stronger rains, thaw and they are able to carry a lot of water and in certain places, they are capable to deliver water in the form of falls to places where ground water movement is not characteristic.

Relatively low lying water reservoirs found at the ground or in the mountains are characterised by extremes which mean that unexpected flash floods can appear. This situation, as a result of climate change, can easily become an extreme situation.

The temperature of the air and climate change have a significant impact on hydrological processes. Consequently, the frequency of almost all water storage elements, as well as characteristics of the water flow are likely to change the frequency of floods and flash floods, ground water, the length of the periods of droughts and their seriousness. (Kis et al. 2015)

These unexpected changes may lead to the shifting of the sensors of the exterior intrusion warning system.

Among the impacts of climate change, probably the most important ones are the influences on the weather. Besides the direct effects of the temperature and precipitation on the sensors of the exterior intrusion system, we need to mention their indirect impacts, too.

The weather depends more on the characteristics of the ground plantation if the temperature and wetness contrast between the ground plantation system and the air near the ground is bigger. In winter when the plantation is cold and the air is relatively warm above the ground, formation of fog in the vicinity of the surface occurs. In these cases, the appearance of frost is also possible. (Ács–Breuer–Horváth 2009)

At this time, the icy frost and the fog covering the sensors of the electronic intrusion detection system negatively influence their functioning.

When establishing the exterior electronic system of the water supply facilities, it is necessary to examine, based on the requirements of the settlement and utilization, the security and reliability of operational technologies in the light of financing the security of the outer conditions of operability. Built on a relatively small area and situated near a regional or central settlement, the exterior intrusion sensor system can be effectively used for the protection of the ground and underground water facilities of the water recovery system that is well protected against the outer traffic with the help of mechanical protection devices. For the physical protection of water bases situated on large areas, a personnel is needed for providing the environmental conditions of the operation. It is also necessary to consider the need for personnel to prevent the intrusion attempts indicated by the warnings. The extreme weather conditions – that will become more frequent with the process of climate change – can build on each other to generate warnings. In this case it can be useful to settle the electronic devices sporadically, in the direct proximity of wells or groups of wells instead of the full coverage of the edges of the area.

Such fixed settled perimeter security devices as hydraulic, pneumatic, seismic based step sensors, in case of electromagnetic area sensors application, during planning it is advisable to consider that in areas where ground movement is frequent, it is better not to use them. We need to consider the conditions of the ground because the change in the ability to conduct can influence the sensitivity of the device.

4.2.3. Boundary-penetration sensors

Regarding the protection of critical processes of the production of water facilities, it is important to provide the sensors of intrusion attempts through the walls of buildings, floors, ceilings, doors and windows, as well as glass doors. Windows and doors that can be opened need to be protected by opening sensors (magnetic door contact switches), for the indication of glass breakage it has to be supplied by glass breakage sensors, wall structure of not appropriate mechanical firmness can be supplied by structural-vibration sensors in the light of dangerous activities, the value of devices and their replacement possibilities.

4.2.4. General requirements for the access control system

The uncontrolled entrance to the area of the object, as well as the unauthorised entrance pose a special danger for the security of the water production facility. The proper differentiation of the entrance authority within the facility is a challenge for the organization of security for the prevention of unwanted activities.

Besides the entrance of the permanent staff, it is an important task to monitor personnel who are contract workers in the facilities of water supply. During personal entrance, the identity can be checked. The movement of the people inside the facility can be monitored.

Entrance to the water production facility and the movements within the facility is regulated on different levels and this is the primary function of the access control system. The system that is able to follow the movements of authorised persons can establish the number of people inside.

In case of places where there are dangerous materials and connected activities, the access control system needs to be based on the use of the proximity smart card. In case of specially protected places, solutions involving at least two persons have to be considered. (Berek 2011a)

If the maintenance, checking or any activity necessary for their operation happens following an entrance with a proxy card, the person and the time of entrance is recorded automatically. Unauthorized entrance is indicated by properly placed sensors and in case of warning entrance is prevented by the security guards.

In water management facilities where dangerous materials are handled, the building supervision function of the access control system is also useful that enables the ventilators of the airing system, the elements of heating and cooling to switch on and off without depending on the number of people inside. Opening the door of the chlorinator cameras can be switched on; with a PLC (programmable logic controller), the air conditioner system can be started or switched off at different times or event controls.

Maintenance at the wells is risky from the point of view of water pollution. Water tests and maintenance can be carried out by a certain amount of personnel and the circle of those who are to do these tasks is limited. The access control system can ensure that the entrance to these areas is allowed for pre-arranged days and only for these people or it can inform the dispatcher centre about the changes and the security supervisor can control further. Unfortunately, we must not forget that the actions of certain employees sometimes do not serve the interests of the employers, they can even be against those. Either we experience sabotage or thefts, there is an employee behind the action or the employee is the perpetrator.

In case if there is a change among the employees, at work time the supervisor can check the authorisation, so activities without permission or a crime may come into light.

There are areas where work necessitates a special permission and because of potential accidents one person is not allowed to do the work. Such work, for example is maintenance performed in the shaft channels and if airing is not proper the gases gathered there can be very dangerous. It can pose a significant risk if somebody falls from the stands. Considering the very dangerous nature of the chlorine, the situation is similar with the chlorine facilities and during their maintenance. Only two people with special training for this job can perform maintenance. The cleaning and maintenance work of the water area require the same. In pools and water towers it is prohibited to work alone and entrance can only be possible with a special permit. In this case the entrance gate can allow getting in after the necessary permits are recorded.

The equipment of the water management facility with a continuously operable chlorine detector and its integration into the network of the complex property protection system are absolutely necessary for work safety purposes.

To summarize the above, the access control system had to ensure the following:

- in certain areas entrance has to be allowed for only two persons
  From the point of view of security, a special function does not let people enter alone due to the possibility of accidents in that area. With the help of the two-card lock, the opening of the locks in such areas is only allowed if two authorised cards are read one after the other.
- in certain cases the bolt of the magnetic lock has to be unlocked
  At the indication of the fire alarm, the doors of the emergency exit and the main entrance which may be the same entrance, and depending on the defence philosophy, provide the unlocking of all the controlled doors for secure escape.
- in case of zone clearing there is automatic locking
  It is a very useful function for security; with its application the automatic lock does not let the doors open by mistake or due to sabotage.

- listing of people inside
  Not only the number of people inside but their identification can also be monitored in the controlled area.

The need for temporary entrance control is also understandable. In addition to those who work here, guests have to be provided with a guest card that gives limited rights for the temporarily present. The guest cards have to have visual difference from the permanent ones and the system has to limit the time of presence.

4.2.5. CCTV surveillance system

The video monitoring system can provide useful help for the observation of different activities in the controlled areas both as assessment and control.

Camera settings need certain requirements. On the one hand, cameras need to be situated where they can record properly so they can record an event important from the security point of view and in case of identification purposes, of a person. At the placing of the camera, since the aim is not deterrence, a discrete setting is needed so that efficiency would not get limited. At certain points of the water management facilities, a work process may be an important document in case of an accident.

The video system obviously cannot hurt the basic right of the personnel working there; it cannot provide information about office activities. When this useful device is set, the recorded images are stored according to the data protection rules and the quality of the image and time synchronisation are also exact. In case of entrance password, it is important to place the cameras in a way that they are not able to read and record passwords.

On the one hand, it can be said that from the point of view of property security, the presence of the cameras can keep unwanted activities away; on the other hand, when following up a case, it is easier to reconstruct the activities. From the security point of view, it is important that in dangerous work places following an unwanted case, the causes and the responsibility can be established. The choice of the camera for certain purposes is influenced by several factors. It is necessary to examine the environment where each camera has to work or the kind of image definition it has to record. Obviously it will define the choice of optics. When examining the image definition, it is obvious that cameras making large definition pictures are expensive. Consequently, cameras are needed to be optimized according to the task. If there is a need for a later analysis of the picture information in the controlled areas in course of which there is continuous identification of persons or events, it is necessary to use large definition cameras. Regarding sensitivity, the cameras have to be operated indoors among changing light circumstances, sometimes 24 hours a day, so strong sensitivity cameras are needed. (BEREK 2011b)

The automatically transformed observation sectors of the fixed outdoor cameras and the PTZ (Pan-Tilt-Zoom) cameras that are monitored and controlled from time to time by the centre, have to be defined so that all cameras would get into the visibility area of another camera or that they can observe the line of the object fence and its inside. Another requirement is that the coverage of the cameras is transparent and obstructs the visibility of the direction of observation.

When cameras are used, it is necessary to build a proper lighting system and their coordination.

In case of a video observation system, it is necessary to consider that extreme weather conditions may limit the observation ability of the cameras.

Convection for example, due to its nature, is able to free high energy atmospheric energies in a short time in the form of strong thunderstorms and it causes dangerous weather phenomena. Convective storms can produce different structures of cloud and precipitation systems. The cells in thunderstorm centres by strengthening each other can produce dozens of dangerous weather phenomena, from hurricane force winds to rain floods and icy rains. In extreme cases supercells can form, too. (Horváth 2007)

In the areas of facilities where due to the use of materials or due to the character of the facility the operation rules require wearing individual protection, the presence of a video camera is beneficial especially if there is a need to establish responsibility in insurance cases due to accidents.

When the chlorine storage vessel is changed and the safety valve is closed or opened, gases can escape. During these events, protection devices are to be used that can be helped by the observation of the video system.

The worker is responsible for wearing protective clothing for a given activity, especially those connected with water and potable water. This protective clothing includes caps, hair nets, disposable protection foils for the shoes. The presence of the cameras can be beneficial not only for subsequent control but for the prevention of improper activities, too.

The recordings can include sensitive material especially using modern IP cameras so the limitation of the access to data and the protection of recordings is very important.

Selecting the number and quality of the camera, as well as determining the position can be made to allow:

- observation
- detection
- recognition
- identification
- recording and remote alarming. (Marković 2017)

4.3. Preventive measures and manpower

Manpower in itself is expensive and considering the possibility of human error is a risky component. For securing its efficiency and for the energy *input* in its operability, it is very important to establish the tasks of the manpower. When tasks are established, it is necessary to consider the characteristics of the water production facilities.

It is a known fact that efficiency is determined by the efficiency of its weakest element. With systems that are not properly established, the weakest element is usually manpower.

For the sustainability of the security of a facility besides the strict establishment of the responsibility, the provision of the control, the documentation of certain operational interference and as one of its conditions, the establishment of the regulation system is a must in all areas of the facility, among others in case of a sabotage, carelessness, neglect, for the establishment of personal responsibility. This can be said about the security service manpower who protects the security of the production and about the employees employed for the interest of the production. (BEREK 2011b)

At the establishment of the defence concept when the service requirements are worked out for the operational background of manpower, it is important to consider that the procedures of incident management are appropriate for the event management process of the water production facility.

Considering that maintenance works at the wells can cause accidents, following regulations and the use of protection devices are important. Consequences due to negligence including penalties from the authorities can cause loss for the facility. Being under the influence of alcohol at work is also a similar problem and it is connected to the above-mentioned.

The security guard, according to the contract with the employer in case of improper behaviour of an employee can check if the person had consumed alcohol. In case of an entering employee, if the influence of alcohol is visible, the security is allowed to make a test. If the alcohol test proves positive, it needs to be recorded and the entrance must be prohibited.

In case of any accident, work must be stopped immediately, reported to the supervisor and he/she has to take care of the event. During the danger, the given area must be closed, entrance must be limited, the task of the security service can be defined here unambiguously.

Power outage is an obvious problem, in this case the manpower of the security service's task is more considerable, and patrolling needs to happen more often and the routes may change. For such cases, security regulations need to have a plan for event management.

Regarding manpower, the cheapest solution is not necessarily the best; it can be very expensive due to the above-mentioned dangers. In the process of choosing, in addition to professional aspects, the work performance ability needs to be considered (physical, health and psychological testing). Besides the desire to work, the independent development is an important issue, too. The guard must be able to adapt the experiences reacting to different events, he/she has to develop further his/her individual methods. He/she needs to manage professionally the subsystems of the mechanical and electronic components that he/she is responsible for, the system of the patrol control. Training is also important since the introduction of the new technological devices, the modernisation of the old ones requires the training of manpower. (BEREK–BODRÁCSKA 2010)

5. Protection of Redundant Resources of Water Supply

During the normal operation of the infrastructure of the potable water supply for the population we have to consider mechanical, natural or human origin sources of danger that directly influence the quality of the water or the security of water supply. For the establishment of the risks of the water supply, their limitation of the water safety plan is established for the improvement of public health and security and it includes the necessary steps at the water supply points, at water management points, at dispersion points and at consumer points, from the use of reserve water points to the change to the redundant subsystems of water transportation considering several intrusion points. It is possible that the water supply system gets seriously damaged that makes the water supplier change to temporary water provision cessation.

The aim of the emergency water supply is to satisfy the water need of the population who dropped out of the water supply with the help of the existing public facilities, with the exploitation of the natural hydrologic and hydrogeological sources in the area.

The sustainability of potable water security does not only mean the provision of good quality potable water; the physical protection of the water supply system also needs to be emphasized.

The previously defined circle of water sources is determined by their minimal water production; consequently, the use of surface water sources can be profitable at first glance especially if we consider their accessibility. We need to face the fact that because of the vastness of the area of a water removal facility which is built on an underground water source, its physical protection is relatively easy to establish, however, the protection of a surface water source is more complex and expensive. Other important aspects of the choice of water sources are their accessibility, the conditions of the area of the water source both from the point of view of the settling of the water cleaning equipment and the transportation of the produced potable water. The accessibility of the surface water stores can definitely be considered favourable. The protection against sabotage is very difficult. At the establishment of the water source security, it is necessary to use manpower.

Taking all these into consideration, with special attention to modest finances, it is especially important to ensure the physical protection of the incidental water supply structure.

In the planning phase of the physical protection of the temporarily established water production facilities, it is necessary to conduct risk assessment.

It is important to establish, besides the polluting processes endangering the security of the potable water supply, those sources of danger that can endanger the water production from the property protection point of view. The description and categorization of these threatening factors can help their assessment on the basis of their probability.

It is important to consider the heightening frequency of risk weather phenomena that is the consequence of climate change. The frequency and intensity of precipitation can influence the wetness of the soil and that influences the weather, too.

The contrast between soil and air has a direct impact on weather differences. The warming of dry soil is a quick and intensive process. However, the warming of wet soil is much slower and less intense. The difference can be so significant that it can determine the weather. (Ács–Breuer–Horváth 2008)

The weather is one of the defining climatic parameters. It is considered extreme if the difference between the temperature of the day and night is significant. Technical equipment that is placed in a shady place or in case of devices that become very hot, an unexpected strong precipitation can cause significant change in the temperature that can cause tension and deformity. Climate change influences the sustainability and maintenance of technical devices and can change their life cycle. The probability of damage of devices affected by the weather is high, as well as the need for maintenance and repair. This leads to financial rise and when planning, a bigger budget is necessary for the maintenance of the technical devices. (Halász 2013)

In the Carpathian Basin icy rain is a frequent event. We could experience its extremity, too. The devices of the exterior electronic protection are extremely affected by this phenomenon which strengthens the rate of damage and the rate of mistaken calls.

The icy rain of the 1st of December caused damage in the Dunazug mountain, in the hills of Gödöllő and in the Northern Mountain. In the forming of the icy rain, the tropical very warm and wet air played a very important role. The warm and wet equator came to Central Europe through the desert, the arctic cold that oozes near the surface formed the icy rain that, mixed with the air, froze on the trees, pylons, power lines so it caused significant damage in the forests of the mountains, hills, as well as in pylons and power lines. (Kolláth et al. 2015)

6. Conclusion

It happens more and more often that extremely low levels of water come together with periods of dryness. As a result, the amount of usable water declines, ending up in smaller flow in the water, bad results in deteriorating water quality and slower storage filling; the longer presence in the storages can induce further deterioration of the water quality. (Glatz 2009)

Water supply is a complex process. Regulations emphasize, and experience also shows that in case of quality deterioration, it is necessary to take comprehensive measures. To establish sustainable water supply is also a requirement. To keep the water supply secure, besides building proper control regulations into the water supply, it is necessary to pay special attention to the security of some special activities that are necessary to ensure the proper quality of potable water. Besides minimalizing the pollution of the raw water, the lessening or removal of pollution guarantees the meeting of national and communal water quality guidelines and regulations. One of these regulations includes the properly sized and established water cleaning technology. Choice of adequate water cleaning technology for the pollutants is of key importance to protect the health of the user.

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László Földi

Climate Change and Our Water Resources

1. Introduction

Water is an indispensable element of life. Water resources are closely related to climate and are highly sensitive to climate variability and change. Water occurs on Earth in many various forms as rivers, lakes, groundwater, or soil moisture. The variation of the hydrological characteristics of water resources in all time and space scales follows the variation of climatic events, mainly precipitation and evaporation, controlled by atmospheric processes. After rainfall or snow-melting, some water infiltrates into the soil, the infiltrated precipitation can be retained by forces of adhesion and capillary, that is by forces of attraction between water and soil. It can occure in unsaturated soil and increases soil moisture, especially in root zones available for plants, or percolate to the groundwater storage and elevate the groundwater level.

The portion of precipitation not infiltrated into the soil can be carried in a relatively short time after rainfall or snow-melting to streams in the form of surface runoff, increasing the water discharge and elevating the water level, leading to the formation of floods, and sometimes even to catastrophic inundation. In periods with no or low precipitation, water resources and the soil moisture content in particular are reduced by evaporation. The evaporation rate depends on the meteorological conditions, mainly on solar radiation and air temperature and also on the amount of water available for evaporation mostly in the soil. An extension of the rainless period between rainstorms can bring about a large increase in the number of days with low soil moisture, in which crops suffer moisture stress.

2. Water Sources

97% of the water on Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater is found mainly as groundwater, with only a small fraction present above ground or in the air. The water resources can be divided into two groups surface waters and groundwater.

Surface water is the water in rivers, lakes or fresh water wetlands. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss.

Groundwater is a fresh water located in the subsurface pore space of soil and rocks. It is also a water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer (sometimes called *fossil water*).

Groundwater can be thought of in the same terms as surface water: inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger (in volume) compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source.

The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans. (GLEESON et al. 2012)

3. Water Sources in Hungary

Hungary is a lowland country, situated in the Carpathian Basin in the heart of Europe. Its terrain is relatively unvaried, 68% of its area is below 200 m altitude, 30% is covered by hills (200–400 m), and only 2% exceeds 400 m. The highest peak of Hungary is the Kékes (1,014 m). The entire area of the country (93,000 km^2) belongs to the Danube catchment. The Danube catchment is the second largest in Europe, covering over 800,000 km.^{2}

The yearly precipitation is 500–900 mm, the lowest values are measured in the Great Plains, while the highest in Western Hungary. Primary wet periods are in early summer (May–June) and in autumn (October–November). Snowfall is observed on 20–30 days in the lowlands and 50–60 days in the higher hills. Snow coverage is 30–80 days, depending on the altitude. The natural water balance of Hungary is positive, the total precipitation is 55,707 million m,^{3} while the evapotranspiration is only 48,174 million m.^{3} As a result of climate change, yearly mean temperature is expected to rise, the yearly precipitation pattern to change (and the total yearly amount to decrease) and the frequency of extreme weather events is likely to increase. This might lead to increased frequency of floods and inland water accumulation. The trend of a more variable precipitation pattern is already visible, 2010 was the most humid and 2011 the driest year since 1901, and 2011, 2012 and 2013 were all significantly hotter than the average. Climate change is likely to affect the availability and quality of water in Hungary, and the climate is expected to shift towards a Mediterranean climate. Droughts are already prevalent, especially in the Great Plains area.

There are 9,800 registered surface water flows in Hungary. 90% of the water flow is from large or medium transboundary rivers. The Danube is the main axis of surface water; its Hungarian segment is 417 km (140 of which is shared with Slovakia). Its average water flow in Budapest is 600, 2,300 and 8,000–10,000 m^3/s in low, medium and high flow conditions, respectively. Its main tributaries are the Lajta, Rábca, Rába, Ipoly, Sió and Dráva. The Tisza is the second largest river of Hungary. Its formerly 950 km segment was reduced to 595 km during the 19th–20th century flood management interventions (straightening by cross-cutting meanders). The flow of the Tisza is 170, 800 and 3,400 m^3/s in low, medium and high flow conditions, respectively. The Tisza is very turbid due to the high particulate matter concentration. Its main tributaries are the Túr, Szamos, Kraszna, Bodrog, Sajó, Zagyva, Körös and Maros. Hungarian rivers usually flood twice a year, in early spring due to snowmelt *(icy flood)* and in early summer, due to the precipitation peak of the period *(green flood).* Per capita surface water resource (11,000 m^3/year) is one of the highest in Europe, but the contribution of the flows within the boundaries is low (600 m^3/year/person), resulting in unequal geographic and temporal distribution of surface water resources. Regional water management systems are designed to overcome the disparities. Flood and inland water management practices significantly decreased the previously predominant wetland area in the Great Plains, and increased its drought vulnerability. Watercourses at higher elevations were also regulated and reservoirs were created, significantly affecting the status of the water system.

Water quality of large rivers in Hungary is mainly determined by the quality of the received water from upstream countries. Small and medium watercourses under low-flow conditions are vulnerable to contamination, which may lead to severe ecological impact.

Majority (75%) of the 4,000 stagnant water bodies in Hungary are artificial lakes. Their total surface is 1,685 km^2, 2% of the area of the country. Lake Balaton is the largest lake in Central Europe (594 km^2). Both the lake and the adjacent Kis-Balaton wetland are nature preserved areas. Lake Balaton also has a high touristic relevance. Its water quality is excellent, due to the drastic interventions to reduce nutrient load and subsequent eutrophication since the 1980s. Lake Velence (25 km^2) and Lake Fertő (322 km^2, of which 75 km^2 belongs to Hungary) are the westernmost examples of steppe lakes. Water levels of both lakes are low, and a large proportion of their surface area is covered by reed. The Western part of Lake Velence is a bird preserve, while the entire Lake Fertő is under protection. In the Great Plain area, salt pans with high alkalinity, salinity and a unique flora and fauna are predominant. Several lakes were created by artificial dams, such as Lake Tisza or the Orfű lakes. The reservoirs have significant ecological and touristic value, often comparable to natural lakes. (Barreto et al.2017)

Hungary – due to its location and unique geology – is exceptionally rich in groundwater. The average depth of shallow groundwater is 2–5 m (extremes 0–16 m) depending on the precipitation. Shallow groundwater is vulnerable to surface contamination and usually not suitable for consumption. Bank filtration, on the other hand, is one of the main sources of drinking water (among others, Budapest relies solely on bank filtration). Deep groundwater is less vulnerable to contamination, but its recharge is much slower. The number of deep groundwater wells is close to 70,000 nationally. Abstraction is mainly used as drinking water, though in several areas naturally occurring chemicals (e.g. arsenic, iron or manganese) hinder the use without treatment. Karstic waters also contribute significantly to drinking water production.

Overall, approximately 95% of drinking water in Hungary is from groundwater source (including bank filtration). However, almost 2/3 of the sources is vulnerable. The geothermic gradient in Hungary is higher than average, resulting in the abundance of thermal (often 70–90°C) waters. Thermal waters are used for recreational and therapeutic purposes. (Barreto et al. 2017)

The main characteristics of water resources are the water availability and the water quality. The net impact on water availability will depend on changes in precipitation (including changes in the total amount, form and seasonal timing of precipitation). In areas where precipitation increases sufficiently, net water supplies might not be affected or they might even increase. If the precipitation remains the same or decreases though, net water supplies would decrease. This is in part due to the predicted temperature rise in most areas, which will cause evaporation rates to increase. Where water supplies decrease, there is also likely to be an increase in demand as a result of higher temperatures, which could be particularly significant for agriculture and energy production (the largest consumers of water) and also for municipal, industrial and other uses.

Water quality changes in the timing, intensity and duration of precipitation can negatively affect water quality. Flooding, a result of increased precipitation and intense rain storms, transports large volumes of water and contaminants into waterbodies. Flooding also can overload storm, combined sewer and wastewater systems, resulting in untreated pollutants directly entering waterways. In regions with increased rainfall frequency and intensity, more pollution and sedimentation might be produced because of runoff. Reduced rainfall can also result in more frequent wildfires, and land areas where wildfires have occurred are more vulnerable to soil erosion.

4. Water Scarcity

Countries may be considered water-stressed if they withdraw more than 25% of their renewable freshwater resources. They approach physical water scarcity when more than 60% is withdrawn, and face severe physical water scarcity when more than 75% is withdrawn.

Water withdrawals for agriculture represent 70% of all withdrawals. The intensive agricultural economies of Asia use about 20% of their internal renewable freshwater resources, while much of Latin America and Sub-Saharan Africa, in contrast, use only a very small percentage.

Given these constraints, the rate of expansion of land under irrigation is slowing substantially. The global area equipped for irrigation may increase at a relatively low annual rate of 0.1%. At that rate, it would reach 337 million ha in 2050, compared to around 325 million ha in 2013. This represents a significant slowdown from the period between 1961 and 2009, when the area under irrigation grew at an annual rate of 1.6% globally and more than 2% in the poorest countries.

Most of the future expansion of irrigated land is projected to take place in low-income countries. Growth in agricultural water use is decelerating, partly owing to the improved performance of irrigation systems and agricultural practices. However, with rapid urbanization, the demand for water is becoming more and more spatially concentrated. Competition for water, and the construction of dams and diversions that interfere with fish migration, can also have a major impact on inland fisheries. While allocations of water are shifting away from agriculture to meet the needs of urban users, there is still room for improving these allocations in both economic and environmental terms. In this regard, finding non-competing uses of water resources, such as using treated urban wastewater for irrigating crops, will become increasingly important. There may be some scope to further exploit water resources, such as rivers and lakes, to increase food production through the development of inland aquaculture. It is expected that aquaculture will continue to expand in the decades ahead through intensification, species diversification, expansion into new areas (such as offshore marine waters), and the introduction of innovative solutions. (OCHA 2010)

The situation will be worsening due to climate change.

5. Climate Change Effects

Global warming is defined as the increase of the average temperature on Earth. As the Earth is getting hotter, disasters like hurricanes, droughts and floods are getting more frequent. Over the last 100 years, the average air temperature near the Earth's surface has risen by a little less than 1 degree Celsius. Global warming is the cause; climate change is the effect. Scientists often prefer to speak about climate change instead of global warming, because higher global temperatures do not necessarily mean that it will be warmer at any given time at every location on Earth. Warming is strongest at the Earth's Poles, the Arctic and the Antarctic, and will continue to be so. In recent years, fall air temperatures have been at a record 5 degrees Celsius above the normal. But changing wind patterns could mean that a warming Arctic, for example, leads to colder winters in continental Europe. Regional climates will change as well, but in very different ways. Some regions like parts of Northern Europe or West Africa will probably get wetter, while other regions like the Mediterranean or Central Africa will most likely receive less rainfall. Melting ice is the most visible impact of a warming climate. The UN Panel on Climate Change (IPCC 2014) finds that over the last two decades, the Greenland and Antarctic ice sheets have been losing mass. Glaciers have continued to shrink almost worldwide (high confidence). It is also observed that extratropical cyclones can begin to take on characteristics that are present in tropical cyclones, such as a warm core. In addition, they noted that the release of latent heat can become very significant for development, just as for tropical cyclones. The latent heat flux at the surface is a combined result of wind speed and the difference in specific humidity between the Earth's surface (be it land or water) and the air 10 meters above it. Cold dry air blowing across a warm moist surface will allow for the upward transfer (flux) of latent heat energy into the atmosphere. The low to mid-level horizontal temperature gradient and the latent heating are significant from a climate change perspective because the way these features are changing – and will continue to change – will counter each other and hence complicate our understanding of how climate change will impact extratropical cyclone activity. Specifically, one of the anticipated changes regarding temperature changes is that the poles (North and South) will warm more than equatorial regions at least at low to mid-levels. This differential warming will therefore reduce the ambient pole-to-equator temperature gradient. Consider that the zonal mean pole to equator temperature difference at the surface in 1970 was (15°C – (–39)°C = 54°C so that an increase of 5°C at the pole and a 1°C increase in the tropics by 2100 will mean a difference of 16°C – (–34°C) = 50°C, that means a reduction of about 7.5%. The reduced gradient will mean less available potential energy at low to mid-levels of the atmosphere for storm development. At mid to high levels, studies have shown that an increase was found over both the North Atlantic and North Pacific during the second half of the 20th century. A decrease in overall activity was also found with a slight increase in frequency and strength of storms over Central Europe, with decreases in the number of storms over the Norwegian and Mediterranean seas. (IPCC 2014)

Most of the global average increase in sea level since 1900 (approximately 1.5 mm/year) is attributable to global warming – divided almost equally between the contribution from thermal expansion of ocean water (50%) and the contribution from melting continental ice sheets and glaciers (40%). (CHURCH et al. 2013) All techniques support a recent (approximately the last two decades) increase in the rate of sea-level rise to more than 3 mm/year. (HAY et al. 2015) This acceleration is commonly attributed to an increased contribution from melting ice on land, and is supported by satellite-derived observations of thinning, accelerating and mass change of glaciers and ice sheets. (CHURCH et al. 2013)

Significant regional variability of sea level exists as a result of changes in weather patterns, ocean circulation, and non-climate change related processes such as land subsidence. (KOPP et al. 2015) Subsidence, or more generally vertical land motion (VLM), is the combined result of tectonic activity, soft-sediment compaction due to overburden or the withdrawal of groundwater or hydrocarbons, and deformation associated with ice–ocean mass transfer. (KOPP et al. 2015)

As climate change continues, coastal flood frequency is expected to increase dramatically. Projections of an increase are robust, mainly because the regional sea level will continue to rise at most global locations and over the long run (although there may be periods during which it could go down) from continued thermal expansion of the ocean water, melting of ice, and changes in terrestrial water storage. Ocean warming and expansion, generally projected using GCMs, are expected to continue and to penetrate deeper into the ocean, with a rate that is linked to atmospheric feedbacks and ocean heat uptake (diffusivity). (CHURCH et al. 2013) Glaciers (land ice) are expected to shrink dramatically over the 21st century, with the maximum contribution to sea level arising from the Arctic, Alaska and glaciers peripheral to the Antarctic and Greenland ice sheets. Finally, other factors, like storage on land (i.e. reservoirs and groundwater withdrawal) may influence sea level, but are generally assumed to be smaller and have less uncertainty.

The long-term implications of worsening extreme weather phenomena are worrying. Even modest increases in temperature beyond the current 1.1°C rise above the pre-industrial baseline can have a significant effect on the risk profile for extreme events. Even more worrying, the various national pledges and commitments for emission reductions that were made in Paris, when aggregated, would likely lead to a 2.9–3.4°C warming by 2100. If the rest of the world adopted a level of ambition equivalent to Australian targets and policies, we would be on track for an even greater rise – 3–4°C rise or more by the end of the century. Those scenarios would push the risks of worsening extreme weather towards the *very high* level.

The IPCC findings indicate that global surface temperatures will likely increase by a few degrees Celsius by the end of the 21st century. However, due to the geographic variability in the climate response and to the presence of internal variability, warming (and changes in other climate variables) will continue to exhibit an inter-annual-to-decadal variability and will not be regionally uniform. Understanding climate-driven changes in extreme weather at small spatial scales is thus a very daunting task. Some changes, such as increases in the number of 60°C days and increases in heavy precipitation, are easier to foresee because they are more robust across models and follow from first principles of what should happen when more CO_2 is put into the atmosphere. However, other impacts on other phenomena such as hurricanes, blizzards and severe thunderstorms are more complicated to predict and often exhibit substantial differences across model ensembles.

In fact, many of the papers cited are published since the last available IPCC (2013) report and provide the very latest research results. In addition, the results focus for the most part on the last 20 or so years of the 21st century. Depending on the year of the study, different Representative Concentration Pathways (RCPs) representing different greenhouse gas scenarios are used.

Direct evidence of precipitation changes can be complicated by its significant spatial heterogeneity. Despite that complication, however, there is a relatively strong evidence in the historical record that precipitation-related quantities including heavy precipitation events, have been increasing. The 2013 IPCC report concluded that precipitation over the mid-latitude land areas of the Northern Hemisphere has also increased. (Collins et al. 2013)

6. Projected Changes for the Future

Modelling results show that annual mean temperature in Europe is likely to increase more than the global mean temperature. Until the end of this century, the average annual temperature in Europe is projected to increase by 2.5–5.5°C for the A2 scenario, and 1–4°C for the B2 scenario. Some regions may experience lower or higher temperature increases than average. For the A2 scenario, temperature increase in some regions in Europe may be as low as 2°C or even higher than 7°C in the scenarios. Southern Europe will be most affected, with consistent temperature increases between 3°C and more than 7°C, with an even greater warming in the summer. Northern Europe will experience temperature increases by less than 2°C and up to 4°C, depending on the scenario and the region, with mainly winters getting less cold. Temperature extremes will decrease in the winter, but increase in the summer.

Annual average precipitation will increase in Northern and North Central Europe, while it will decrease in Southern Europe. Annual precipitation patterns will also change. Southern Europe will experience lower rainfalls all year round. There will be less precipitation during summer time in Atlantic and Continental Europe, but more winter precipitation. Decreases in annual average precipitation in Southern and Central Europe can be as high as 30–45%, and as high as 70% in the summer. (IPPC 2007)

6.1. Predicted climate changes in Hungary

Most of climate projections predict further increase of temperature and climatic aridity for the 21st century in Hungary and in the Carpathian Basin. The rate of warming depends on the emission and climate scenarios and can be in the interval of 2–5°C. Temperature rise is expected in all seasons. The annual precipitation is expected to decrease with considerable seasonal shifts, i.e. mostly increase in winter and decrease in summer. Studies related to the National Climate Change Strategy foresee that extreme weather events (heat waves, heavy rains) will be more frequent and intensive. Regional climate scenarios for the period of 2020–2040 based on medium emission scenarios (A1B) and three different global circulation models (ECHAM, NCAR, ARPEGE) have been projected using regional climate models (REMO, RegCM, ALADIN). (Bartholy et al. 2009) Generally, all regional climate scenarios outline an increase of annual and seasonal temperatures with substantial spatial variability, while the highest rate of rise is expected in eastern regions, especially on the Hungarian Plain. The change of precipitation is largely uncertain, predicted rates in the regional scenarios differ not only in the magnitude but also in the direction of the change.

Precipitation projections indicate both increase and decrease depending on the given scenario. It is most likely that annual and summer precipitation will decrease and winter precipitation increase, the frequency and intensity of intensive rainfall and dry spells will grow, but the predicted change is not significant, and might be the consequence of natural climate variability. (Szépszó–Horányi 2008)

6.2. The general effects of climate change on water resources

Any climate related change will impact on water quality and availability. Examples of such changes include those listed here:

- Increase in lake and river surface water temperatures, causing changes such as the movement of freshwater species northwards and to higher altitudes, alterations in life-cycle events (earlier blooms of phytoplankton and zooplankton), and the increase of harmful cyanobacteria in phytoplankton communities causing a rise in threats to the ecological status of lakes and increased risks for the human health.
- Reduced water flows from shrinking glaciers and longer and more frequent dry seasons; decreased summer precipitation, leading to a reduction of stored water in reservoirs fed by seasonal rivers; biennial precipitation variability and seasonal shifts in stream flow; reduction in inland groundwater levels; an increase in evapotranspiration as a result of higher air temperatures; the lengthening of the growing season; and increased irrigation water usage.
- Increased household water demand in the hot season, water scarcity and drought, impairing the reliability of raw water sources, as it is altered by changes in the quantity and quality of river flow and groundwater recharge.
- Heavy effects on drinking water quality as a consequence of the decrease in pollutants being diluted (resulting from increasing water temperatures, and water scarcity/flow); and increased water flows displacing and transporting different components from the soil to the water through fluvial erosion.
- Unsuitability of water for drinking and agriculture purposes, as a consequence of saline intrusion.

Both major extremes of global climate change can have serious impacts on coastal areas, as detailed here:

- Drying and water scarcity may result in the over-exploitation of groundwater resources, reducing their availability as well as impairing their quality (through contaminant concentrations) with harmful consequences for water supply to the population, agriculture and energy production.

- Extreme rainfall and storms may result in increased runoff, river discharge, more intense erosion and the mobilisation of chemical and biological contaminants by surface runoff from urban and agricultural areas.
- A combination of rising sea level and more intensive coastal storms would create the highest environmental and health risk stemming from a salinisation of water supplies, including aquifers used for drinking-water. The major problem is that, in most if not all of the coastal regions, groundwater is a key source of water supply, especially of drinking water (more than 2 billion people worldwide depend on groundwater).
- Saline water intrusion, accelerated by both the rising sea level and the over-exploitation of groundwater resources in a drying climate, poses both quantitative and qualitative risks to the population. Extreme storm surges combined with the rising sea level could result in much higher rates of coastal erosion, which would in turn further increase saline water intrusion. A 5% increase in salt content will rule out many important uses, including drinking water supply and the irrigation of crops, parks and gardens, and will threaten groundwater-dependent ecosystems. (Green et al. 2011)

Additional effects of global climate change that have important implications for water resources include increased evaporation rates, a higher proportion of precipitation received as rain, rather than snow, earlier and shorter runoff seasons, increased water temperatures and decreased water quality in both inland and coastal areas. The physical and economic consequences of each of these effects are discussed below.

Increased evaporation rates are expected to reduce water supplies in many regions. The greatest deficits are expected to occur in the summer, leading to decreased soil moisture levels and more frequent and severe agricultural drought. More frequent and severe droughts arising from climate change will have serious management implications for water resource users. Agricultural producers and urban areas are particularly vulnerable. The droughts also impose costs in terms of wildfires, both in terms of control costs and lost timber and related resources.

Water users will eventually adapt to more frequent and severe droughts, in part by shifting limited water supplies towards higher-value uses. Such shifts could be from low to high-value crops, or from agricultural and industrial to environmental and municipal uses. A period of delay is likely, however, because gradual changes in the frequency and severity of drought will be difficult to distinguish from normal inter-annual variations in precipitation. Economic losses will be larger during this period of delay, as compared to a world with instantaneous adjustment, but pre-emptive adaptation could also be costly given the uncertainty surrounding the future climate. Rising surface temperatures are expected to increase the proportion of winter precipitation received as rain, with a declining proportion arriving in the form of snow. Snow pack levels are also expected to form later in the winter, accumulate in smaller quantities, and melt earlier in the season, leading to reduced summer flows.

Such shifts in the form and timing of precipitation and runoff, specifically in snow-fed basins, are likely to cause more frequent summer droughts. Changes in snow pack and runoff are of concern to water managers in a number of settings, including hydropower generation, irrigated agriculture, urban water supply, flood protection and commercial and recreational fishing. Timing of runoff will affect the value of hydropower potential in some basins if peak water runoff occurs during nonpeak electricity demand. Energy shortages and resulting energy price increases will provide incentives to expand reservoir capacities or develop alternative energy sources. If the runoff season occurs primarily in winter and early spring, rather than late spring and summer, water availability for summer-irrigated crops will decline, and water shortages will occur earlier in the growing season, particularly in watersheds that lack large reservoirs. Agricultural producers, in response to reduced water supplies and crop yields, will adjust their crop mix.

6.3. Effects of climate change in the hydrological system of the Carpathian Basin

Climate impact assessment studies in hydrology started some decades ago in Hungary. The early impacts assessments can be characterized as follows:

- They are based on assumed change of climate and without any climate scenario based projections.
- They use simple empirical-statistical approaches, and address averaged hydrological parameters.
- Some simple physical based models are also applied, the input time series of precipitation and temperature are based on weather generators.

Some important results of these early impact assessments are:

- The decrease of mean annual precipitation coupled by the increase of mean temperature would lead to the decrease of the mean annual flow with a higher rate than in the mean annual precipitation; the regions with arid climate are more sensitive to change. (Nováky 1994b)
- The increase of temperatures by up to 3°C in catchments of the upper Danube would significantly affect mean annual flow, and even stronger its seasonal distribution, the earlier occurrence of snowmelt induced floods. (Bálint–Gauzer 1994)
- The increase of winter temperature would result in earlier snowmelt, some increase of winter flow would appear on the Danube, and more increase on the Upper Tisza and some of its tributaries. (Bálint et al.1995)
- The decrease of summer precipitation would lead to significant decrease of low-flow on several rivers, the lowest decrease rate expected on the Danube and the highest one on the Maros River. (Nováky 1994b)
- An increase of early spring flood peaks is likely, on the other hand, later spring floods may decrease. Snowmelt induced floods in the Upper Tisza and Zagyva would occur earlier and have a higher peak. The peak discharges of floods generated by intensive rainfall would increase by a rate of up to 30% in the catchment of Sajó. (Bálint et al. 1995)
- Sensitivity analysis proved that decrease of precipitation coupled by increase of temperatures would lead to a slight decrease of the (regulated) outflow from Lake Balaton to maintain the present regulated water surface. (Nováky 1994a)

Climate change impacts are already visible in the hydrometeorology of the Danube Basin in the form of increasing number and intensity of extreme weather conditions; the temperature and precipitation changes in the following form:

- An increase in air temperature with a gradient from northwest to southeast, particularly in the summer in the south-eastern Danube region.
- Overall small annual precipitation changes for the whole basin on average, but major seasonal changes in the Danube River basin.
- Changes in the seasonal runoff pattern, triggered by changes in rainfall distribution and reduced snow storage.
- The likelihood that droughts, low-flow situations and water scarcity will become longer, more intense, and more frequent.
- An increase in water temperature and increased pressures on water quality.

The country is located at the frontier between the temperate Continental and the Mediterranean climate zones, with complementary effects of the temperate oceanic climate. From the analyses of the 60-year long observation series, the following conclusions can be drawn. In function of climate on the upstream catchment, the water of the Danube is generally warmer at the entrance to the Carpathian Basin than that of the Tisza, but in the summer, the Tisza water reaches higher temperatures and also its annual temperature range is higher. In November, the water of the Tisza cools more rapidly than the Danube. The overall rising trend in the monthly mean temperatures of the Danube water indicates remarkable climate change, winters getting milder in the catchment section upstream of Dunaremete, while a similar trend cannot be pointed out for the Tisza catchment in the north-eastern Carpathians. These trends do not show steady warming but are interrupted by short spells of positive and negative fluctuations, which primarily depend on winter and summer air temperatures.

When the weather is abnormal or the climate is under pressure, water and wastewater service systems stand to lose much of their environment and health benefits, for two main reasons:

- They lose their ability to deliver the services required because of direct infrastructure damage (from floods, windstorms and tide surges) or from lack of water (e.g. when a cold spell turns water to ice).
- They become a significant source of chemical and biological contamination of ecosystems, water bodies and soil by means of their discharges and polluted overload. (Radvánszky–Jacob 2008)

6.4. Effects of climate change on the rivers of the Carpathian Basin

The extreme rainfall events increase the risk of flood and inland excess water. The occurrence probability of flash floods will change locally on small watersheds due to the changing extremes. The amount of the surface water resource will also change due to the temporal change of precipitation. Winter precipitation will be rainfall with an increasing probability, which results in an increasing winter runoff and earlier and higher flood peaks compared to the present floods, because what was accumulated as snow will then runoff without any delay. The inland excess water is not primarily affected by the climate change, but late winter and early spring extremes will still occur.

The effect of less summer precipitation and increasing potential evapotranspiration will be the increasing ratio and duration of low-flow periods, which results in the decrement of the water resource without retention (the decreasing low-flow water resource will be significant on the Danube). The capacity of reservoirs will be limited by the winter extremes determining their impounding, and the water loss caused by the increasing evaporation. The water resource of lakes will also drop due to the same reasons, leading to low water levels more often.

Decreasing low-flow discharges will also result in more vulnerable rivers against pollutants. Due to less amount of water, the dilution will also decrease, while the higher temperature increases the speed of biochemical processes, thus the decay of the contaminants will be faster. Sudden occurring fast floods will carry more pollutants from the catchments, and will worsen the nutrient balance of the rivers. The probability of havaria events will also increase. The most dominant climate drivers for water availability are precipitation, temperature and evaporative demand (determined by net radiation at the ground, atmospheric humidity and wind speed, and temperature). Temperature is particularly important in snow-dominated basins and in coastal areas, the latter due to the impact of temperature on sea level (steric sea-level rise due to thermal expansion of water). (Gleeson et al. 2012)

The three largest river basins in the Carpathian region are the Danube, Dniester and Vistula basin. Generally, river valleys in the Carpathian region have a small retention capacity, causing violent surface runoff during heavy rainfall, resulting in sudden and prolonged increase in water level in rivers and streams. The Danube and Tisza valleys are very prone to frequent flooding. Also, the Dniester has a specific flow regime with up to five flooding events per year. In 2005 floods killed 34 people, displaced 2,000 people, inundated 690 km^2 and caused 625 million USD (€396 M) damages in Hungary, Romania, Bulgaria and Moldova. A year later a flood displaced 17,000 people, inundated 1,450 km^2 and cost 8.6 million USD (€5.5 M) in Romania. Part of these changes are due to a different climate, but other factors like increasing water use, abstractions, urbanization and deforestation can also have a major impact upon water flow and availability and determine the vulnerability of the water resources to climate change. The Danube and its tributaries are especially under pressure by impoundments (barriers/hydropower dams) and water abstractions. About half of the water bodies are affected by hydrological alterations to such an extent that the remaining flow below the water abstraction or dam is too small to ensure the existence and development. (Stagl–Hattermann 2015)

High flow events have impacts on the river. Due to increase of water flow and water level, erosion of the river banks is very likely. This also applies to existing dikes and other flood protection measures. An overall increase in winter flow was detected in future projections and a rising tendency (although not always significant) towards flood extremes was also noted. (Albert et al. 2013) Most studies indicate an increase in flash floods, due to increase in winter precipitation and altering snow storage. Furthermore, anthropogenic contributions like overgrown river flow channel, regulation of rivers and land use also have their impact on future flood events. Due to increased water velocities, the river channels may erode and become damaged along with the flora and fauna within the channels. This results in increased sediment load which affects the water quality in the rivers and its receiving waters (lakes and sea). With respect to water quality, increased flash floods events will lead to (more) uncontrolled discharges from urban areas and increasing storm events, especially a storm after a long period of drought, will flush more nutrients from urban and rural areas. (Whitehead et al. 2009)

In general, low-flow and drought periods as well as water scarcity events are expected to increase. Regional studies point at periods of low precipitation resulting in lower summer river flow. (Mic et al. 2010) In the southern and eastern parts of the Danube river basin a decrease in runoff is projected, while in the northern and western parts no clear trend or even an increase in runoff is projected until 2050. It is projected that low-flow and droughts will become more severe in summer and the periods of low-flow, drought and water scarcity will be longer, while in winter they will become less severe. In particular, the southern parts of Hungary and Romania as well as the Republic of Serbia, Bulgaria and the region of the Danube Delta are expected to face severe droughts and water shortages. This will in turn affect water quality. In periods of drought and high temperatures less flow will enhance eutrophication and can trigger toxic algal bloom. Pollutants that originate from point and diffuse sources are less diluted, so concentrations of dangerous and emerging substances will increase. Drought will increase the demand of water (agriculture, human consumption, cooling), which in turn can enhance the lowering of flow and water tables and impaired water quality.

6.5. Effects of climate change on the lakes of the Carpathian Basin

Lake Balaton is the biggest freshwater lake in Central Europe. It is a typical shallow lake of 588.5 km^2 surface, 3.25 m average depth and 236 km shoreline length, with high sensitivity to the fluctuation of hydro-meteorological factors. In winter, the lake is generally covered by ice. In summer the average water temperature is 23 ºC.

The water catchment area of the lake is approximately 5,774 $km.^2$ The main inflow is the Zala River at the south-western end, while the Sió-canal drains the water from the eastern basin into the River Danube. However, the most significant part of the lake's water supply comes from two sources, the approximately 130 underwater springs, and precipitation in the form of rain and snow. The catchment area receives on average 621 mm of precipitation each year.

Lake Tisza is the second largest freshwater body in Hungary and the largest artificial lake in the country. The original Kisköre Reservoir was built in 1973, as part of the River Tisza flood control project, and its filling was finished in the 1990s. The completed reservoir – renamed as Lake Tisza – is 27 km long with a 127 km^2 surface. The River Tisza's length within the reservoir is 33.6 km. Lake Tisza is also a typically shallow lake, with an average depth of 1.3 m and a maximum depth of 17 m. Unlike Lake Balaton, Lake Tisza contains several small islands of 43 km^2 total surface.

Warming increases the amount of algae present, which is an indicator of the development of chlorophyll-A concentrations. The presence of algae in the water has various effects: green colouring as a visual effect, perceived low quality as an impact on visitors' satisfaction, and the development of allergic symptoms in cases of sensitivity as a health impact.

Water quality at the four Lake Tisza beaches, as measured by the National Public Health and Medical Officer Service, generally improved during the period of 2001–2003. However, by the end of the 2003 season, the quality of the water only proved acceptable at two beaches, due to the high summer month temperatures and to the impact of tourist use.

Climate change directly affects the natural supply of the Lake Balaton and Lake Tisza regions: temperature increase lengthens the season as late spring and early autumn also become suitable for bathing, but at the same time July and August may be uncomfortably hot for tourists. Water quality is directly affected, particularly through eutrophication and by threatening the lakes' fish stock. (Nováky 1994a and 2008)

The major shallow lakes in Hungary, the Balaton, Neusidler/Fertő and Velence are very sensitive to climate fluctuations. The water balance and water level of lakes are regulated by structures controlling outflow released from the lakes. The aim of regulation is to maintain the water level within the prescribed interval, the defined range or water levels to avoid the inundation of the coastal zone on the one hand and to store enough water to maintain sufficient depth for recreation purposes. (Varga 2005) In case of long drought periods, the water levels may fall below the thresholds and cause a critical situation for recreation, hitting tourist industry. Such critical situations in lakes occurred during the 20th century. In the 1990s the water level of Lake Velence was below the critical limit for a long period. The water level of the Balaton was low in 1952–1954, and in 2001–2004. In 2003 depths along the southern cost remained less than 1.0 m as long as 0.5–1.0 km distance from the shore.

Although the water level is regulated, climate fluctuation remains the important factor in the fluctuation of water level and water balance of lakes. (Varga 2005) The role of climate may be followed especially well through the fluctuation of natural water budget (NWB). NWB is the difference between the total inflow (that is the sum of precipitation and inflow to the lake) and the evaporation from the lake surface for a given time interval. (Nováky 2008) Annual NWB has been available since 1921 for Lake Balaton and has since shown a decreasing tendency (Kravinszkaja et al. 2010) with a 30 mm (or 6%) depletion for 10 years.

Lake Neusiedler (or Lake Fertő in Hungary) is by far the biggest lake in the Carpathian region (315 km^2). It is a very shallow lake (depth < 2 m) situated at the foothills. Its shallowness results in a unique ecosystem but also makes the lake vulnerable for changes in the water level. Furthermore, there are about 450 small lakes in the mountainous area of the Carpathian region (total surface 4 km^2), most of them postglacial.

6.6. Effects of climate change on groundwater resources of the Carpathian Basin

Climate change will also affect the quantity and quality of groundwater. Due to the drier soil circumstances, the decreasing refilling effect of precipitation is expected, mainly on the Great Plain. The amount of groundwater available for irrigation will decrease on the Great Plain, and in the term of 50–100 years it also threatens the heavily groundwater dependent drinking water supply. The worsening ecological status due to the drier climate will cause problems in the groundwater related ecosystems, wetlands. Climate change will also affect the quantity and quality of groundwater.

Due to the unequal distribution of precipitation in time and space 28 years out of 100 are expected to be droughty in Hungary. The drought primarily affects the centre of the Great

Plain, where the evapotranspiration usually exceeds the precipitation amount (climatic water scarcity). The climatic water scarcity/excess is ranging from 100mm/year excess to 350 mm/year scarcity, with the peaks in the southern Tisza catchment. This periodically occurring phenomena – causing long-term water scarcity for the flora and fauna, the agriculture and for the society – will be worsened by climate change. Due to the interventions after the mid of the 19th century, the reduction of floodplains and the changing land use also increased the area and duration of drought.

The fight against the extreme water management circumstances is a major driving force in Hungary. Flood protection, inland excess water protection, the protection against drought damages are all on a national scale, but are especially important on the Great Plain and the Tisza catchment.

The occurrence probability of drought shows an increasing tendency on distinct regions of Hungary. The chance of a moderate drought significantly increased in the last years – most probably due to the more and more significant change in the climate – and the probability of extreme droughts in winter and spring also increased. Hungary can be divided into two regions by the scale of the climate change effect on droughts. The Transdanubian region and the northern mountainous region is not effected even in case of an extreme climate change, but the Great Plain is vulnerable, especially the region of the Sand Ridges of the Duna–Tisza Interfluve, the Middle Tisza region, the Berettyó–Körös region, the Nagykunság, the Hevesi plain, the Borsodi lowland and the Nyírség. The most dominant climate drivers for water availability are precipitation, temperature and evaporative demand (determined by the net radiation at the ground, atmospheric humidity and wind speed, and temperature). Temperature is particularly important in snow-dominated basins and in coastal areas, the latter due to the impact of temperature on sea level (steric sea-level rise due to thermal expansion of water). (Homolya et al. 2017)

A unique groundwater system is the bank-filtration system, the exposure of which is regulated primarily by the meteorological conditions of the catchment area (in many cases having a transboundary character) of the recharging surface water system instead of the nearby area. The exposure of these groundwater systems are characterised mainly by the water level fluctuations of surface water systems.

The aridity index is defined as the ratio of precipitation and potential evapotranspiration. Potential evapotranspiration has been calculated using Thornthwaite's method. (Ács–Breuer 2013) Projected future changes in the aridity index based on the ALADIN-Climate data show a continuous decrease from the western parts of Hungary towards the eastern areas, suggesting the climate to get dryer in the whole country but to a different extent regionally. The drying process is likely to intensify by the end of the 21st century.

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Andrea Márton

High North Strategy of the United States of America and Russia’s Arctic Strategy: A Comparative Analysis

1. Introduction

At the end of the 20th century the Arctic region was forgotten. Due to the mineral treasures discovered in the first decades and the climate change caused by global warming, it has become a source of interest in geopolitical and geostrategic aspects. The melting ice cap, the opening navigation routes, and the hydrocarbons and other mineral treasures in the Arctic continental shelf opened a new chapter in the history of the region.

Security, economic, legal, political and defence aspects should be taken into account for the Arctic. In the Arctic region, particular attention should be paid to the Russian Federation, as this country is the most significant arctic player. This can be regained for several reasons: one is that the country has great ambitions and significant development potential. The other reason we need to keep in mind is that the region plays a central role in its strategic thinking, and it is still very much defining the country’s defence policy. Another part of my study deals with the fact that the United States of America has not yet given such a high priority to the region. This is partly due to the fact that the country has many interests in other parts of the world. Much of the resources that make up the basis of its economy do not come from this region.

Climate change impacts in the region happen at a faster rate and more severely than anywhere else in the world. These effects dramatically re-map the geopolitical image of the region. As the ice cover retreats, new opportunities and new security challenges and threats emerge. (Padányi 2010)

However, the earlier rumours – unprecedented commercial traffic and the opening of new shipping routes – turned out to be too optimistic. Similarly to the predictions about the military conflict in the region, which are usually marked *all free,* rather the increased interest in the region has led to intense political processes between the Arctic states. Due to these political processes, the region gradually came in the forefront of interest.

2. The Arctic Strategy of the Russian Federation

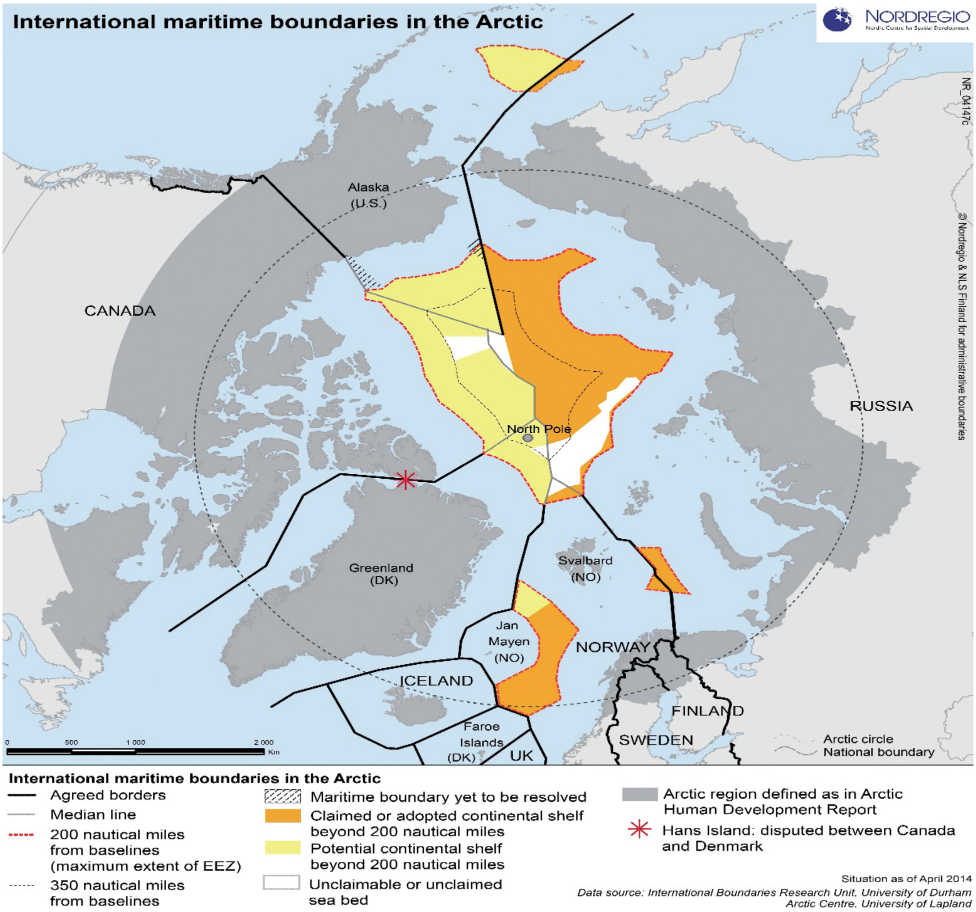

Figure 1.

The international maritime boundaries in the Arctic

Source: nordregio.se

Russia is the largest coastal state in the Arctic region. The country's Arctic Strategy was published in 2009, with a summary sentence: "Maintaining Russia's Leadership in the Arctic Region." (Heinen 2009) Does the above summary sentence really cover the policy goals that the Russian Federation's Arctic policy represents and will be characterised by 2020?

The document approved by the Security Council of the Russian Federation highlights the main goals that are only formulated in general terms such as socio-economic development, military security, environmental security, science and technology development. The aim of the document is to preserve the peace and security of the region and the need to create international cooperation. In a study on Russian foreign and security policy, Zysk (2008) writes that the military Arctic force, Artic Spetsnaz (Special Operations Force) is intended to protect Russian national interests in the Arctic region. The study also points out that Russia is aiming at achieving the status of a great power and an important element of this aim is the development and modernisation of its naval forces. Here it is necessary to point out that Russia's military doctrine has played a major role in the development of the Navy and in the modernisation and development of its nuclear submarine fleet which is subordinated to the Northern Fleet. Of course, the Arctic region is not only important for Russia's foreign and security policy as a result of obtaining the coveted great power status. During the Cold War years, Russia has monitored huge maritime areas, but changes in the climate have offered new potential economic opportunities for the country. The highlight of Russia's Arctic Strategy is the exploitation of economic opportunities. The strategic document states that both the shipping and the oil and gas infrastructure should be built and developed in the region.

The development of shipping infrastructures is also necessary because of the need for special diving vessels for the North Atlantic transit, due to the low depths of the Kara and Laptev seas and because of the lack of ice-breaking vessels during the autumn and winter period when the section is not navigable. Another purpose of the development is that the port infrastructure used for inland waterways should be made available for commercial navigation, as well. According to the IPCC report, (IPCC 2007) the ice cover in the Arctic will be melted over the next decades, which will open a new shipping route in the North Atlantic, which is the Northern Transit route, some of which also affects Russian waters. The development of commercial shipping, which shortens the routes between the Atlantic and the Pacific, raises a number of questions which are not answered in the Russian Arctic strategy, however, we can have an image on the basis of the statements of the Russian politicians and security experts.

In Russia's Arctic strategy, however, the position on the Svalbard Islands does not appear, but Gennadiy Oleinik (2009), chairman of the Russian Federal Council, is well versed in the Russian position on the archipelago: "It is necessary and important to secure the Russian presence in this region." (Oleinik, 2013) Russian political and military circles think that Norway's position on the island group is unfair and legally dubious, with the aim of keeping Russia away from the islands and adjacent waters. As it has been already mentioned, (Márton 2012) Russia does not recognise the protected fishing zone established by Norway around the archipelago. In the coming years, Russian politics will have to respond to the question of how Russia is developing a relationship with the NATO member state Norway in the changing geopolitical situation. It should be noted that one of the highlighted points of the Russian Arctic is to secure the Russian borders in the region. The settlement of border issues is complicated by the fact that they are located in the Arctic region or have established boundaries or are partially covered by the UN Convention on the Law of the Sea or bilateral agreements are reached between maritime borders between the two parts. However, with the change in the geostrategic situation, disputes occur over and over again on the boundaries set for the fishing and shipping options. It is a fundamental strategic interest for Russia to ensure its maritime borders, as it can exploit only this way its economic potential in the region in the coming years and decades.

3. The Russian–American Maritime Border

In 1867, the United States of America bought Alaska from Russia. (U.S. Library of Congress s. a.) With the purchase, the agreement also defined the sea border between the two countries. During the Cold War period, the border was continuously monitored by both navies. When both countries signed the UN Convention on the Law of the Sea that the United States of America did not ratify, Russia had to amend the agreement reached in 1867 due to the creation of exclusive economic zones. In 1990, Foreign Ministers of the East changed the agreement on sea borders, but after the collapse of the Soviet Union, the emerging Russia did not ratify the agreement with the inability to create a disadvantageous situation. Russia wants to review the contract on the grounds that its fishing vessels have access to cross-border fishing quotas. The United States of America rejected the Russian request. Although according to international law the United States is in the right, there is a continuing conflict between the two countries in the Bering Sea. Do the economic interests only motivate the Russian political circles? The answer is not that simple in this case because not only the changes caused by climate change and fishing quotas are motivating but also the shortcomings of the contract concluded in 1867. The contract's shortcoming is that Russia and the United States of America are already using a geometric projection to fix boundaries, so there is a 15,000 km^2 area bordering on the maritime borders of the two states whose affiliation is disputed. The two countries agreed that the provisions of the 1867 treaty were respected, but in the 1980s negotiations on the boundary were negotiated. The 1990 agreement stipulates the boundary between the two countries on the basis of the principle of equal distance. The resulting maritime border has a negative impact on Russia's use of maritime resources, so the country has never ratified the agreement. According to the Russian opinion, the agreement is also detrimental to the country because it has renounced the legitimate land areas and many of Chukotka's and Bering's natural gas and potential crushing mills and the sea exit used by submarines. From a Russian point of view, the fate of the agreement is still uncertain, but based on international custom, it is possible to determine the maritime power of the two countries in the current situation. At the same time, the emergence of the Russian fishing fleet in the U.S. exclusive economic zone generates disputes and conflicts between the two countries. However, addressing outstanding problems can only be negotiated when the 1990 agreement is ratified by Russia.

Russia still considers the Lomonosov and Mendeleev areas of great importance. In 2001, the country turned to the United Nations Continental Standards Committee to claim territories, as it belongs to the Eurasian continental shelf. The United Nations urged Russia to submit scientific evidence of its affiliation.

The Russian Arctic Strategy addresses both the shipping and the situation of the Svalbard Islands as a priority, but also questions about the various living and inanimate marine resources. Russia and Norway have concluded a number of agreements on fisheries issues over the last decades. Fisheries cooperation between the two countries generally works well, and the Common Fisheries Committee sets fishing quotas. Since the 1990s, there are differences between the two countries because Norway claims that Russia is overfishing the area.

During the Cold War, the southern region of the Barents Sea, the Norwegian mainland between the Svalbard Islands and the Novaya Zemlya and Franz Josef Land, secured marine resources to the settlements of North Norway and the Russian Arkhangelsk region. During this period, the Russian side had political and ideological reasons of secondary importance only because the Russian basin of the Far East was considered the primary fishing basin. (Hønnerland 2007) The most important trade stock in the Barents Sea is the Northern Arctic cod, whose fishing and fishing rights were resumed after the entry into force of the United Nations Convention on the Law of the Sea under the auspices of the North East Atlantic Fisheries Commission. Following the break-up of the Soviet Union, a large part of the agreements was not respected because of partial lack of control; a mechanism for regulation and control established in 1993 led to the two countries being able to cooperate on issues affecting the Barents Sea despite disagreements. (Hønnerland–Jørgensen 2003) However, in the millennium, a new source of conflict emerged, partly because of climate change and partly due to physiological reasons, the cod stock began to decline. Marine biologists and marine scientists have recommended that the two countries drastically reduce the fishing quotas for the stock. (Hønnerland 2007) Although Norway has in principle supported the quota reduction, the Norwegian fishing industry had a completely different standpoint. Thus, the fishing battle has also become a political battle between Russia and the NATO member state of Norway.

Russia's priorities for the National Arctic Strategy and foreign and security policy papers are to promote energy-related developments and related defence investments. The country's Arctic strategy (Government of the Russian Federation 2009) addresses energy policy as a key issue. One of the potential economic opportunities of climate change impacts on global warming is to uncover undiscovered hydrocarbon stocks in the Arctic region. Studies by the American Geological Survey have shown that the Arctic has the largest unexploited oil and natural gas resources in the world. For Russia this is also important because most of these hydrocarbon reserves are located on the Russian Arctic. The currently known sites are located on the Russian Arctic, on the continent and partly on the territorial waters, about 500 m below sea level.

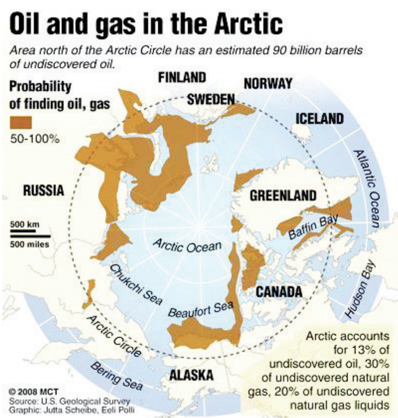

Figure 2.

Oil and gas in the Arctic

Source: www.mcclatchydc.com 2018

That is why, the holding of energy resources on the Barents Sea and other parts of the Arctic is at the heart of the Russian Arctic Strategy. Vladimir Putin (2010) when he was Prime Minister said in his speech that the holding of energy resources is a Russian national interest, but the use of military force cannot be ruled out as long as competition for the energy sources in the region emerges. "Moreover, – said the Prime Minister, – this point of the strategy provides an opportunity to improve the living conditions of local populations and indigenous peoples, as well as stimulating investment." (Putin 2010) Although natural gas and petroleum exports are a priority for the Russian foreign policy, it is important to note, that the technology in the northern region is available, no discovery has been carried out at the sites, the unpublished artefacts in the Arctic region are based on estimates.

Changes due to climate change may make the extraction of marine oil and natural gas fields in the Arctic region less expensive, while permafrost melting in land infrastructures can cause significant damage. In Putin's speech, he pointed out that the implementation of energy investments would take the most stringent environmental standards into account. The mention of environmental factors and the environment is presented as a new element in the document.

4. The Arctic in the Russian Military Thinking

The Arctic has occupied a very special place in the Russian defence strategy since industries and infrastructures with significant economic potential have been installed in the region since the 1950s. In addition, the Northern Fleet is located in this area, as part of the Russian nuclear deterrent. (Márton 2012)

After the geopolitical and geostrategic appreciation of the region, in 2015 a new maritime doctrine (Government of the Russian Federation 2015) was adopted by the country. The maritime doctrine states that in the third millennium, the most important direction for civilization development will be the conquest of the world's water resources when the leading maritime powers will work alone or in co-operation with each other. (Márton 2012) Taking into account the territorial and geophysical features of Russia, as well as its place and role in global and regional international relations, it is the leading maritime great power. In addition, maritime transport plays a major role for Russia, particularly in regions where maritime navigation is the only (non-alternative) transport sector and one possible way for foreign trade. Maritime transport remains indispensable for the survival of the Far East and the northernmost areas. To this end, it is necessary to increase the participation of shipping companies in Russia on the whole of foreign trade and transit freight; modernise the trade fleet; appropriate conditions must be established for domestic plants; preservation of world domination in the construction and operation of nuclear-powered icebreaker ships; coastal, port and navigation infrastructure needs to be developed.

The exploitation of the world's raw materials is indispensable to widen the raw material base in Russia, to safeguard its food and economic independence. Conservation and further expansion of raw material stocks, the creation of a strategic reserve of raw materials, the exploitation of the mineral resources and resources of the world in the long run, the raw material reserves of the continental shelf of the Russian Federation should be defined; exploit the mineral treasures and raw materials of the world's sea.

Addressing the threat of the Russian Federation and its allies in the world, their national interests are based on the preservation of the power of the Russian Navy. The military should arrest the country's military force, take part in securing the sovereignty of the country, protect the country's rights in its exclusive economic zone and the continental shelf. It must uphold the presence of the navy in world states and take part in military and peacekeeping operations appropriate to the country's interests. In line with the maritime doctrine and the Arctic policy, the defence of the country's Arctic positions also appears in the naval policy: (Márton 2012)

The document emphasises that the Navy should ensure Russia's rights in the Arctic region and ensure the freedom of Russian activity in the Black and Caspian Sea and on the continental shelf of the country. (Márton 2012) It states that the Azov Sea must be fixed as a hinterland of the Ukraine and Russia and ensure the unobstructed passage of the Navy's units through international harbour. It is necessary to ensure the legal background of the deployment of naval forces abroad, the international legal settlement of the status of the Black Sea Fleet, and the enforcement of Russian sovereignty in the designation of the territorial seas, the exclusive economic zone and the continental nature of the country.

As it is apparent from the documents in the geostrategically valued region, the stake is enormous, as currently, the Russian fleet only reaches the Atlantic by touching the territory of the NATO member states. This generates a constant tension between Russia and the NATO. Strategically, therefore, the Russian fleet wants to increase the protection of Barentsburg and the Russian fishermen. To this end, Russia conducted a military exercise, for example in the summer of 2008 near the Spitzbergs (Barentsobserver.com 2008) or in September 2017, the Zapad military exercise. (AldriMer.no 2017) In addition, the Northern Fleet has increased its activity in the region. Since the end of the Cold War, strategic bombers flew over the area for the first time. The flights generated negative echoes from coastal countries. Meanwhile, the Ministry of Defence announced that it will create a new unequal power to support Russia's Arctic policy.

The appreciation for Russia of the Arctic region shows that its new military doctrine, adopted on 26 December 2014, mentions the Arctic region for the first time. (Government of the Russian Federation 2015) The doctrine, however, deals with the Arctic in one sentence, and it mentioned in the activities of the armed forces that their task is to ensure Russia's national interests on the Arctic.

In 2014, the Arctic Strategy Command was established at the base of the Northern Fleet, and then reinforced the bases of the Western, Middle and East military districts beyond the Arctic Circle. In October 2014, Lieutenant General Mikhail Mizintsev announced that Russia will expand its capacities in the Arctic region and will set up 10 airports and 13 air defence radars on Novosibirsk, Franz Josef, Novaya Zemlya and other priority areas. (Russia Today 2014) In December 2015, Minister of Defence Sergei Shoigu announced that four of these bases have been completed.

Figure 3.

Russian expansion in the Arctic

Source: Reuters 2017

Russia did not make any secret of the constructions carried out on the Arctic. When the existence of the Arctic Trefoil base was discovered, the Russian Ministry of Defence organised a virtual tour on its web site. (BBC News 2017) This was also of a symbolic significance since Oleg Salyukov, commander of the 2017 Victory Daily Parade, announced that Arctic units were first to be part of the parade. (PECK 2017)

5. Changes in the Arctic Policy of the Russian Federation

Russia defined the development of the Arctic region as a strategic priority. Russian President Vladimir Putin stated that the Arctic resources are of paramount importance for national security, military, political, economic, technology and environmental protection. (Kremlin 2014) While Russia traditionally treats members of the Arctic Council as partners in solving regional issues, and Western European countries are principally the primary markets for Russian energy, still because of the Ukrainian crisis and the annexation of the Crimea, the country has been *alienated* from its western partners. As a result, the Russian leadership's interests turned to the Asian and Pacific regions. The most accessible political documents already reflect this turn. Changes in Russian energy policy and turning to the East Pioneers are primarily seen as the acceptance of China as a strategic partner. This is not only a matter of considerable debate between the researchers, but also the government and its opposition, as Russia has been trying to prevent China from expanding on the Arctic until the imposition of sanctions imposed under the Ukrainian crisis. The political changes that had occurred made it inevitable that Russia would try to replace its failed Western energy partners with non-eastern countries. China as an emerging economy has a significant economic potential, but also huge raw material requirements. Much of the Russian energy sector needs capital and technological imports, which China is currently able to satisfy. At the same time, Russia has not allowed Chinese companies into research and production projects so far. The Western sanctions imposed on the Ukrainian crisis and political pressure, together, act as catalysts for the Russian political leadership, in which there is less and less political fear of China and its growing strength and the need to complete gas and other energy investments is growing. Against this background, the political and social and economic problems between the two countries hinder the rapid resolution of disputed issues. China and Russia, however, carry out a number of common developments in the Far East and Siberia. The question arises as to how much Russia is committed to the Eastern Partners in the long run? We cannot give a clear answer to this question at present.

6. The National Arctic Strategy of the United States of America

During the Cold War, the North American region and the Soviet Union were the geostrategic and geopolitical playgrounds, strategy bombers and atomic submarines travelled over and over the ice cap. After the end of the Cold War, U.S. political and civilian decision-makers turned away from the region. The region is out of the focus of official policy. However, changes to climate change have revalued the region. Now, 20 years later, diplomats and military decision-makers appreciate the region very differently from the time of the Cold War.

The effects of climate change have highlighted geopolitical calculations, potential economic opportunities, environmental problems and international cooperation that have an impact on the security of the region.

The National Arctic Strategy of the United States was announced in 2013. The introductory part of the document states:

"The United States is an Arctic Nation with broad and fundamental interests in the Arctic Region, where we seek to meet our national security needs, protect the environment,

responsibly manage resources, account for indigenous communities, support scientific research, and strengthen international cooperation on a wide range of issues." (U.S. Government 2013)

The strategic document defines the U.S. Government's priorities for the Arctic region. One of the main objectives is to enable the country to respond effectively to the challenges and opportunities in addition to the changing environmental factors. It also defines the country's national security interests, emphasising that decisions related to it must be taken on the basis of international, cultural and environmental considerations.

The United States considers itself an Arctic state. Its unique location is located next to Russia and Canada, next to the Bering Sea, the Chukchi Sea and the Beaufort Sea. In the previous section, I have written about the Russian–U.S. border issue and the immediate solution, but the U.S. is also bordering on Canadian maritime areas and waterways. These debates will not be settled quickly, as the interests of the state parties dictate otherwise.

The Arctic Strategy mentions several times that the United States Government is in favour of and supports the improvement of maritime, aerial and space capabilities that have an impact on the country's security perceptions. According to the Strategic Document, the United States has a national interest to preserve all the rights and freedoms of the sea and airspace recognised by inter-law. The following position can also be deduced from this passage:

The United States maintains that the Northwest and Northeast Passages must be international waters. According to the current regulation, these waterways cross the sea, so the coastal states have the right to determine the conditions for shipping. Internationalisation serves the U.S. economic interests and closes the Northwest Passage dispute with Canada. Another important issue is the question of submitting claims to the continental shelf, whose settlement also promotes the pursuit of U.S. regional economic interests.

It should be noted here that the U.S. did not join the UN Convention on the Law of the Sea. The rights granted by the convention cannot be fully exploited by the U.S., even if it does not commit itself. Diplomats and military decision-makers have repeatedly warned policy-makers that the United States' non-acceptance of the UN Convention on the Law of the Sea would have an adverse impact in the long run. The Arctic strategy also proposes the adoption of the United Nations Convention on the Law of the Sea, in order to be able to support the U.S. position and to demonstrate the international landmark of the Alaska continental shelf. If this happens then the state also has oil, natural gas and other resources here. The Strategy notes that the states of the Arctic region in cases where their maritime borders overlaps have begun to conclude bilateral agreements on the basis of the UN Convention on the Law of the Sea and other international rules.

Another highlight of the strategy is energy security, which has become an essential element of the national security strategy. In the Arctic, there are significant, proven and potential oil and gas resources that are suitable for meeting U.S. energy needs. The development of Arctic resources and the use of renewable resources will strengthen the country's energy security.

The emphasis in this document is to protect the changing environment of the region. Environmental issues are also being addressed in improving the living conditions of indigenous peoples, in discussions about the introduction of scientific and technical developments. The document states that efforts need to be made to ensure sustainable development in the long run. Supportive activities should be developed to address the risks of climate change and other stressors.

The strategy states that addressing the environmental issues of the Arctic requires the understanding of changes in the environment. Huge areas of the Arctic Ocean are undiscovered and we do not have much knowledge to handle the problems that arise. We can only grasp the problems that are present here in a global context. In recent years, many components of climate change impacts have been identified, which have given particular attention. The results of international research programs helped predict weather and ice changes and helped to exploit natural resources. Environmental issues include the mapping of the waterways and internal wetlands of the area covered by ice caps for decades. This is important because in the sensitive arctic environment marine navigation is safer and ecologically sensitive areas can be protected against further injury.

The Arctic Strategy emphasises the importance of international cooperation in several points, which states:

- *Enhance the capability of U.S. forces to defend the homeland and exercise sovereignty.*
- *Strengthen deterrence at home and abroad.*
- *Strengthen alliances and partnerships.*
- *Preserve freedom of the seas in the Arctic.*
- *Engage public, private and international partners to improve domain awareness in the Arctic and evolve DoD Arctic infrastructure and capabilities consistent with the changing conditions and needs.*
- *Provide support to civil authorities, as directed.*
- *Partner with other departments, agencies and nations to support human and environmental security.*
- *Support international institutions that promote regional cooperation and the rule of law.* (U.S. Government 2013)

The intensified co-operation of the document has been realised within the Arctic Council over the past period and has focused mainly on energy and environmental issues in the U.S.

7. The Arctic in the American Military Thinking

The strategy of the U.S. Department of Defense is based on the National Security Strategy issued in 2009, the National Security Council Directives and the National Strategy for the Arctic Region published in 2013, as outlined above. The Arctic Arsenal Strategy of the Department of Defense is located between two comprehensive national documents. The Department announced the strategy issued in 2016, referring to significant changes in the international environment, based on the National Defense Authorization Act. The document states: "The Arctic region is a secure stable region where US interests are protected, protecting the United States, and nations working together to address the challenges."

According to the document, the two main objectives remain unchanged:

- *ensure security, support safety, promote defense cooperation; and*
- *prepare to respond to a wide range of challenges and contingencies – operating in conjunction with like-minded nations when possible and independently if necessary – in order to maintain stability in the region* (DoD 2016)

In the strategy released, the upcoming time lag will extend to 2023, the mid-term 2020–2030 and the long-term from 2030. The definition of deadlines approximates the uncertainty of future environmental, economic and geopolitical conditions and the growth rate of the human activity in the Arctic. (DoD 2016)

The 2016 Arctic Strategy updates the methods and tools to achieve the goals set by the Department of Defense to implement the Arctic Strategy. The goals set include increasing the capacity of U.S. forces to protect the country and exercise sovereignty, strengthen deterrence both domestically and abroad, strengthen partnerships and alliances, safeguard the freedom of seas on the Arctic, defence forces into arctic infrastructure and capabilities in line with the changing conditions and needs.

According to the Department of Defense, security includes a wide range of activities, such as resource extraction, fishing, trade, scientific research and nation defence. U.S. Arctic Military Objectives support broader national security goals in the Arctic Strategy and Arctic politics. According to U.S. military thinking, military activities in the region should be developed so that conflicts can be avoided. It is necessary to anticipate and respond to emerging security challenges in order to promote the implementation of U.S. national security objectives.

At the same time, the Department of Defense held several large-scale military exercises in the Arctic region, working with Arctic and non-Arctic allied nations. The purpose of the exercises held was to improve preparation and cooperation skills in bad weather conditions.

The second part of the Strategy commands commanders of combat forces to prepare for answering unexpected events and to develop military response options. In planning, the commanders should focus on the existing forces and solve the problems they face. Commanders advise their superiors about the potential surplus resource they may incur. According to the Department of Defense, the development of military requirements and capabilities play an important role in preparing for the fulfilment of its obligations.

The current requirements of the Department of Defense, known as the Joint Capabilities Integration and Development System, are the primary decision-making process for the development of military forces. The current system is a need-centred process that identifies, evaluates, validates and prioritises common military capabilities. The process takes into account the full range of material and non-financial solutions. (DoD 2016)

From a military point of view, the United States North command is responsible for operating capabilities in the Arctic environment. The headquarters created the Arctic Capability Advocacy Working Group to examine the identified deficiencies and establish a ranking for limited resources within the shortest possible time. For the execution of the Arctic region military tasks, two Headquarters are responsible for USNORTHCOM and USEUCOM. The command team of the USNORTHCOM works closely with Canada. If tasks and strategic challenges so require, each headquarters will share its information within the Office of the Secretary of Defense and will coordinate the commands of the headquarters. (DoD 2016)

As it is apparent from the foregoing, U.S. military thinking has not yet attracted much attention to the region as Russia had. Military considerations are not prioritised in the current situation and division of tasks and implementation is also shared between designated command niches.

8. Changes in U.S. Arctic Policy

In recent years, the United States Arctic policy faced many challenges. On April 24, 2014, the United States took over the Arctic Council Presidency. (The Arctic Council 2014) The Presidency provided an opportunity to shape the political agenda of the region. The Bureau's position in the Arctic Council is not necessarily a strong one, but the U.S. had to use it to foster Arctic economic freedom and to increase developments in the United States with the region and Alaska. Promote work in the field of peaceful settlement of border disputes in the past and the evaluation of the European Union observer's request. During the Presidency of the United States, there was only a limited advance, and cooperation with the next Finnish Presidency was of decisive importance. The security of the Arctic has already been discussed in various U.S. strategies, but the United States has not been able to raise the security challenges of the region under the 2016 Warsaw NATO summit. The military alliance, a security organization that guarantees the territorial integrity of its members and includes the Arctic region and its five member states[1] is an Arctic country, has no common stand on its role in the Arctic. (Coffey–Kochis 2016) Earlier NATO summits identified new security challenges – energy security, cyber security – the security of the north corner was not included in either. (NATO 2016) The American stand is known about the economic freedom of the north heel. Current knowledge suggests that shipping, tourism and resource exploration will increase in the near future. The region is rich in minerals, wildlife and fish, and therefore the best way to improve the living conditions of the Alaskan population is to pursue policies to promote economic freedom. Economic freedom promotes the alleviation of regional social and technological backwardness with an effort to reduce the effects of natural disasters. Among the economic challenges we have to mention are the inhabitants of the Alaska archipelago.

In recent months, an emerging, non-regional state has challenged U.S. interests. This country was China. China's new Arctic strategy (The State Council 2018) clearly defines the interests of the country in the region. According to the document, the region is the third silk road, the *blue economic gateway.* This means that China does not seek to increase its presence in the region by increasing its economic interests and infrastructure investments, not by military force. The strategy was also the launch of high-level diplomatic visits. The President of China met seven presidents of states from the Arctic region in the past. A high-level diplomatic delegation from Iceland came to further deepen economic relations between the two countries. During his visit to the United States, the Chinese President met with the American President and the Alaskan Governor. The meeting focused on China's new Arctic strategy and issues of central concern in the region on shipping routes, oil and mineral resources, fisheries and tourism. Because of China's developing economy, it needs alternative resources. American policy-makers have to see that this development has an increasing influence, which is challenging in the short term, and in the medium term, it encroaches on American interests.

The challenges outlined above and the strategies already developed may, in the short term, also generate changes in American politics. In the current situation, these changes are not yet apparent and appear only in one area. The radical change in regional policy requires

[1] Canada, Norway, Denmark, USA, Iceland.

years and is likely to be a demanding challenge for immediate response not only to domestic politics but also to foreign policy.

9. Comparison of the Strategies of the Two Countries

In the 21st century, the Arctic region is gaining more and more geopolitical and geostrategic importance. Over the last two decades, due to the effects of climate change, a number of major changes have taken place in the region. Changes to environmental safety clearly define the economic development and development potential of an area. In the above, I presented the Arctic strategy of a regional great power, Russia and a *superpower,* the U.S. Over the last two decades both the world and the two countries have changed significantly. Russia was born after the break-up of the Soviet Union and reached its current status after political, economic and social crises, while the situation in the United States did not seem to change. Learning from the historic lessons both states treat the same region differently and see other opportunities and weaknesses in it. Experts warn that there are a number of latent conflicts in the Arctic region, which do not even rule out military clashes, but the countries in the region are trying to find a peaceful solution. The question arises, however, whether any problem can be solved, and the issue of state sovereignty can be settled peacefully. The answer is complicated because it needs to be built on a geostrategic chessboard. The next question group is about the situation of the economic sectors, which can be classified in several respects. In this paper, I highlighted only a few sectors that make the comparison possible. I have finally left military security issues because of the need for political academic and economic strength.

Let us now consider the strategic priorities of the two countries. While the Arctic region was not pushed out of the strategic thinking of Russia in recent decades, the U.S. political decision-makers and diplomats have forgotten the region. The difference can be well characterised by numbers. Russia's Arctic area accounts for about 50% of the region, (arctic.ru s. a.) whereas the size of the U.S. area of the region is negligible. From the point of view of security and defence policy documents of the two countries, we can conclude that Russia have been afraid in the region for the past two decades of the U.S.-led NATO invasion policy, and it has tried to show a policy that partially neutralises this in their security policy documents.

From an economic point of view, however, the crisis has stressed for Russia the stock of oil, natural gas and mineral resources in the Arctic region, which made it possible for them to be able to receive stable returns. In addition, there are about 4,000,000 people living in the Russian Arctic region, (arctic.ru s. a.) which the Russian state has to carry with industry. By contrast, the situation in the United States is quite different, as there are a small number of people living in the Alaskan area. From an economic point of view, infrastructure shortages need not encourage investment and the country has not faced any challenges in using mineral resources and renewable energy sources in the region.

Energy security is mentioned in the strategy of both states, but the Russian strategy is discussed in a separate section, while the U.S. strategy calls for national security strategy.

The strategy of both countries states that it aims to maintain a conflict-free region. However, none of the countries' strategy has any reference to how this is imagined. It should be noted here that the region has been subject to numerous latent conflicts. Furthermore, both states have settled border disputes. In addition, the continental shelf is a growing source of tension. Russia undertook to provide geological evidence to the UN Continental Landfill Commission on the areas it requires, but the rest of the region has not made such a commitment. The question of the use of waterways freed by melting ice in the region appears as a source of conflict. As I have already pointed out in the study, the relevant part of the Russian Maritime Strategy and American opinion are different from each other. The situation is complicated by the fact that the NATO member state Canada agrees with Russia on this issue, and China also wants to use the shipping routes freely. If both states intend to negotiate the possible sources of conflict negotiated, then negotiations on these issues should be started.

Numerous publications have appeared on the vulnerable species of the Arctic region. Environment organizations report on the destruction of indigenous animal and plant species in the region. More and more analysis deal with how the retardation/decrease of the ice cap affects these species. The issues of environmental protection are outlined in the Arctic strategies, but the emphasis is significantly different. While the U.S. strategy puts itself in the context of research and understanding of the environment and the effects of weather change reduction, the Russian strategy speaks of enhancing the protection of existing infrastructures and merely refers to the protection of the sensitive Arctic-country environment. Although the Russian strategy does not raise the issue of environmental protection, many areas of nature conservation have been built in the Russian Arctic, partly during the Cold War and partly in the last 20 years. In these nature conservation areas, numerous research have been carried out to increase the number of endangered species. (Kremlin 2017)

In this part of the study, I have also dealt with the issue of using waterways. Not only international regulation and state sovereignty should be analysed, but also an economic point of view should be taken into consideration. As a result of sea ice retreat, and due to the rise in the number of ice-free days, traffic on the Arctic region is growing year by year. Growth is currently being generated by commercial fishing fleets, but commercial vessels crossing the region have already appeared. According to expert materials, regional ship traffic will exponentially increase over the next decade. The revenue of merchant shipping traffic is shared by coastal countries, since port user fees and other service charges such as the necessity of icebreaking capacity are being charged. However, the increasing traffic flow is far behind the forecasted magnitude, and the Arctic region waterways are shorter than those passing through the Suez Canal, but due to easier navigation, significant traffic is not expected in the short term. The other branch of commercial shipping, which means hiking boats, has also started to grow. In the Arctic region, Franz Josef Land and Norway showed significant traffic growth, and the number of vessels used by tourists has increased significantly on the Greenland coasts. The increase in traffic is partly due to the fact that the northern countries (especially Europeans) try to attract tourists with a number of cruise ships. (Brigham 2016)

The growth of regional tourism has brought the development of other industries, as well. In many areas, traditional handicrafts have been developed, as well as a range of services to cater for visitors. Because of the development of the economy, unemployment in Europe has fallen.

The U.S. strategy deals with the economic development of the Alaska region as a key issue because it is in disadvantage compared to the other parts of the country. The Arctic Region Policy announced by President Obama has not strengthened the economy of the area and the service sector is weak. The Trump Administration, on the other hand, seeks every opportunity to keep the region below the regional comparison. At the same time, economic realities are not yet ready for achieving rapid results because the country still has very little investment in the region. The infrastructure needed for commercial shipping is in many places incomplete or very poor. The partial absence or limited availability of modern telecommunication networks also does not support the development of the economy. Another problem is that there is no regional economic development strategy for the North American region.

The Russian strategy discusses the possibilities of economic development in the energy sector. A significant part of Russia's oil and natural gas deposits are located in the Arctic. That is why the country is aiming to develop areas beyond the Arctic Circle. Russia's neighbouring areas of the European Union are in favour of investment and the development of service sectors because many of these programs have already been implemented in the Barents–Arctic–Euro region, which was jointly established with the Scandinavian countries. In the rest of the country, the reconstruction of former Soviet infrastructures has begun according to the central political will. Due to investments, unemployment has fallen in many areas and the standard of living has risen.

The strategy of both countries includes defence elements. However, the position of the region in military thinking can only be interpreted from military strategies. During the Cold War era it was a *great power playground* where strategic bombers flew and nuclear submarines were hiding under the ice cap. However, times have changed. As the Cold War ended, the region was left out of focus of the American defence thinking. It is due to this that the U.S. Navy's strategy for the region was only modified in 2016. In addition, enhancing defence capacities and rebuilding icebreaking capacity in the region is also slow.

On the other hand, the Russian military thinking, partly because of economic opportunities, partly because of the stationing of the North Fleet and other geopolitical reasons, did not turn away from it. In the current situation, Russia maintains the largest military units in the region. This means not only the development of the North Fleet, but also the beginning of the reconstruction of the former Soviet military bases. In recent years, new bases and airports have been developed in the region.

Over the past few years, fighting units have appeared on the Arctic. Both states organised a number of large-scale military exercises. Among others, the Cold Response exercise in 2013 or the Northern Flag exercise in 2016, which is organised annually with the participation of NATO member states and partner countries, where the United States took part for the first time. Of course, Russia also takes part in the Arctic exercises. Since 2013, it has been conducting periodic exercises with its various military units in the region. (Klimenko 2013)

It is evident that the two countries have been carrying out a number of military operations in the region.

Looking at the military aspects, it can be seen that the international regulation in the region is incomplete and cannot be applied to the current situation. There is no special rule developed in the Arctic region at international level to regulate the use of the region and limit the use of military force. The current rule is the UN Convention on the Law of the Sea and

International Law. In the region, there is a single international convention, which applies to the Svalbard island group, the so-called Svalbard Convention determining the status of the area. Despite political aspirations, inadequate international regulation and disputes over maritime borders make the region in the medium term unstable. From a military point of view, at many points in the Arctic Ocean, shipping requires a sober and extraordinary navigational knowledge, since in shallow seas safe travel is cumbersome. Although a number of maps have been made in the region over the past decades, the retreat of the ice cap may still have many surprises. From a military and defence point of view, the size of the maritime areas controlled by the Navy is hundreds of thousands of miles. Naval units and the Coast Guard have to carry out a number of tasks.

Table 1.

The Coast Guard task

Types	**Maritime task**
Law–Defence:	Policy tasks (antiterrorism, smuggling)
Law:	Board controlling
Law–Environment:	Fishery controlling
Defence:	Defence of state sovereignty
Security:	Research and rescue, helping passing and navigation
Security–Environment:	Oil pollution and other environmental damages liquidation

Source: Østhagen 2016

At the same time, it should be noted that the table presents the tasks in general, and the countries of the Parallel region have developed a function and organizational form corresponding to their national interests.

In the region, military considerations and task groupings can be analysed in many ways. In this short summary, I outlined only the most important aspects of the sketch.

10. Summary

In this paper, I have elaborated a security and defence policy theme. I have presented and compared the Arctic Strategies of the United States of America and the Russian Federation. An international outlook was needed to make the processes in the region more understandable. The Arctic region has undergone many major changes in the post-Cold War period because of the effects of climate change. After the Cold War came to an end, it became the focus of international politics, and about two decades later, awakening from sleepy dreams, it became the focus of geopolitical and geostrategic interest. The Arctic region has a number of latent problems, but the countries in the region want to keep it as a conflict-free zone. On the geostrategic chessboard, there is a need to bring a number of interests into line at some level so that only latent problems can be solved in a negotiated manner. Most of the problems are caused by shortcomings in international regulation, but economic and environmental security issues should not be ignored. These are those that have emerged due to the effects of climate change. These effects have largely determined and still determine the future of the Arctic region.

In general, we are talking about the effects of climate change in the region, but there is very little talk about reducing adverse impacts, preserving economic infrastructure and protecting indigenous species. The question may arise when approaching the Arctic strategy of the two countries, based on security and defence policy, why it is necessary to talk about the effects of climate change. I found it important because the foundations of the current opportunities, challenges and potential military emergencies in the Arctic region were created by climate change. Another question may be what kind of benchmarking evaluates the strategies for a comparative analysis. In this analysis, based on the limits of space, I presented the chosen topic based on the few strategies available, as well as other strategies that might be associated with them, using the possibilities of subjective emphasis, economic development and military aspects. Although I have been dealing with the Arctic region strategy of the Russian Federation several times before, I have made this type of comparison for the first time. Security and defence policy comparisons always linger a little, since countries have to be assigned a place at a given moment within a region, but realpolitik cannot be completely disregarded, as well.

The current situation of the two countries, as I have shown, is quite different. Russia was the successor state of the Soviet Union, a nuclear power. The formation of the country has involved many political, economic and social problems. Political and economic crises followed each other, while the country had no major influence zone. The former Soviet offspring were partially removed from this area. Russia needed time to recover and reorganise the economy on a market basis. By contrast, the United States of America retained its place in the world and strengthened its ability to enforce its interests in some regions. It was not shaken by a social and political crisis, but the economic crises in the wider economy could not be avoided. With all this, its economy has provided a stable background to its political goals.

The political understanding of the Arctic region is well reflected in the strategy of both states, and also shows its role in political thinking. While Russia's economy relies on mineral resources, oil and gas resources in the region, so far the resources of the United States' economy have only been secondary. It is apparent from the current U.S. strategy that the issue of energy security already accounts for raw materials in the region. The country sees the future in research and development and wants to continue to develop environmentally conscious developments. Russia's economic policy and energy security are different in terms of raw materials in the region. Russia is already actively using the accessible resources here. It has also played a decisive role in setting up its economy and has the resources of the region. Discussions about fisheries issues are more likely to occur only from Russia, because a significant part of U.S. vessels work in the Bering Sea. Due to the migration of indigenous fish species, U.S. merchant fishing fleets will be more likely to appear in the area in the near future.

Over the next decade, the effects of climate change will boost momentum in further economic sectors. These include the steep rise in Arctic tourism. The increase in commercial traffic flows brings with it the opening of islands to the public that have not been visited so far. However, the natural environment will be threatened by the escalating tourist traffic. In the first part of the analysis, I have already indicated that the strategy of both countries is to protect the Arctic environment. Environment-related issues are more emphasised in the U.S. strategy, while the Russian strategy only mentions it. This is because Russia has independent state and regional strategies to address climate change and its impacts, including environmental issues.

Comparing the Arctic strategy of the two countries, I have determined that the priorities of the Russian strategy are best suited to the current situation, but the American strategy only outlines the objectives to be achieved in general. Changes in realpolitik have to change the views on the region, which the Russian official bodies are constantly communicating, while the U.S. is doing it so very narrowly.

One of the most important points in my paper is the role of the region in military thinking. It is clear that each state wants to maintain the region as a conflict zone. Current military thinking does not reckon, either in the short or medium term, with the outbreak of a military conflict in the region. It is apparent, however, from the study of the Russian naval and military strategy that Russia has begun to militarise the region. On the American side, the change in naval strategy shows that more and more armed units are and will appear in the region. All this is evidenced by the recent military exercises.

I believe that the security and stability of the Arctic region and its economic prospects will determine the security of the region's states in the near future. American policy-makers have not been concerned with the region for years. The most striking consequence of this is the lack of infrastructure investments in Alaskan areas. The Obama Administration composed the country's Arctic strategy late, as it was released in 2013. The shift of the American administration has brought a slow but steady change in the country's Arctic policy. In the future, the U.S. official policy is expected to give greater attention to the region. Consequently, the emergence of more ambitious economic and military interests cannot be closed in the medium term.

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The Effect of Climate Change on Occupational Heat Stress and Its Impact on Human Health

1. Introduction

The United Nation's Intergovernmental Panel on Climate Change (IPCC) reported in 2014 the health outcomes and other consequences of lost work capacity and reduced labour productivity due to rising temperatures. The most recent Report also gives greater attention to the high-end climate scenarios, reflecting recent research and the persistent failure of international negotiations to make credible progress toward substantial reduction in emissions. Some scenarios project warming of 4–7°C (on average) over much of the global landmass by the end of the 21st century. If this change happens, then the hottest days will exceed present temperatures by a wide margin and increase the number of people who live in conditions that are so extreme that the ability of the human body to maintain heat balance during physical activity and unprotected work is no longer possible. Other risks are associated with high-end scenarios, for instance, those affecting urban settlements, food production, and water resources. (Woodward et al. 2014)

The World Health Organization (WHO) has estimated that all populations will be affected by a changing climate. Elderly people, women, children and people carrying out heavy labour in hot environments, and poor people in general are more vulnerable than others. WHO is appealing to policy-makers to take the right actions as soon as possible.

In Hungary the climate change-related research began at the beginning of the 2000s. Health impact assessments were carried out, and the effects of heat waves based on real-time health data were continuously monitored. Research has also been carried out in relation to vector-borne diseases. Changes in flowering seasons and the spread of allergenic plant species are also an important public health issue. Extreme precipitation and more frequent floods have focused attention on the need to protect vulnerable drinking water sources and to elaborate complex flood prevention and mitigation plans. The years 2007 to 2011 drew attention to the increased variability of weather and temperatures. The results of these studies, along with international experience, reinforce the need for climate change adaptation. (Bobvos–Páldy 2009)

Hungary's heat-health warning system was described within the project *Prevention of Acute Health Effects of Weather Conditions in Europe* (PHEWE 2003–2005). Budapest was one of five cities in which such a system was created by the chair of meteorology at the University of Birmingham. (Páldy–Bobvos 2008) The heat-health warning system was based on daily mortality and meteorological data for Budapest. The Hungarian research group created a three-level warning system based on temperature thresholds defined in a time series analysis of Budapest data for the 1970–2000 period.

- First warning level (for internal use): when the daily mean temperature is forecast at ≥ 25°C for one day, with a likely 15% excess mortality.
- Second warning level (alert): when the meteorological service forecasts a daily mean temperature of ≥ 25°C for at least three consecutive days with 15% excess mortality; or when the forecast daily mean temperature is ≥ 27°C for one day with a predicted excess mortality of 30%.
- Third warning level (alarm): when the meteorological service forecasts a daily mean temperature of ≥ 27°C for at least three consecutive days with excess mortality of 30%.

There were two heat alerts in 2011, and four in 2012. In 2011, the excess mortality was 5.4% at country level during the second-level heat alert, and 17.4 % during the third-alert. The highest excess mortality (22%) was recorded in the North of Hungary during the second-level alert, and 23% in Central Hungary during the third-level alert. A total of 593 excess death cases were registered during the heat alerts in 2011. In 2012, the excess mortality was 33% in the capital during the third-level heat alert (13 days), while the excess was 27% at country level. Altogether 1,666 excess death cases could be attributed to the 26 days of the four heat alerts. In both years, mortality among women during the heat alerts was somewhat higher than among men, the difference being bigger during the third-level alerts. In terms of age, mortality rates were differed between the 0 to 64 age group and the 65 to 74 age group. In the latter group, almost twice as many elderly people died during the heat alerts than in the younger age group. In spite of the heat alerts, excess mortality during heat waves was registered each year, the absolute number of heat-related excess deaths being highest in 2012 (1,666 cases) out of the last 10 years. These facts underline the need to create more effective measures to prevent heat-related excess mortality. (Páldy–Bobvos 2012)

2. Human Response to Hot Environments

It is well known that a normal person's core body temperature at rest is close to 37°C. To keep the core body temperature at 37°C, the body needs to transfer metabolic heat to the surrounding environment and insufficient heat interactions will lead to a raised temperature and serious health consequences.

Six parameters were found to have caused the heat exchange between human beings and the environment in which they live; air temperature, radiant temperature, humidity, air movement, metabolic heat generated by human activity and clothing worn by a person. The first four are the major determinants in heat interaction. (Parsons 2003)

The metabolic heat production is a non-stop procedure which will always produce heat, and the heat will flow away from the body through breathing warm air out. If the external environment's air temperature is lower than 35°C, most of the metabolic heat from the body will directly flow out to the environment. On the other hand, if the environment's air temperature is higher than 35°C or if the person is doing some activities then the main way of cooling the body temperature is through secreting sweat for evaporation. (Miller–Bates 2007)

It is these six basic parameters which are believed to cause the metabolic heat produced in the body to be dissipated through the process of respiration, evaporation, radiation, conduction and convection. Insufficient dissipation of heat will lead to different heat illnesses while long term insufficient dissipation of heat will lead to chronic diseases such as cardiovascular and kidney diseases. (Kjellstrom et al. 2009b)

2.1. Heat waves and public health

Due to climate differences, each country has its own critical level for a heat wave, but generally, heat wave can be defined as: "a prolonged period of excessively hot weather, which may be accompanied by high humidity". Heat waves cause lots of heat related diseases such as heat stroke, cardiovascular diseases, respiratory diseases or kidney diseases. Thus heat wave increases the morbidity and mortality of a country and therefore it needs attention from the public health sector.

In 2003, heat waves caused 14,802 deaths within 20 days in France, 3,134 deaths within 12 days in Italy, 1,854 deaths within 20 days in Portugal and 3,166 deaths within 30 days in Spain. It was after the disastrous consequence of heat waves which happened in Europe in 2003, that most of the Western European countries had implemented health warning systems for making people aware of upcoming heat wave days. This was a significant contribution from the public health sector of those countries. (Kovats–Hajat 2008)

In Hungary, the National Adaptation Geo-Information System (NAGiS) helps the adaptation process of climate change. The Hungarian Central Statistical Office provided the daily mortality data for the period of May 1 – September 30, 2005–2014. The observed daily mean temperature data for the same period at small area level (NUTS 4, Nomenclature of Territorial Units for Statistics) was provided by the Hungarian Meteorological Service (HMS). The modelled daily mean temperature data at NUTS 4 level based on the ALADIN-Climate model for three periods, May 1 – September 30 of 1991–2020, 2021–2050, and 2071–2100, was also provided by HMS.

During 2005–2014, the range of daily threshold temperature was between 22.3°C and 25.4°C, the mean excess mortality was 15.8% on the heat wave days at NUTS 4 level. At national level, daily mortality was higher by 51 cases on heat wave days than on cool days, which corresponded to an excess of 783 death cases per year in average. According to the climate model, the number and intensity of heat wave days will increase in relation to the present situation. Assuming the same population and level of sensitivity, for 2021–2050 a 2.6-fold, for 2071–2100 a 7.4-fold increase of excess deaths is predicted causing 2,030 and 5,800 cases per year, respectively. (Bobvos et al. 2017)

2.2. Heat related disease

People working in high temperature environments with no sufficient cooling measures, are under the risk of getting occupational heat stress. People exposed to occupational heat stress have many negative impacts on health, which can even lead to the risk of developing heat related diseases.

Heat illnesses include:

- Heat stroke: occurs when the core temperature is over 40.5°C. The symptoms would be dry skin, rising core temperature, fail of excreting sweat, loss of consciousness and so on, it would lead to death if treatment cannot be applied in time.
- Heat syncope: often occurs before acclimatisation. The main symptom is fainting.
- Heat exhaustion: occurs after a long time of exposure to high temperature environment and dehydration. The main symptoms include fatigue, headache, a feeling of vomiting and small amount of urine.
- Heat cramps: could occur after the body lost sufficient amount of salt. Cramping mainly in the abdomen, arms and legs.
- Heat rash: normally occurs when the skin is continuously exposed to hot wet environment.
- Heat fatigue: occurs after a long time work in high temperature and could directly lead to loss of work capacity and concentration. (Parsons 2009)

The rise in temperature is paralleled by an increasing shortage of water, with the percentage of the world population suffering from moderate water shortage (defined as 1.0–1.7 m^3 water/person per year) rising from 5% in 1800 to 50% in 2005, and with 10% of the world population currently suffering from extreme (< 0.5 m^3 water/person per year) water shortage. (Kummu et al. 2010) While increased risk for heat stroke is an obvious manifestation of global warming, climate change affects health in many other direct and indirect ways. (Luber–Lemery 2015) Dehydration secondary to heat stress (relative water loss with development of hyperosmolarity) is associated with cognitive dysfunction, hypotension and acute kidney injury. (Lieberman 2007) Alterations in water supply, with variations in precipitation, can lead to emergence of water-borne and vector-borne infectious diseases. (Warrick 2015) Drying up of wells can lead to increased concentration of heavy metals and/or toxins. Furthermore, subjects who are chronically dehydrated may not excrete toxins as effectively as those who are well hydrated, leading to higher concentrations of toxins in the serum and kidney. In addition, chronic dehydration and hyperosmolarity have also been linked with increased risk for obesity, diabetes, coronary heart disease and metabolic syndrome. (Stookey et al. 2007)

The physiological changes taking place in the body due to exposure to occupational heat stress are as follows:

- Impact on the circulation system: working in high temperature environments results in excretion of large amount of sweat which increases the heartbeat, blood pressure and cardiovascular burden of the body.
- Impact on the digestive system: working in high temperature would result in loss of appetite, indigestion, and slowing down the movement of the small intestine which directly lead to lots of gastrointestinal diseases.
- Impact on the urinary system: people working in high temperature environment need to excrete a large amount of sweat which directly results in the concentration of urine and give burden to the kidney.

- Impact on the nervous system: working in high temperature will decrease the ability of work, coordination, accuracy of movement and the speed of response whereas it increases the distraction of attention.

Working in high temperature environment not only has a negative impact on health, but also affects work capacity. If the ambient temperature is high, the person working in the environment not only has to reduce the intensity of work but also has to take rest more frequently, in order to reduce the production of the metabolic heat to keep the body's core temperature at a normal level which would result in lower labour productivity.

Workers in outdoor occupations with a high physical load are most at risk of severe heat exposure. Furthermore, workers at high risk are required to wear semipermeable or impermeable protective clothing and/or personal protective equipment (PPE) that severely impedes heat exchange through evaporation. (Bernard 1999)

Heat can cause workers to take off protective clothing due to discomfort, putting the worker at high risk for dangerous exposure and injury. (Wästerlund 1998) There are also possible heat implications for indoor workers in buildings without air conditioning or proper ventilation systems during heat waves. Most of the heatstroke deaths reported have been associated with occupational exposure at construction sites, agricultural settings and hot industrial jobs requiring heavy work. The increased cardiovascular load experienced during heat stress compromises the capacity for physical work. (Holmér 2009) Cognitive and physical performance decrements can occur at hyperthermic and/or dehydration levels lower than those causing heat injuries. (O'Brien et al. 2011) Furthermore, socioeconomic factors such as income and urbanisation can compound the adverse health outcomes from heat stress on workers as it may indirectly cause psychological distress due to reduced work productivity, lost income and disrupted daily social activity. (Tawatsupa 2010)

Heat exhaustion is most often preceded by dehydration and is usually associated with unacclimatised workers. Heat stroke in otherwise normal and healthy people results from a combination of excessive heat exposure and physical work. Fluid requirements generally depend on work rate, the ambient climatic conditions, and on individual physiological and biochemical characteristics.

Implementation of strategies to maintain adequate hydration is the single most important intervention in the management of work in heat. Where this cannot be achieved, it is necessary to set dehydration limits of the percentage lost in body weight (e.g. a 2% decrease translates into 1–4 litres of liquid). (Hanna 1983) Workers in hot environments must also be educated regarding the importance of drinking enough water while working and continuing generous rehydration during off-duty hours. (Miller–Bates 2010) Another intervention could be to implement traditional work-rest schedules developed for centuries to deal with heat, instead of simply implementing an industrial model, or to develop individual work-rest schedules. Urban workers may also be exposed to additional heat stress as a result of the urban *heat island effect* of the urban built environments. (Schulte–Chun 2009)

2.3. Individual aspects

Individual factors such as physical fitness and health status play a fundamental role in heat tolerance. When working in heat, people with the highest risk are those with small body size, overweight, elderly and people with medical conditions such as cardiovascular diseases, diabetes, skin, liver, kidney and lung problems and pregnancy. Additional factors affecting heat tolerance include intake of alcohol, caffeine and nicotine. Individual differences include the effects of age, gender, body morphology, disability, aerobic capacity, acclimatization, state of health, clothing and personal protection equipment. Knowledge of the mechanisms behind subjective differences is important for risk assessment and the next sections will explore these aspects further. (Brake–Bates 2002)

2.3.1. Gender differences

Men and women have slightly different physiology, endocrinal physiology and body characteristics; one example being that men have on average greater body size, weight and strength. In general, yet with large individual differences, women have a larger surface to mass ratio, which implies that women are more prone to heat loss. On the other hand, women have a higher whole body and subcutaneous fat content than men, which in turn increases insulation. Women are known to have colder skin at distal areas, despite the increased body fat content relative to men. Part of this effect can be attributed to reproductive hormones and the menstrual phase. In general, relative to men, the thermoneutral zone of women is shifted upward (the temperature range at which the person feels *comfortable*). (Kingma et al. 2012) When comparing the sexes, it has been observed that women tolerate humid heat better as females are superior in suppressing excess sweating and therefore conserve body water. Both sweating and vasoconstriction thresholds are 0.3–0.5°C higher in women than men, even during the first days of the menstrual cycle. Differences are even greater in between menstruations. Males have higher maximal sweat rates, which may enhance tolerance for extremely hot and dry environments. (Sessler 2008)

Some studies have found that there is no or little difference between men and women in either metabolic heat production or in heat exchange by radiation, convection or evaporation. The observed superior capacity of men for sustained exercise in a hot environment is rather related to their higher aerobic capacity and not to a difference in capacity for thermoregulation. Differences in heart rate between men and women are mainly dependent on individual differences, fitness and stress level rather than differences in thermoregulation.

Females have generally higher core temperatures, heart rates, blood pressure and set points for sweating, in comparison to males. The effects of heat stress on performance seem to be more adverse for males than for females and females show a greater increase in the core temperature onset threshold for sweating in both moderate and intense exercise. (Kenny–Olley 2007)

Two specific female processes do affect thermoregulation: the menstrual cycle and menopause, although the effect of the menstrual cycle at rest (a higher core temperature in the postovulatory phase) seems to be almost absent during heat exposure. Postmenopausal hot flashes and night sweating provide evidence that thermoregulation is affected by oestrogen withdrawal. The effect of pregnancy on women's heat tolerance is not clear, but altered hormone levels, added weight, reduced adaptive capacity and the increased circulatory demands of the foetus on the mother may increase the susceptibility to fainting. Severe maternal hyperthermia (overheating) due to illness appears to increase the incidence of foetal malformation. Some studies have found that human temperature regulation is altered in pregnancy. Maternal core temperature is at its highest in the first trimester but falls during pregnancy with its lowest point at 3 months post-delivery and persists until 6 months after delivery in breast-feeding women. The causes of the delayed return to normal temperature can currently only be speculated on. It also appears that women, especially older women, are more at risk, in both relative and absolute terms, of dying in a heat wave. (Hartgill et al. 2011)

2.3.2. Climate change and productivity

Productivity is strongly dependent on thermal conditions, in particular during physically demanding work. Studies on the influence of high ambient temperature on performance have examined variables such as reaction time, tracking and vigilance, as well as memory and mathematical calculations. When the body is hot, vasodilation (a widening of blood vessels) enhances ease of body movement although sweating may affect grip, cause distraction due to discomfort, fatigue and psychological strain. Thermal conditions can affect output, accident rates, behavioural and cognitive performance. (Lloyd 1994)

The results of many studies indicate that changes in temperature of a few degrees can significantly influence performance in several tasks including typewriting, factory work, signal recognition, time to respond to signals, learning performance, reading speed and comprehension, multiplication speed and word memory. It is estimated that approximately a 7% increase in productivity is present in a workplace maintained at the population-average neutral temperature of between 20–24°C. (Fisk 2000; Balakrishnan et al. 2010) It is also estimated that productivity is affected after about one hour of moderate physical work in temperatures above 32°C. (Bell 2005)

A natural reaction of a working person to heat is to reduce physical activity, which reduces the body's internal heat production. An outcome of this preventive reaction is reduced hourly work capacity and economic productivity during the exposure to heat. As a result, the worker's action to prevent ill health will lower productivity and a loss of daylight work hours will occur. In the long term, this will affect individual, local, national and regional economic productivity. An enterprise can compensate for this by carrying out heat sensitive work during the cooler night hours of the hot season or by scheduling such work in the cooler season, but as climate change progresses, the duration of cooler periods will be shortened. In addition, some work has to be carried out during daylight. Without adaptation, the economic losses of reduced labour productivity relative to baseline could potentially be up to 20% of the gross domestic product (GDP). (Kjellström et al. 2009a)

3. Heat Balance and Heat Exchange

An essential requirement for continued normal body function is that the deep body temperature will be maintained within a very narrow limit of ± 1°C around the acceptable resting body core temperature of 37°C. To achieve this, body temperature equilibrium requires a constant exchange of heat between the body and the environment. The rate and amount of the heat exchange is governed by the fundamental laws of thermodynamics. In general terms, the amount of heat that must be exchanged is a function of:

- the total metabolic heat produced
- heat gained from the environment

The basic heat balance equation is:

$$\Delta S = (M - W_{ex}) \pm (R + C) - E \qquad \text{(Equation 1)}$$

Where: ΔS = change in body heat content; $(M - W_{ex})$ = net metabolic heat production from the total metabolic heat production (W_{ex} = mechanical work); $(R + C)$ = convective and radiative heat exchange; E = evaporative heat loss.

In the situation of thermal balance $\Delta S = 0$, then:

$$(M - W_{ex}) \pm (R + C) = E_{req} \qquad \text{(Equation 2)}$$

This form defines the required evaporation to achieve thermal balance (E_{req}). Evaporative capacity of the environment is in most of the cases lower than Ereq; and thus, the maximal evaporative capacity of the environment (E_{max}) should be considered. The ratio E_{req}/E_{max}, which denotes the required skin wettedness to eliminate heat from the body, is a *heat strain index* (HSI). (LILJEGREN et al. 2008)

3.1. The six agents of heat stress

It follows from the heat balance equation that ambient temperature per se is seldom the cause of heat stress; it is only one, and rarely the most important, of several factors that compose the term *heat stress*. The interactions of six fundamental factors define the human thermal environment and its sensation of thermal comfort. These parameters are subcategorized into environmental factors and behavioural factors. Ambient temperature, radiant temperature, humidity and air movement are the four basic environmental variables; the metabolic rate and clothing provide the behavioural variables that affect human response to thermal environment. Thus, any consideration of thermal stress should explore these six factors. (TALEGHANI et al. 2015)

Tradeoffs have been established between these six factors with respect to their effects on human comfort and infer the effect of five on ambient temperature (Ta):

- Metabolic rate: an increase of 17.5 W (above resting level) is equivalent to a 1°C increase in Ta.

- Clothing insulation (clo.): a change of 1 clo. is equivalent to a change in 5°C at rest and 10°C while exercising.
- Radiant temperature (MRT): a change of 1°C in MRT can be offset by a 1°C in Ta.
- Wind speed: a change in 0.1 m/sec in wind speed is equivalent to a change in 0.5°C in Ta (up to 1.5°C).
- Humidity: a 10% change in relative humidity can be offset by a 0.3°C in Ta. (Shapiro–Epstein 1984; Goldman 2002)

3.2. Thermal comfort

Thermal comfort is defined as: "that condition of mind which expresses satisfaction with the thermal environment". According to this definition comfort is a subjective sensation. Based on ASHRAE definition, the zone of thermal comfort is the span of conditions where 80% of sedentary or slightly active persons find the environment thermally acceptable. In terms of climatic conditions, the acceptable ambient temperature of comfort would be slightly higher in summer than in winter, being 23–27°C and 20–25°C, respectively. (ASHRAE 1992)

Fanger defined three parameters for a person to be in thermal comfort:

- the body is in heat balance
- sweat rate is within comfort limits
- mean skin temperature is within comfort limits (Fanger 1970)

These conceptual requisites for determining thermal comfort can be expressed by measurable terms as: body-core temperature within a very narrow range of 36.5–37.5°C, a skin temperature of 30°C at the extremities and 34–35°C at body stem and head, and the body will be free of sweating. (Hensel 1981) Any deviation from these assertions results in sensation of discomfort. In reference to equation 1, thermal comfort will be attained when the rate of heat dissipation from the body by means of radiation and convection (cardiovascular tone) will equal the rate of metabolic heat production and, consequently, heat storage (S) will be nil. In other words, heat stress results from imbalance between the demands imposed on the worker by the task and the environment, and the worker's capacity to eliminate the heat load as modified by clothing. It follows that thermal comfort is directly related to sweat evaporation. This can be expressed by the ratio of demand to capacity (Ereq/Emax). As this ratio exceeds 0.2 (20%), the worker is moved from a *comfort* condition to *discomfort.* As the ratio increases to 0.4–0.6, the worker is subject to performance decrements. Above 0.6, work will be usually discontinued or will be performed for only a limited period and above 0.8 there is substantial risk of heat illness. (Goldman 1988)

Thermal sensation and thermal comfort are bipolar phenomena ranging from *too cold* to *too hot* with comfort or neutral sensation in the middle. This continuum of sensations has been described by several scales. (Bedford 1936; Rohles–Levins 1971)

Throughout the 20th century and into the 21st century there has been an active research on what conditions will produce thermal comfort and how to grade heat stress. These efforts resulted in various models attempting to describe thermal comfort. (Błażejczyk et al. 2014)

3.3. Occupational heat stress

A comprehensive register of 162 human thermal climate indices has been recently assembled and categorised into eight classes by de Freitas and Grigorieva. (De Freitas–Grigorieva 2015) The development of a heat stress index as "a single value that integrates the effects of the basic parameters in any human thermal environment such that its value will vary with the thermal strain experienced by the individual" has been fraught with difficulties. A number of scientists have approached the issue in different ways. Epstein summarized 46 indices that have been published since Haldane proposed the *Wet-bulb Temperature* more than 100 years ago. (Epstein–Moran 2006; Haldane 1905) This single parameter is still used in climate change impact research. Sherwood and Pal used wet bulb temperature (psychrometrics) Tw measured in well ventilated conditions for the assessment of survivability of humans due to heat stress in hot climates. (Pal–Eltahir 2015)

Havenith and Fiala recently reviewed 35 heat stress indices and models, and pointed out that simple indices are most popular for use in the field. (Havenith–Fiala 2016) The acceptance of complex models seems limited and is usually used in a research context. No index meets all and sometimes conflicting demands of simplicity, availability, accuracy, validity, reliability, repeatability, continuous recording, data storage, etc. appear. Different heat stress indices have their own advantages and shortcomings. At present, based on international standardisation work (ISO), Wet Bulb Globe Temperature (WBGT) is meant to be used for heat stress screening and Predicted Heat Strain (PHS) for assessments of both heat stress and strain, forming the base for heat stress management. (ISO 9920 2007)

Some assumptions (e.g. clothing and work intensity) at population level need to be made for heat stress assessments, based on climate models. The evaluation method of thermal strain, five heat stress indices and heat stress assessment methods with a focus on their applications in workplace situations are: individual heat strain monitoring, Wet Bulb Globe Temperature (WBGT), Discomfort Index (DI), Predicted Heat Strain (PHS), and Universal Thermal Climate Index (UTCI). The latter is not developed for use in workplace situations, but we include it here as it is one of the most recent indices, and it has been promoted as an advanced heat stress index based on the meteorological input.(Jendritzky et al. 2012; Blazejczyk et al. 2012)

3.4. Individual heat strain monitoring

For the most detailed monitoring of individual thermal physiological responses to heat, personal measurements of core body (usually rectal) and skin temperatures, body mass loss (dehydration) due to sweating and heart rate can be carried out. Furthermore, the measurement or estimation of oxygen uptake (VO_2) quantifies aerobic workload and metabolic heat production of the whole body. The rating of perceived thermal sensation and thermal comfort, and perceived physical exertion, can complement the key quantitative measurements. Individual heat strain monitoring can detect early thermal physiological and psychological responses in vulnerable workers, (e.g. un-acclimatised, untrained, frail, ageing workers and workers with chronic diseases and disabilities), and accordingly provide timely and targeted personal protection and health care when confronted with heat waves. (Parsons 2013) Due to biological variability it is not easy to accurately predict the response of any particular individual to climatic extremes. Therefore, it is necessary to provide appropriate medical supervision for individuals prior to and during severe heat stress exposures. (ISO 7933 2004)

3.4.1. Wet bulb globe temperature (WBGT)

WBGT is among the most widely used occupational heat stress indices across the world (Parsons 2014) and its inclusion in international standard indicates that it has been widely accepted since it was developed in the 1950s by the U.S. Army. (Yaglou–Minard 1957) The WBGT index can function as a screening tool for the assessment of heat stress. It applies to the evaluation of the mean effect of heat on humans during an eight-hour work day and during an hourly work period in determining work rest cycles, and the WBGT reference values do not apply to the evaluation of heat stress suffered during very short periods. WBGT can be measured in hot environments with and without solar radiation. However, these devices were made in the 1950s so some improvements should be considered, e.g. allowing quicker response time. (Johansson et al. 2018) Several mathematical methods to calculate WBGT from weather station data have been published and are of value for the assessment of climate change impact, particularly when there is lack of the standard measurement devices and lack of first-hand data measured in workplaces. (Lemke–Kjellstrom 2012)

An important advantage with WBGT as an occupational heat stress index in climate change impact assessments, is the availability of a small number of occupational epidemiology studies of heat stress on work capacity loss that was assessed and associated with WBGT levels. (Sahu et al. 2013) In spite of the availability of a large number of heat stress indices for many decades, practical field studies quantifying the relationship between heat stress indices and occupational illnesses/injuries are lacking. Most of the studies were purely descriptive and used air temperature as the only heat stress parameter. (Xiang et al. 2014)

Solar radiation is not always directly measured and included in standard meteorological data. To accurately measure mean radiant temperature (Tmrt) it requires measurements of short- and long-wave radiation, diffuse and reflected radiation from six directions using pyranometers and pyrgeometers. (Schreier et al. 2013) However, not only Tmrt but also Tg and Tnw can be indirectly estimated using various models based on weather station data, geographical locations, time of the day, day of the year, etc. (Kruger et al. 2014) Another limitation that applies to all heat stress index estimates based on weather station data is that specific workplace conditions and urban environments can be significantly different from conditions at the nearby meteorological station. (Kjellstrom et al. 2013; Spector–Sheffield 2014)

Current WBGT index reference values have considered physical activity and acclimatization. But the values can only apply to standard clothing and various protective clothing options need to be considered. In addition, there is the specific sensitivity of a vulnerable workforce, e.g. older workers. A correction factor for different protective clothing properties is being considered in the revision of the standard based on related research. The WBGT index will play a major role in monitoring occupational heat stress in the future. With climate change, occupational heat stress assessment using WBGT will be an important first line of defence in the avoidance of heat casualties, although the WBGT is limited in its applicability across a broad range of climatic scenarios due to the inconvenience of measuring Tg. (Ashley et al. 2008)

3.4.2. Discomfort index (DI)

$$DI = 0.5Tw + 0.5Ta \qquad \text{(Equation 5)}$$

Where Tw is aspirated (psychrometric) wet-bulb temperature, and Ta is the air temperature.

Some authors recommended a simpler and easily used index, Discomfort Index (DI), as a heat stress index while recognising the lack of integration of all six factors, for instance the lack of heat radiation data. Clothing is only restricted to light summer clothing. The authors found that DI correlates well with WBGT ($R^2 = 0.95$ in the range of 15–33°C of WBGT index, $n = 108$). However, Tw is not directly available from weather station data. Since Tw is a function of air temperature and relative humidity (RH%), it can be estimated using the above equation. (Stull 2011)

3.4.3. Predicted heat strain (PHS)

Predicted heat strain describes a method based on human body heat balance equations for predicting both sweat rate and internal core temperature that the human body will develop as a result of heat stress. The heat balance is calculated by taking into account all factors involved in the heat transfer between the body and environment, i.e. four thermal climate factors, physical work intensity (metabolic rate) and clothing thermal properties. (Malchaire 2006)

Currently the PHS method may be considered the most developed analytical method for predicting potential health problems for individuals due to work in the heat. However, the clothing insulation in the PHS model is limited to 1.0 clo. The validity of the PHS model and possible integration with meteorological data in the context of climate change need further development and evaluation. Some limitations of the PHS model, when dealing with protective clothing (insulation and evaporative resistance) used in hot environments, can be found in recent studies. (Wang et al. 2011) In spite of criticism, the model is a useful tool for heat strain estimation. (Rowlinson–Jia 2013; Kuklane et al. 2015; Lundgren et al. 2014)

3.4.4. Universal thermal climate index (UTCI)

A recently proposed Universal Thermal Climate Index (UTCI), based on an advanced human thermoregulation model, directly uses meteorological data to predict the impact of outdoor climate on thermal physiological and perceptual responses. (Kampmann et al. 2012) The UTCI equivalent temperature for a given combination of wind, radiation, humidity and air temperature is defined as the air temperature of a reference environment, which produces the same heat strain. The reference environment is defined as an environment with 50% relative humidity, still air and mean radiant temperature equal to air temperature. Mean radiant temperature is usually not directly measured at weather stations, so it cannot be directly used as an input parameter for the calculation of UTCI; however, it can be estimated based on synoptic observations (e.g. cloud cover, global radiation) and various models based meteorological variables. (Bröde et al. 2016) However, the application of UTCI to the assessment of outdoor environmental and occupational heat stress and resulting body heat strain is limited by the assumed moderate activity level (135 W/m^2) and the chosen exposure time of two hours. (Bröde et al. 2012)

The assessment of the thermo-physiological effects of the atmospheric environment is one of the key issues in human biometeorology. The UTCI provides an automated approach to incorporate complex physiological models of the thermo-physiological responses to outdoor thermal climate. (Richards–Havenith 2007)

In workplaces and in the context of global warming, the criteria of air temperatures for hot weather warnings in most of the countries are higher than 30°C and the insulation of work or protective clothing in occupational settings is usually higher than 0.5 clo. Consequently, occupational heat stress is likely underestimated by the UTCI. This aspect is a further limitation of the UTCI when applied to the assessment of occupational heat stress and heat strain for an eight-hour shift in workplaces when facing heat waves. The UCTI is based on an advanced and complex model, it is more confined to the assessment of the outdoor thermal environment in biometeorological applications. (Vuckovic 2016)

3.4.5. Future heat stress assessment

Future heat stress assessment tools in the context of climate change should be valid in high-risk climate zones and they should be interpretable and translatable, acceptable and accessible. The assessment should be linked to recommendations of flexible and hierarchical control measures by taking vulnerabilities into consideration. It should be based on solid thermal physiological and physical basis for both hot dry and hot humid environment conditions and allow for a wide range of clothing adjustments including protective clothing. An applicable heat stress index must meet the following criteria:

- feasible and accurate at relevant range of environmental and metabolic conditions
- considers all six factors
- the measurement should reflect the worker's exposure
- exposure limits should be reflected by physiological and/or psychological responses

Heat stress indices should also make clear links to the practical consequences for the work activities, including productivity loss and economic impacts. (Kjellstrom 2016)

4. Conclusions

The alleviation of occupational heat stress impacts on health and productivity of working people is ultimately through mitigating climate change. This is what is recommended by the IPCC (Smith 2014) and the global climate change policy meeting in Paris in 2015 produced an agreement by 195 nations to limit the global mean temperature increase to less than 2°C, and ideally at 1.5°C. The current voluntary offers of greenhouse gas emission limitations would lead to a temperature change of 2.7°C, so further policies and actions need to be developed in most countries. (United Nations 2015)

Even a climate change induced global mean temperature increase of 1.5°C will lead to more frequent and more intense hot periods in large parts of the world: *heat waves* in countries with generally cool climate and sustained intensified hot seasons in the already hot countries. Protection against occupational heat stress via *adaptations* to climate change will be needed around the world, and such prevention adaptation actions are already being introduced in locations with very hot days. (Collins et al. 2013)

Health impact assessments are based on mortality indicators and health care data. Studies are also integrating territorial and social aspects to analyse health impacts of climate change, because it is a growing demand to use different socio-economic indicators which can provide comparable information of the impact of climate change on mortality and morbidity in different geographic regions. During the last 20 years when the health impacts of climate change have started to be examined in Hungary, many scientific results and evidences have been published.

There are some active research groups and authors dealing with this topic and some institutions coordinating these research projects (e.g. the National Institute of Environmental Health, Eötvös Loránd University, National Directorate General for Disaster Management and the Hungarian Meteorological Service). (Páldy et al. 2005)

One of Hungarian climate change vulnerability assessments has studied public health challenges of heat waves in Hungary. This research project was part of an international project (CLAVIER) in the second half of the 2000s managed by Pálvölgyi and his research group. (Pálvölgyi–Hunyady 2008) According to their results and experiences, 52% of the total area of Hungary is vulnerable by heat waves that means 37% of the total population is vulnerable. The most vulnerable area is the Southern part of Hungary where on the one hand, exposure is high, but on the other, disadvantaged socio-economic position can result in a higher level of sensitivity and lower level of adaptive capacity. (Pálvölgyi et al. 2011)

"Climate change will be the most serious public health threat in the 21st century." (IPCC 2014) According to the scientific evidences, climate change and its local consequences will adversely affect the health status in the following decades. Identification of local communities vulnerable to climate change can help health policymakers prevent associated adverse health impacts. The discourse on climate change related health draws attention to the role of integrated approaches in the possible responses. The model of heat-health vulnerability is focusing particularly on the vulnerability of the society to the impacts of heat waves on human health and is dedicated to the possible interventions at national and local level. It shows the primary responsibilities of national and local authorities and it spells out what preparations both individuals and organizations can make to reduce health risks and includes specific measures to protect at risk groups. In the future it is necessary to prepare a heat wave plan for those societies which are mostly affected by heat waves. This heat wave plan is providing guidance on how to prepare for and respond to a heat wave which can affect everybody's health.

The potential health risks and worker productivity reductions due to climate change are substantial. The increasing heat exposure due to local climate change is likely to create occupational health risks and to have a significant impact on the productivity of many workers, unless effective preventive measures *(adaptation)* reducing the occupational heat stress are implemented.

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József Csurgai

Behaviour-dependence of Filtering Materials and Nuclear Waste Container Materials on Extreme Climatic Conditions

1. Introduction

We spend a considerable part of our lives in building interiors and only a smaller part in the open, fresh air; the majority of the time is spent in inhabited settlements, if we are fortunate in a provincial town, if not that fortunate in a big city. We spend most of our time in our home and at our workplace but sometimes we go out in the nature or to the sea beach for holidays. Of course we can do this if we obey the most important rules for protecting the environment, preserving its resources, not affecting essential natural processes. Unfortunately, we live in the beginning phase of climate change, partially resulted by our industrial and agricultural activities. (Halász et al. 2012; Padányi–Földi 2016) Climate change will cause warming, more wet or dry local climate effects and extreme meteorological events.

This chapter deals with a very thin slice of our technical environment:

- temperature and wetting effects on some filtering materials used in everyday practice
- behaviour of some materials affected by heating and wetting used in nuclear waste handling

Various industrial and service equipment discharge all kinds of air polluting materials into the environment even under normal operating conditions. For this reason, the concentration of air polluting substances can be higher in interiors, therefore it is very important that we breathe in clean air. From the materials in the air, particulate matter poses one of the greatest threats which is a mixture of solid and liquid airborne particles. Particulate matter absorbs toxic substances, bacteria and viruses, etc.

In order to supply clean air to workplaces and other facilities that have high levels of traffic (factories, public buildings, shopping malls, hotels, hospitals, subways, metro and underground lines, etc.) heavy-duty filtering/ventilation systems are operated. Similarly, but of course at a smaller scale, clean air is provided to passengers and engines by filter equipment on the means of public transport and even in passenger cars.

The dust, aerosol and gas filtration of air has additional significance for special applications such as the respiratory protection devices of individual and collective protective equipment of fire-fighting and military organizations (vehicles, air-raid shelters, etc.). The intended purpose of these is the protection against radioactive, biological and chemical contaminants present in the environment in gaseous form. A highly efficient dust, aerosol and gas filter is an integral part of such combined filters and equipment.

2. Temperature Effect on Carbon Filters

Activated carbon is used in a wide variety of purification techniques including gas and water purification, metal extraction, water purification, pharmaceutical manufacturing, gas masks, and air filters. Several physical forms of activated carbon exist, including powdered, bead and extruded, yet granular activated carbon is one of the most commonly used for air filtration. Activated carbon filters are produced in two main styles, granular multi-layer free fill and bonded filters. Granular multi-layer carbon filters contain loose fill carbon media layered to meet specific chemical filtration needs. Bonded filters utilise various chemical processes to bond the carbon particles into a rigid matrix. This study tested the hypothesis that granular activated carbon filters, specifically SKT-6, have a longer useful life and greater filtering efficiency on lower temperatures than on higher at the same relative humidity of the air. To test this hypothesis, a HAVARIA laboratory analysed the adsorption efficiency of a 10 kg SKT-6 granular loose fill filter in different temperatures and constant relative humidity.

The investigated filter retained 1,872.5 grams of isopropanol at a run time of 300 minutes before reaching 5 ppm in the outlet at a temperature of 20°C. The other filter retained 1,377.3 grams of isopropanol after 225 minutes before reaching 5 ppm in the outlet at 40°C. This difference of 495.2 grams represents a 26.4% greater efficiency at lower temperature. The filter took 35 minutes longer to reach 5 ppm saturation, suggesting a significantly longer useful life at lower temperature.

The results of this test verify that under similar laboratory settings, a 10 kg SKT-6 carbon filter has a higher filtering efficiency and will maintain safe operating conditions for a longer period of time at 20°C than the same one at higher, 40°C temperature.

2.1. Background

Activated carbon includes a wide range of amorphous carbon-based materials prepared to exhibit a high degree of porosity and an extended interparticulate surface area. These qualities give activated carbon excellent adsorbent characteristics that make carbon very useful for a wide variety of processes including filtration, purification, deodorisation, decolourisation, purification and separation. The effectiveness of activated carbon as an adsorbent is attributed to its unique properties, including a "large surface area, a high degree of surface reactivity, universal adsorption effect, and pore size" (Figure 1). Due to its increased porosity, a single gram of activated carbon contains 500–2,000 m^2 aggregate surface area. Activated carbon is widely used in critical purification techniques in gas purification, metal extraction, water purification, medicine, gas masks, and air filters.

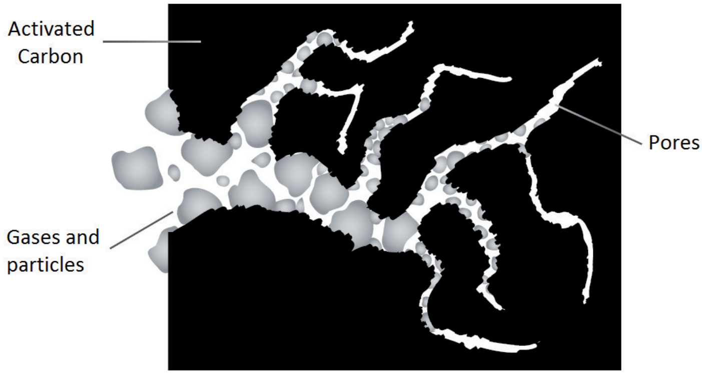

Figure 1.
Internal pore of activated carbon granule

Source: Depicted by the author.

2.2. Production

Activated carbon is produced from a wide variety of carbon-rich raw materials, including wood, coal, peat, coconut shells, nut shells, bones and fruit stones. New materials are currently under investigation as sources for activated carbon. The two primary types of activation are:

- *Chemical Activation.* This technique is generally used for the activation of peat and wood based raw materials. The raw material is impregnated with a strong dehydrating agent; typically, phosphoric acid or zinc chloride mixed into a paste and then heated to temperatures of 500–800°C to activate the carbon. The resultant activated carbon is washed, dried and ground to powder.
- *Steam Activation.* This technique is generally used for the activation of coal and coconut shell raw material which is usually processed in a carbonised form. Activation is carried out at temperatures of 800–1100°C in the presence of steam.

2.3. Principles of adsorption

The main principle on which the filtration of gas molecules is based is the concept of adsorption. Two main processes by which adsorption takes place are physical adsorption and chemisorption.

2.3.1. Physical Adsorption

Physical adsorption is non-specific and adsorption of the gas molecule is by diffusion (Brownian movement) or adsorption/condensation using van der Waals forces. The gas molecules move into an empty area and diffuse into the pore where they impact the walls and are trapped. The number of pores present in the carbon is vast and therefore the total surface area is extremely large. Depending on the carbon used and the type of filter, the aggregate surface area can be in the range of 2,000 m^2/g (roughly equivalent to about 4 football fields).

2.3.2. Chemisorption

The physical process of adsorption is followed by chemical adsorption (chemisorption). This is a chemical reaction in which the two substances react together and the resultant chemical is trapped on the filter material. The impregnation of filter media can greatly extend the range of gases that can be removed from the air stream.

A number of physical forms of activated carbon exist, including powdered, bead and extruded, yet granular activated carbon is the most commonly used for air filtration. Compared to powdered activated carbon, granular activated carbon has a much larger particle size with a small external surface, which increases its diffusion rate and makes it the carbon of choice for vapour adsorption. Activated carbon filters can be manufactured in a number of forms, including bonded, multi-layer free fill, and hybrid which can be impregnated with chemicals to assist in the adsorption process and to increase filter efficacy.

2.4. Regulations – Compliance

Carbon filter manufacturers can perform testing and compliance reviews for a number of state, local and internal company standards; however, the methods most widely used as general industry guidelines are the Scientific Equipment & Furniture Association (SEFA) 9-2010 Recommended Practices for Ductless Enclosures. Manufacturers will typically request a questionnaire to be completed during the purchase of a filter to ensure that the list of chemicals to be used in the fume hood are sufficiently compatible with the filter type based on SEFA 9-2010 standards.

The SEFA 9-2010 guidelines provide recommended benchmark testing for ductless fume hood filtration according to three classifications:

- *DH I:* Nuisance odours and non-toxic vapours only. No testing required.
- *DH II and DH III:* General laboratory fume hoods containing noxious or potentially harmful fumes. Testing, hood maintenance and calibration must be closely monitored and recorded.

Filter monitoring should aim to detect the period of initial breakthrough (Figure 2) and in all cases should warn the operator well before the permissible exposure level (PEL) is reached. For the purposes of this test, reaching 5 ppm (1% threshold limit value – TLV) was a sufficient benchmark in both concentration and temporal monitoring to determine the efficiency of carbon filtration under normal operating conditions. The threshold limit value is the level at which a worker can be exposed to a chemical daily for a working lifetime without adverse health effects. A concentration of 1% TLV captured for most chemicals is determined an accurate measure of filter efficiency, as determined by SEFA 9-2010, 4.3.1 (for more information on benchmark testing procedures see SEFA 9-2010, 4.3.1 and ASHRAE 110-1995 for instrumentation setup).

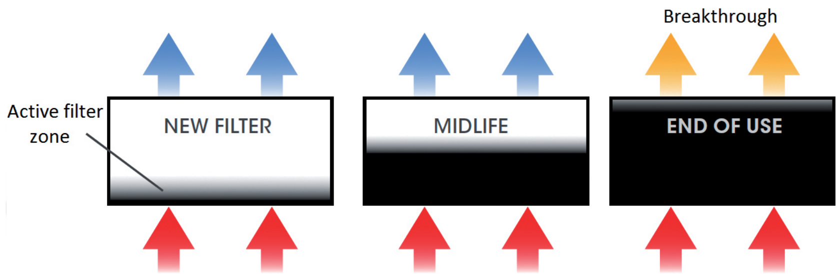

Figure 2.
Chemical adsorption and breakthrough of carbon filter

Source: Depicted by the author.

Adsorption takes place in a filter bed in what is known as the active filter zone (represented above as a dark saturated area). As the filter is used, this active zone progressively moves up the filter bed until it approaches the top surface of the filter. At this point there is an initial breakthrough by the contaminant vapour(s), and thereafter the percentage of contaminant gas that escapes filtration increases.

2.5. Types of carbon filters

Activated carbon filters are constructed in two main styles, granular multi-layer free fill and bonded filters. Granular multilayer carbon filters contain loose fill carbon media layered to meet specific filtration needs. Granular carbon media is filled into a solid filter frame which allows minimal media settling for optimal airflow through the loose carbon fill. Granular activated carbon filters can contain carbon impregnated for a single target analyte or can be layered with carbon impregnated for a number of analytes, increasing the range of containment. Granular filtration maintains the original physical and chemical properties of the carbon and offers the greatest amount of surface area for chemical bonding sites. Bonded filters utilise the same granulated carbon as loose-fill carbon filters, but use various chemical processes to bond the carbon together into a solid matrix. This creates a rigid carbon filtration system that is often chosen for its convenience of handling. Bonded filter manufacturers claim that due to the solid nature of the filter, there is a less chance of user exposure to the chemicals contained within a used filter. Bonded filters are also typically claimed to be *dust-free* because the carbon particles are bonded together in a solid form. It is possible, however, that as a result of the brittleness of the bonded filter, partial filter erosion may take place in shipping and allow fine particles to be exhausted during initial fume hood start-up following a filter change out.

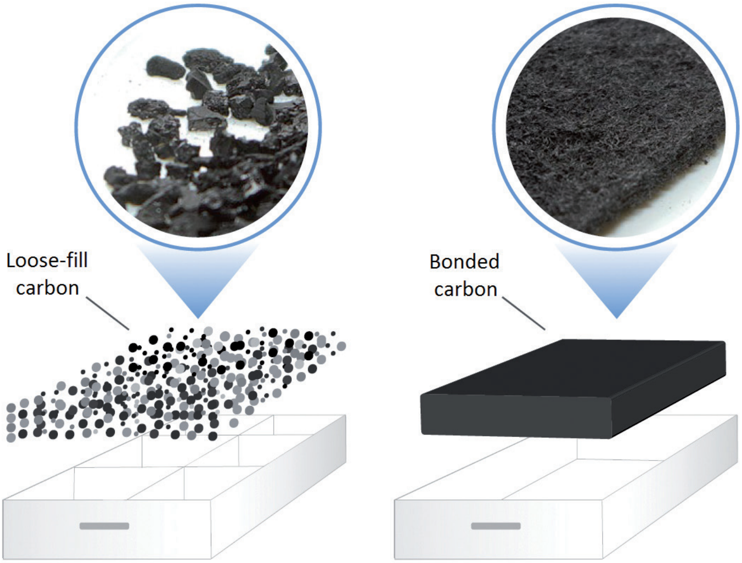

Figure 3.
Chemical adsorption and breakthrough of carbon filter

Source: Depicted by the author.

2.6. Issues with bonded carbon filters

Bonded carbon filters are widely marketed as having equal, if not better efficacy than loose fill granulated carbon filters. Manufacturers claim that a solid filter matrix minimises dead zones in the filters and maximises capacity. Others in the industry, however, have questioned the effect that a solid matrix has on filter performance. Regardless of the proprietary process, to create a solid matrix from loose granulated carbon, the physical and chemical properties of the carbon particles must be altered. These alterations likely have detrimental effects on the ability of the carbon particles to bond with target compounds and could also decrease flow rate compared to a loose fill filter.

Bonded filters tend to weigh more than granular filters (density of the bonded filter of the same capacity exceed density of the granular carbon filter for approximately 1.5 times) which can make filter change out more difficult, while their brittle nature can lead to quality issues in the shipping and handling process. Additionally, bonded filters are typically only offered with a single type of impregnation due to the difficulty associated with leaching during the bonding process. This can limit the use of the fume hood in which bonded filters are installed and increase the expense of maintaining compliance for certain laboratory operating procedures.

2.6.1. The bonding process

The bonding process typically requires the activated carbon to be soaked in water for approximately 24-hours prior to being bonded. This soaking can leach out the impregnated chemicals required to effectively manage certain types of vapours, decreasing the efficacy of the final filter.

Additionally, the bonding agents used to create bonded carbon filters are normally a type of resin, such as polystyrene. The amount of resin used has a critical impact on the adsorption capacity of the filter and it is not inconceivable that over half of the space on the carbon granules can be covered with the bonding agent. This renders the filtering capacity of the carbon granules at least temporarily useless and may have long term effects on filter efficiency.

2.7. Benefits of granular carbon filters

The granular carbon filters have none of the issues associated with bonded filters, and provide a higher retention capability over the useful life of the filters. This decreases the frequency, associated downtime and expense of filter change outs. Granular carbon filters utilise the multiplex filtration system, which consists of a pre-filter, main filter and optional safety filter to create a combination of chemical and physical architecture customised to each application.

2.8. Hypothesis

Granular activated carbon filters, specifically the STK-6 filters have a longer useful life at lower temperatures than the same ones at higher temperatures with none of the associated performance defects.

2.9. Methods

To test this hypothesis, a HAVARIA laboratory analysed the adsorption efficiency of an STK-6 granular loose fill filter based on the SEFA 9-2010 benchmark testing methods. The carbon filters were loaded into a laboratory fume hood and 99.9% isopropanol was evaporated from a hot plate placed inside the hood. The total mass of isopropanol evaporated and the concentration of isopropanol in downstream sample air (parts per million or ppm) was measured over time by a Gasmet DX4040 portable gas analyser placed 15 inches above the centre of the exhaust grid. Air concentration readings were recorded every 15 minutes until the reading measured 1% of TLV as determined by SEFA 9-2010 recommendations. Similar cabinet conditions were maintained throughout testing for both the granular loose fill filter and the bonded filter. Table 1 depicts environmental and equipment conditions maintained during testing of both filter types.

Table 1.
Conditions of ductless fume hoods during testing

	20°C	40°C
Relative humidity %	50	50
Barometric pressure kPa	98.6	98.7
Face velocity m/s	0.508	0.508

Source: Depicted by the author.

2.10. Results

The table and graphs below depict the concentration of isopropanol absorbed over time by each of the two filters. The filter at 20°C was able to retain 1,872.5 grams of isopropanol at a run time of 300 minutes before reaching 1% TLV. The other filter at higher temperature retained 1,377.3 grams of isopropanol after 225 minutes before reaching 1% TLV. This difference of 495.2 grams represents a 26.8% greater efficiency than at lower temperature. Additionally, the same filter took 35 minutes longer to reach the 1% TLV saturation, indicating a significantly longer useful life than the same one at higher temperature.

Table 2.
Measured concentrations on the outlet of the ductless fume hoods carbon filter during testing at different temperatures, see diagram below

Temperature 20°C	
Absorbed mass (g)	**Concentration in outlet (ppm)**
0	1.43E-02
160	5.71E-02
289	1.57E-01
415	2.71E-01
501	3.29E-01
635	4.29E-01
799	7.71E-01
1,023	1.33E+00
1,132	1.70E+00
1,385	2.61E+00
1,658	3.56E+00
1,751	4.13E+00
1,873	5.00E+00

Temperature 40°C	
Absorbed mass (g)	Concentration in outlet (ppm)
0	0.00E+00
144	1.45E-02
286	4.34E-02
337	3.32E-01
399	3.61E-01
473	5.20E-01
547	6.79E-01
619	8.38E-01
715	1.23E+00
795	1.69E+00
851	1.81E+00
904	2.05E+00
964	2.28E+00
1,021	2.76E+00
1,081	3.03E+00
1,138	3.38E+00
1,192	3.61E+00
1,223	3.99E+00
1,253	4.35E+00
1,311	4.73E+00
1,379	5.00E+00

Source: Depicted by the author.

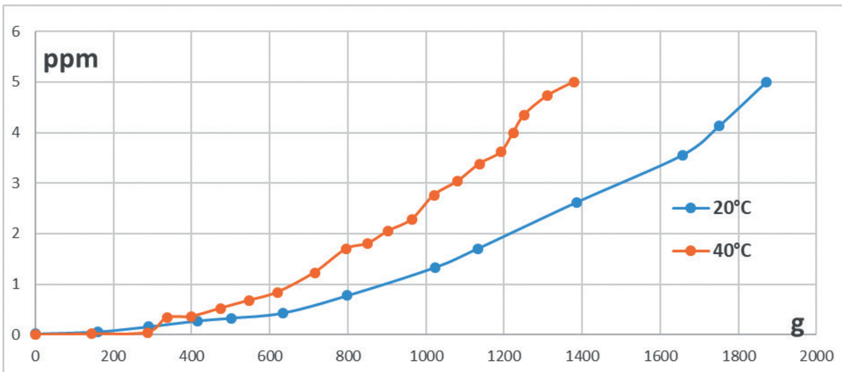

Figure 4.

Filtration efficiency of a granular loose-fill carbon filter measured at different temperatures

Source: Depicted by the author.

Measured data show the sufficient reduction of adsorbtion capability of activated carbon filters at increasing temperature. This fact must be accounted during filter system design process.

3. Temperature Effect on the Leaching Radionuclides from the Nuclear Waste Container Materials

For a number of years increasing attention has been given in Hungary to the management of the low and medium level radioactive wastes (LLW, MLW) being produced in Paks nuclear power plant. These efforts primarily serve the protection of our water resources and the preservation of environmental properties. (Halász et al. 2012; Berek 2016; Berek–Rácz 2013)

Some of these wastes, for example, evaporator bottom concentrates, pond sludge and spent ion exchange media are produced in relatively large volumes. In addition to national programs on the development of immobilisation processes, the European Community commissioned programs on the immobilisation of LLW and MLW. These wastes are immobilised by incorporating them into cement. In order to optimise these immobilisation processes, for example with respect to waste loading, it was necessary to characterise the products with respect to such properties as density, strength, dimensional stability, leach resistance and so on. Besides that, the waste containing material has an immobilisation capability significantly depending on outer circumstances as temperature or water concentration in the surrounding media. In this section there are reports about an accelerated leach test method and the basics of evaluation program.

The actual method was developed to accompany a new leach test for solidified radioactive waste forms. The method algorithm is designed to be used as a tool for performing the calculations necessary to analyse leach test data, a modelling algorithm to determine if diffusion is the operating leaching mechanism (and, if not, to indicate other possible mechanisms), and a means to make extrapolations using the diffusion models. The method contains four mathematical models that can be used to represent the data.

The mathematical models describing leaching mechanisms are as below:

1. Diffusion through a semi-infinite medium (for low fractional releases).
2. Diffusion through a finite cylinder (for high fractional releases).
3. Diffusion plus partitioning of the source term.
4. Solubility limited leaching.

The method uses simple mathematical models described in the ASTM C1308-08[1] standard and the fundamentals can be seen below in the next subsection.

3.1. The short description of models used for data processing

Recently, several test methods have been developed to measure diffusive releases including:

- *ASTM C 1308,* Standard Test Method for Accelerated Leach Test for Diffusive Releases from Solidified Waste and a Computer Program to Model Diffusive, Fractional Leaching from Cylindrical Waste Forms (ASTM 2008).

- *EPA Method 1315,* Mass Transfer Rates of Constituents in Monolithic or Compacted Granular Materials Using a Semi-Dynamic Tank Leaching Procedure. (EPA 2009)
- *ANSI/ANS-16.1-2003; R2008; R2017,* Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure.

Unlike the ANS-16.1 and EPA 1315 methods, the ASTM 1308 method calculates a diffusion coefficient based on a cumulative release rather than an incremental release. It effectively calculates an average over the duration of the test; it was chosen for our investigation. (PATZAY et al. 2017)

3.2. Basics of diffusion

Diffusion is the movement of any species in a medium along a given direction. It takes place in solid liquid or gas. It is associated with the movement of atoms, molecules or small particles of the medium and the species present in it. It occurs even in the absence of any external force. In liquid or gas, such movements can be seen or felt easily. If movements occur under external force, the process is called thermophoresis (in presence of a thermal gradient), or electrophoresis (under the influence of a spatially uniform electric field).

Diffusion is the process by which a species moves in a given direction. The rate at which it moves can be measured in terms of the mass/unit area/unit time. This is termed as flux. Higher the difference in the concentration of the species in neighbouring region higher is the flux. The concentration is defined as the mass in a unit volume of the medium (or matrix). The diffusion of species (or material) is governed by Fick's first law. This states that the rate of the flow of material is proportional to its concentration gradient and it occurs down the gradient.

Mass transfer via diffusion is described by the Fick laws. In a simplest case, the diffusion does not depend on time and is described by *Fick's 1st law:*

$$\Phi_m = -D\frac{\Delta C}{\Delta x} \qquad \text{(Equation 1.)}$$

$$\Phi_m = \frac{\Delta m}{A \cdot \Delta t} \qquad \text{(Equation 2.)}$$

where:

Φ_m	mass flow density (mass flux), mass of material diffused through a unit of area during unit of time	kg/(m^2*s)
D	diffusion coefficient	m^2/s
C	mass concentration	kg/m^3
x	diffusion path parallel with	m
m	mass in diffusion	kg
A	area (cross section) normal to diffusion	m^2
t	time	s

3.2.1. Physical means of diffusion coefficient

Atoms or molecules in a medium are not stationary. They keep moving randomly in all possible directions. Using this, it is possible to derive the first law of diffusion. Let the concentration of a particular species in a medium be *C(x)* at a distance *x* along *x* axis. Its concentration at *x+Δx* is *C(x+Δx)* and its concentration at *x-Δx* is *C(x-Δx).* We accept the change of concentration near the position *x* constant with the rate of *dC/dx.*

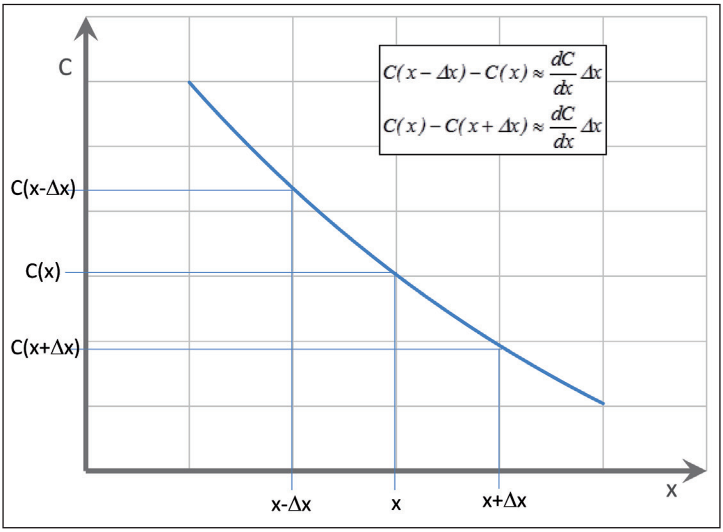

Figure 5.
Concentrations along axis x

Source: Depicted by the author.

Let us consider a 2 dimensional case where particles can move in all four directions with a chance *pi=p=1/4.* We assume the concentration changes only along *x* axis, the concentration along *y* axis remains constant; therefore, these flux components have been neglected. Using Equation 2 we can express mass flux components in all directions from the initial position of *x:*

$$\Phi_i = \frac{\Delta m_i}{A\Delta t}; \Delta m_i = p_i C\Delta V; \frac{\Delta V}{A} = \Delta x \quad \text{(Equation 3.)}$$

$$\Phi_i = p_i C\frac{\Delta x}{\Delta t}$$

Writing flux components for axis *x* we are given:

$$\Phi_i = p_i C \frac{\Delta x}{\Delta t}$$
$$\Phi = \Phi(x+\Delta x) - \Phi(x-\Delta x) \quad \text{(Equation 4.)}$$
$$\Phi = p \frac{\Delta x}{\Delta t}\left[\left(C(x) - \frac{dC}{dx}\Delta x\right) - \left(C(x) + \frac{dC}{dx}\Delta x\right)\right]$$

$$\Phi = 2p \frac{\Delta x^2}{\Delta t}\frac{dC}{dx} \quad \text{(Equation 5.)}$$

Merging Equation 1 with Equation 5 we express the *diffusion coefficient:*

$$D = 2p \frac{\Delta x^2}{\Delta t} \quad \text{(Equation 6.)}$$

Where *2p* is the degree of freedom of the particle in question.

This process is ideal, supposing timeless inflow of diffusing material and constant concentrations in time at various distances.

3.2.2. Fick's second law

What would happen if the concentration profile at a given time t is not linear, because we have assumed it in Figure 5 to be linear only near the position x. Here is a situation where the concentration gradient keeps changing with distance. According to the first law, the flux is directly proportional to the local concentration gradient. Therefore, the flux Φ at a given time t would be different at different locations.

In case of changing concentrations in space and time Fick's 2nd law describes the phenomenon

$$\frac{\Delta C}{\Delta t} = D \frac{\Delta\left(\frac{\Delta C}{\Delta x}\right)}{\Delta x} \quad \text{(Equation 7.)}$$

where:

$$\frac{\Delta\left(\frac{\Delta C}{\Delta x}\right)}{\Delta x}$$ linear concentration gradient change in space

In a general form, we express the two main equations for diffusion:

$$\Phi_m = -D\frac{dC}{dx} \quad \text{Fick 1st law} \quad \text{(Equation 8.)}$$

$$\frac{\partial C}{\partial t} = -D\nabla^2 C \quad \text{Fick 2nd law} \quad \text{(Equation 9.)}$$

3.3. Basics of the test and requirements for the test components

The basis of the leach test is a semi dynamic method, when a cylindrical specimen is immersed in a leach solution (water or aqueous solution), then usually in time the specimen is exchanged with a new one and the leached concentration or mass is determined. This compared to the original total concentration or mass results in the Incremental Fraction Leached (IFL). Summing the IFL values till a given leach time, we get the Cumulative Fraction Leached (CFL) values. More frequent exchange of specimens during the test results means more exact modelling with Fick's 2^{nd} law, but the leached amount of material will be lower and the determination uncertainty will be larger. Because of the above restrictions, the leaching time intervals are optimised. For that reason, the leach test should be completed under standard conditions, including the specimen and leach solution characteristics, as well as the leach vessel material and auxiliary conditions (specimen fixation, mixing, filtering etc.).

1. Requirements for the leaching liquor:
   - leach solution will not react with the material of the specimen and will not modify it
   - leach solution should not contain such a component, which modifies the leaching mechanism
2. Requirements for the leaching vessel:
   - the wall of the vessel could not react with the solution and leached components
   - the exchange of the solution should be easy and the solution in the vessel should not evaporate
3. Requirements for the auxiliary components:
   - their materials should not react with the solvent and with the leached materials
   - filtered leached materials could be analysed
   - filter will remove particles with diameter > 45 μm
   - hanging the specimen should not influence the leaching and should not cover more than 1% of the surface
4. Requirements for the specimen:
   - the specimen is a cylindrical body with a diameter/height ratio 1/1 and their value is 2.5 cm
   - the specimen composition should be identical with the waste composition
   - distribution of the radioactive isotope(s) or heavy metal material should be uniform in the specimen
   - the structure of the specimen material should be identical at the surface and in the bulk
   - every specimen's geometry, mass and embedded radioactive or heavy metal content should be accurately determined
5. Other requirements:
   - the temperature during leaching should be constant with a maximum fluctuation less then: 1°C
   - surface to volume ratio for the specimen should be constant during leach test(s) and the ratio should be:

$$S_V = \frac{S_S}{V_L} = 0.1(cm^{-1}) \qquad \text{(Equation 10.)}$$

where:

S_V	specific surface	1/cm
S_S	specimen surface	cm^2
V_L	volume of leaching liquid	cm^3

Regularly, a determined term in the leaching liquid should change the amount of the leached material or activity should be determined. These intervals should be started from the beginning of leaching, in the 2,nd 7,th 24th and 48th hour, until the end of the 11th day.

Using the determined leached amounts of material(s) or activities, one can calculate the Incremental/Cumulative Fraction Leached IFL/CFL):

$$IFL = \frac{a_{i,j}}{A_{i,0}}$$

$$CFL = \frac{\sum_{j=1}^{n} a_{i,j}}{A_{i,0}} = \sum_{j=1}^{n} IFL_j \qquad \text{(Equation 11.)}$$

where:

i	index of the radioactive isotope or heavy metal	i
j	index of the leach time interval	j
a	leached in the actual-time interval activity (concentration) for the actual isotope or heavy metal	a
$A_{i,0}$	activity or concentration of the actual-radioactive isotope or heavy metal in the specimen before the start of leaching	$A_{i,0}$

Using the IFL/CFL values, the effective diffusion coefficient could be determined. Accuracy of fitting of the leach data could be characterised by the following equation:

$$E_{R^2} = \frac{\sum_{j=1}^{n} \left(CFL_{j,model} - CFL_{j,measured}\right)^2}{CFL_{n,measured}} \qquad \text{(Equation 12.)}$$

where:

E_{R^2}	fitting error between the measured and calculated CFL values at a given fitting model	E_{R^2}
%n	number of leaching time intervals	%n
$CFL_{j,model}$	calculated by fitting model CFL value at the j-th interval	$CFL_{j,model}$
$CFL_{j,measured}$	measured leached CFL value at the j-th interval	$CFL_{j,measured}$
$CFL_{n,m}$	measured leached CFL value at the n-interval (sum)	$CFL_{n,m}$

A fitting model is suitable to describe the measured leaching CFL data if $E_{R^2} < 0.5\%$

3.4. Leaching models used in the test method

1. Diffusion leaching model

This model follows the ideal physical mechanism of the diffusion where the ions leached from the specimen remain in the leachant and the key law describing this process is Fick's 2nd law.

In the beginning of the process, the concentration is distributed in the specimen evenly:

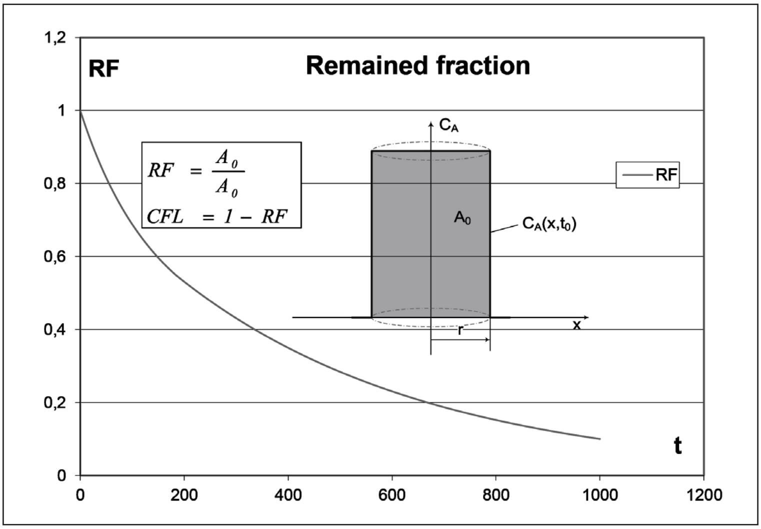

Figure 6.
Initial concentration distribution inside the specimen body

Source: Depicted by the author.

The model uses two calculation methods:
- diffusion in semi-infinite specimen
- diffusion in finite cylindrical specimen

Calculation starts with the diffusion in semi-infinite specimen using some early leaching data pairs (CFL<0.2) determining the diffusion coefficient, and continues the calculations with diffusion in the finite cylindrical specimen. Diffusion in semi-infinite specimen method uses the following equation:

$$CFL = \frac{\sum_{j=1}^{n} a_j}{A_0} = 2\frac{S}{V}\left[\frac{D_e t}{\pi}\right]^{1/2} \qquad \text{(Equation 13.)}$$

where:

a_j	activity leached in the actual time interval	Bq
A_0	sum of activity present in specimen at t = 0	Bq
n	number of time intervals	
S	surface area of the specimen	cm^2
V	volume of the specimen	cm^3
D_e	effective diffusion coefficient	m^2/s
t	time of leaching	s
a_j	activity leached in the actual time interval	Bq

In this phase, diffusion follows Fick's 1st law:

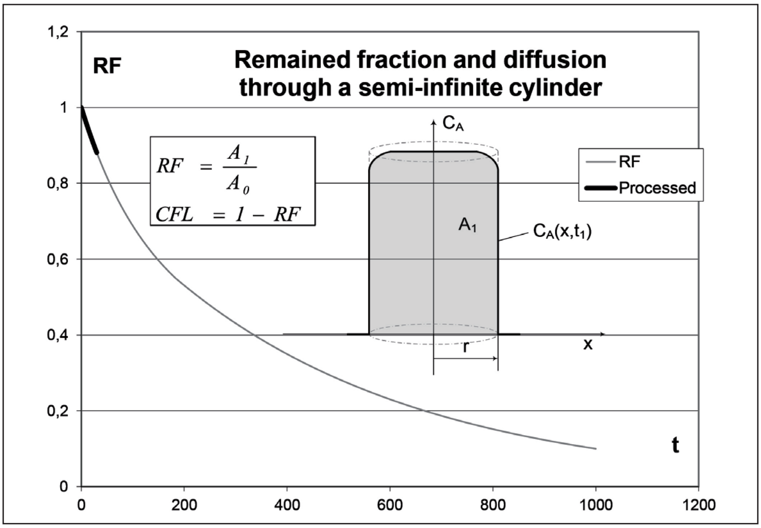

Figure 7.

Concentration distribution inside the specimen in semi-infinite region

Source: Depicted by the author.

If CFL > 0.2 calculation continues using the diffusion in the finite cylindrical specimen method, where the cumulative fraction leached (CFL) is calculated using a double series expression, S_p and

$$CFL = \frac{\sum_{j=1}^{n} a_j}{A_0} = \left(1 - \frac{32}{\pi^2} S_p(t) S_c(t)\right) \qquad \text{(Equation 14.)}$$

with the series and Sc defined in the standard. Calculations for CFL values in the program are based using equations developed by Pescatore. (PESCATORE 1990)

This phase is characterised by partial migration inside the medium (specimen) because in its central layers there is no migration of ions. This phase can be shown by the iteration method described above till the moment when migration reaches the central point of the medium. During this phase a significant part of the leaching material will leave the medium body, approximately 40%. After this moment, the concentration distribution inside the medium will follow the Gaussian and the process described by Fick's 2nd law:

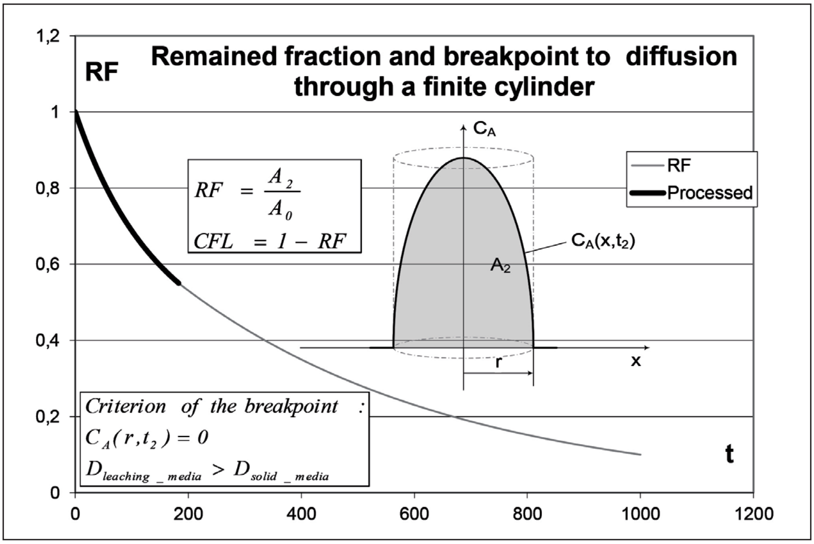

Figure 8.

Concentration distribution inside the specimen in the finite region in the moment of establishing ideal diffusion process

Source: Depicted by the author.

After the breakpoint, the leaching process can be calculated using the exponential distribution for the remained fraction when the exponent has a constant character and is proportional with the diffusion constant:

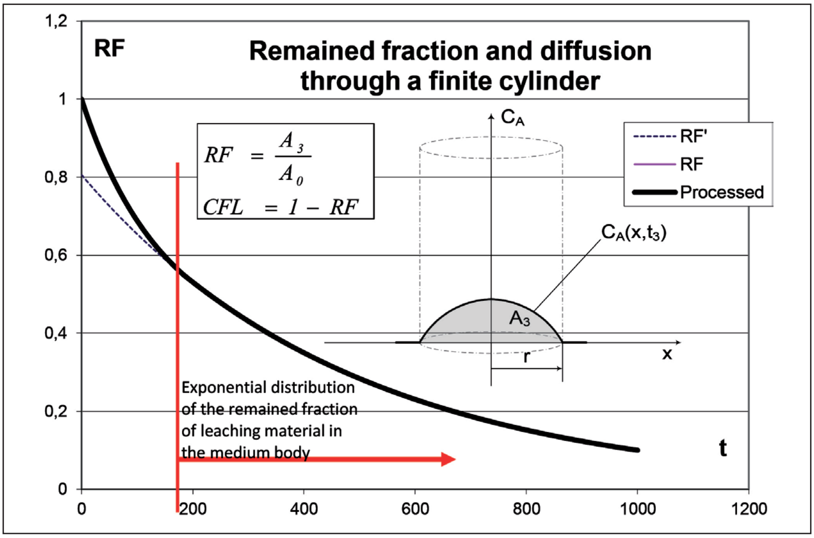

Figure 9.

Concentration distribution in the specimen in the finite region from the moment of establishing ideal diffusion process

Source: Depicted by the author.

2. Diffusion plus partition leaching model

In the partition model a fraction of the contaminant is considered to be immobile and not leachable. This model uses the model for diffusion from a finite cylinder (or a semi-infinite cylinder) if the CFL leached is less than 0.0124, but alters the result by reducing the original source term so that the cumulative fraction leached is determined according to the following equation:

$$CFL = \frac{\sum_{j=1}^{n} a_j}{PA_0} = 2\frac{S}{V}\left[\frac{D_e t}{\pi}\right]^{1/2} \qquad \text{(Equation 15.)}$$

$$0 < P < 1$$

where P is the source term partitioning factor between 0 and 1.

3. Solubility-limited leaching model

This model accounts for a leaching system in which diffusion is affected by the limited solubility of a radioactive isotope or heavy metal. The model is based on the concept that the leached incremental fractions will be the same at the end of each 1-day sampling interval in case of solubility-limited leaching. This is a non diffusion controlled leaching.

3.5. Validation of the leaching model calculations

The validation method for leaching models can be performed by building a numeric diffusion model that uses Fick's laws for elementary layers within the specimen body. The essence of this model is to divide the specimen cylinder to *n* elementary layers and calculating in a short period of time Δt the mass flow Δm using Fick's 1st law. For the other period of time this process must be repeated and between time periods Fick's 2nd law must be fulfilled.

Mathematically, this model can be written as below:

$$\text{time index} = \mathrm{j}$$
$$t = j * \Delta t$$
$$\text{number of layers} = \mathrm{n}$$
$$\text{layer index} = i$$
$$\text{for 0. layer:}$$
$$C(0,j) = C(0,j-1) - D\left[\frac{(C(0,j-1) - C(1,j-1))}{\Delta r_0 V_0} S_0\right]\Delta t$$
$$\text{for i}^{\text{th}}\text{ layer:}$$
$$C(i,j) = C(i,j-1) - D\left[\frac{(C(i,j-1) - C(i+1,j-1))}{\Delta r_i V_i} S_i - \frac{(C(i-1,j-1) - C(i,j-1))}{\Delta r_{i-1} V_{i-1}} S_{i-1}\right]\Delta t$$
$$\text{for last layer:}$$
$$C(n-1,j) = C(n-1,j-1) - D\left[\frac{C(n-1,j-1)}{\Delta r_{n-1} V_{n-1}} S_{n-1} - \frac{(C(n-2,j-1) - C(n-1,j-1))}{\Delta r_{n-2} V_{n-2}} S_{n-2}\right]\Delta t$$

At the same time, a mass flow will occur between layers and an income and outcome flow component must be calculated as it is seen above. The most inner layer has only outcoming flow. The input parameters used for modelling are related on the one hand to the specimen body, and on the other hand, to the calculation process. The following table contains the input data for *n = 10* layer-model:

Table 3.

Input data for the numeric validation model

Cylinder parameters	radius	1.25E-02	m	**Process parameters**	D_t	600	s
	height	2.50E-02	m		m_0	100	mCi
	layers	10			C_0	8.15E+06	mCi/m^3
	Dr	1.25E-03	m		D	6.00E-11	m^2/s
	V	1.23E-05	m^3				

Source: Depicted by the author.

The following graphs depict the graphical result of the numeric model containing concentration distribution within the specimen body in time and the remained fraction and the cumulative fraction leached:

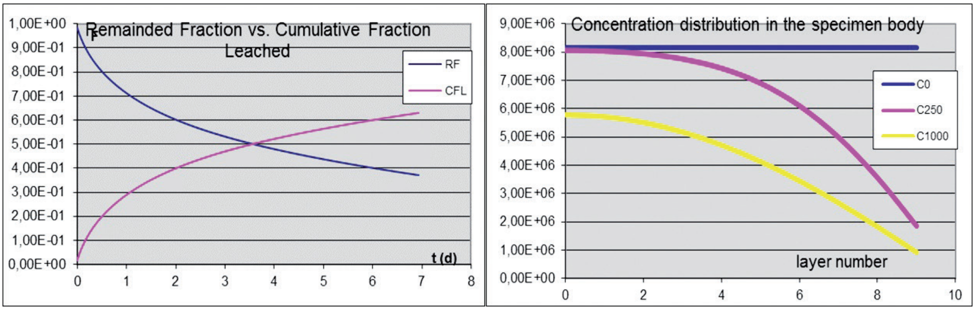

Figure 10.

Graphical result of the validation numeric model

Source: Depicted by the author.

The main success of the numeric model is the full control of the leach test evaluation method. The leach test evaluation method in general predicts the diffusion coefficient from the initial stage of the leaching process with some uncertainty having only the probability of the run of the whole leaching process. The numeric model supports a tool for completing the leaching process for characterisation of the investigated material.

3.6. Evaluation of the measured data

When the test begins, the measured leach data must be entered from experimental results (e.g. leach time and counts per minute – cpm or – concentration). Additionally, the height and diameter of the solid cylindrical specimen must be the input and also the volume and surface and material of the leacher and the number of summa count of radioactivity or concentration must be determined.

As an example the Cs-137 leach test data is used, measured from a c400 cement cylinder with the embedded evaporator bottom residue of the chosen tank of the NPP (Table 3).

Table 4.

Measured intensity of the bottom residue of the tank of the NPP

Index	Time of Measuring (day)	Measured count (cpm)	Measuring duration (s)
1	0.08	70.9	6,912
2	0.29	63.9	25,056
3	1	130	86,400
4	2	103	172,800
5	3	64.2	259,200
6	4	54	345,600
7	5	35.8	432,000
8	6	35.1	518,400
9	7	28.9	604,800
10	8	22.3	691,200
11	9	20.6	777,600
12	10	14.3	864,000
13	11	17.2	950,400

Source: Depicted by the author.

After completing the data input (and/or editing), the fitting model must be selected, first the *Diffusion Leaching Model* and the essential parameters are calculated as CFL values, for each leach time, as well as the determined diffusion coefficient in cm^2/sec and in cm^2/day unit and the relative error of fitting in percent. A fit is usable if the relative error is less than 0.5%. After the calculation, the raw data must be compared with the calculated ones to see how they fit:

Table 5.

Calculated data of the bottom residue of the tank of the NPP by Diffusion Leaching Model

Index	CFL measured	CFL (calculated)
1	7.09E-02	7.95E-02
2	1.35E-01	1.51E-01
3	2.65E-01	2.57E-01
4	3.68E-01	3.50E-01
5	4.32E-01	4.16E-01
6	4.86E-01	4.69E-01
7	5.22E-01	5.12E-01
8	5.57E-01	5.50E-01
9	5.86E-01	5.82E-01
10	6.08E-01	6.12E-01
11	6.29E-01	6.38E-01
12	6.43E-01	6.62E-01
13	6.60E-01	6.83E-01
Diffusion coefficient (cm^2/sec) =	1.25E-07	
Diffusion coefficient (cm^2/day) =	1.08E-02	
Relative error (%) =	2.14E+00	

Source: Depicted by the author.

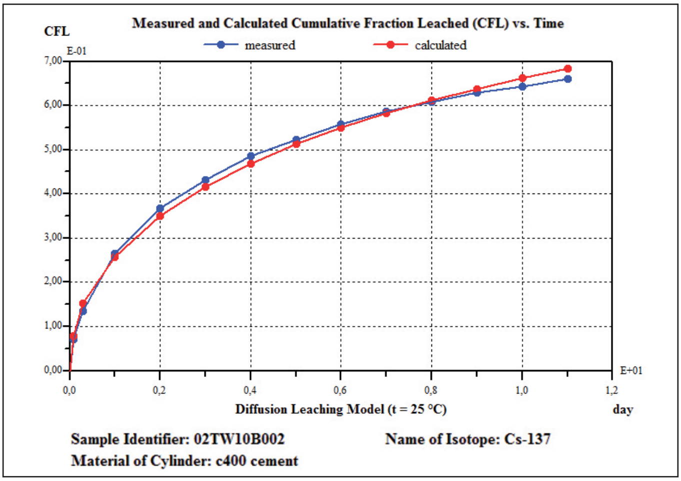

Figure 11.
Graphical result of fit Diffusion Leaching Model

Source: Depicted by the author.

After saving the data and diagram, we used the other two fitting models, too to find the most accurate fitting model.

The calculated CFL data and graphical fitting results of the *Diffusion Plus Partition Leaching Model* and the *Solubility Limited Leaching Model* are shown in Tables 6–7 and Figures 12– 13.

Table 6.
Calculated data of the bottom residue of the tank 02TW10B002 of the NPP by Diffusion Plus Partition Leaching Model

Index	CFL measured	CFL (calculated)
1	7.09E-02	8.52E-02
2	1.35E-01	1.62E-01
3	2.65E-01	2.69E-01
4	3.68E-01	3.62E-01
5	4.32E-01	4.27E-01
6	4.86E-01	4.77E-01
7	5.22E-01	5.18E-01
8	5.57E-01	5.52E-01
9	5.86E-01	5.81E-01
10	6.08E-01	6.07E-01
11	6.29E-01	6.30E-01
12	6.43E-01	6.50E-01
13	6.60E-01	6.68E-01
Diffusion coefficient (cm^2/sec) =	2.01E-07	
Diffusion coefficient (cm^2/day) =	1.74E-02	
Relative error (%) =	1.57E+00	
Partitioning factor =	8.43E-01	

Source: Depicted by the author.

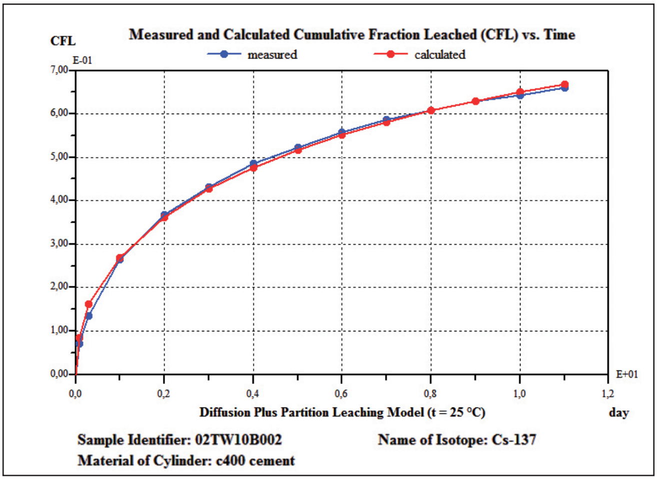

Figure 12.

Graphical result of fit Diffusion Plus Partition Leaching Model

Source: Depicted by the author.

Table 7.

Calculated data of the bottom residue of the tank of the NPP by Solubility Limited Leaching Model

Index	CFL measured	CFL (calculated)
1	7.09E-02	7.09E-02
2	1.35E-01	2.06E-01
3	2.65E-01	2.53E-01
4	3.68E-01	3.01E-01
5	4.32E-01	3.49E-01
6	4.86E-01	3.97E-01
7	5.22E-01	4.45E-01
8	5.57E-01	4.92E-01
9	5.86E-01	5.40E-01
10	6.08E-01	5.88E-01
11	6.29E-01	6.36E-01
12	6.43E-01	6.83E-01
13	6.60E-01	7.31E-01
Diffusion coefficient (cm^2/sec) =	1.01E-07	
Diffusion coefficient (cm^2/day) =	8.76E-03	
Relative error (%) =	0.00E+00	
Partitioning factor =	0.00E+00	
Average daily leaching rate	4.78E-02	

Source: Depicted by the author.

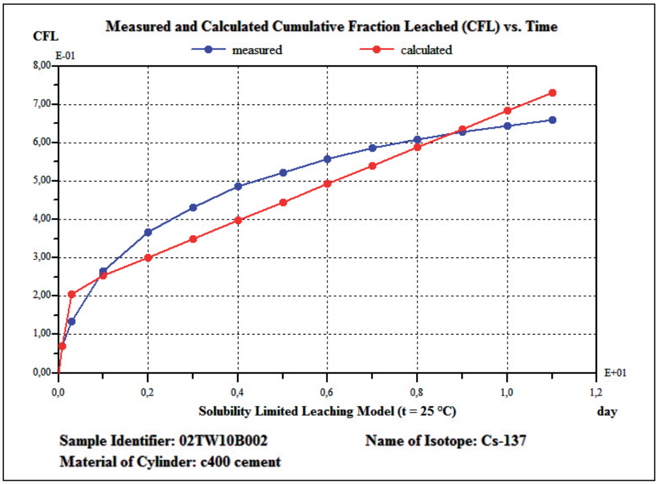

Figure 13.
Graphical result of fit Solubility Limited Leaching Model

Source: Depicted by the author.

3.7. Temperature dependence of the diffusion and leaching process

We have just seen how the self diffusion coefficient can be estimated using radioactive tracer. Diffusivity *(D)* of a given species in a specific medium can also be obtained from the concentration profile along a diffusion couple. Diffusion of species is associated with the mobility of atoms or ions. This increases with increasing temperature *(T)*. Therefore, it is expected to be a strong function of temperature. The temperature dependence of diffusivity is often represented as follows:

$$D = D_0 e^{-\left(\frac{E_A}{RT}\right)} \qquad \text{(Equation 16.)}$$

Where R is the universal gas constant, E_A is the activation energy for diffusion and D_0 is a constant. Linearising equation (Equation 16) we are given a linear form:

$$\ln D = \ln D_0 - \frac{E_A}{RT} \qquad \text{(Equation 17.)}$$

If D is known at several temperatures, E_A and D_0 can be obtained from the slope and intercepts of the plot given in Figure 14:

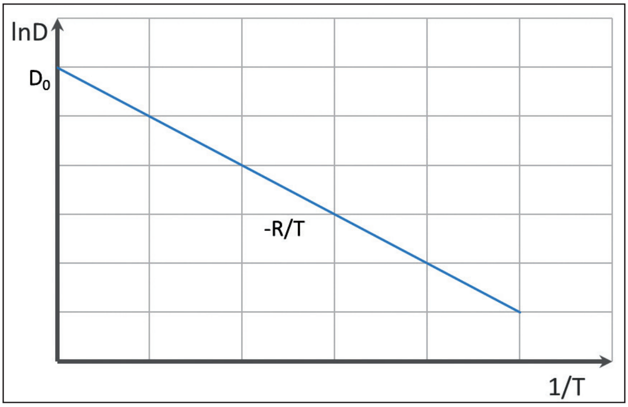

Figure 14.

Illustrates temperature dependence of diffusivity. It follows from Equation 17 that intercept = ln(D_0) and slope = – Q/R

Source: Depicted by the author.

3.7.1. Diffusion paths in solids

Diffusion of species in solids also depends on the path that it follows. In a solid, we can think of three distinct paths. Metals are made of several crystals that meet along grain boundaries. If a species has to move through this, it could either move through the grain, the grain boundary or the top surface. The diffusivity through the grain is denoted by D_g. This is often known as bulk diffusion coefficient. The diffusivity through the grain boundary is denoted by D_{gb}. The space between atoms because of irregular arrangement is more at the grain boundary than that within the grains. This is why the mobility of atoms through the grain boundary is expected to be higher than that through the grain. The same logic can be extended to the exposed top surface. There is enough space to accommodate extra atoms at the free surface if required. Therefore, the mobility of the atoms along the free surface (D_s) is much higher. The relation between the three could be described as $D_s > D_{gb} > D_g$.

3.8. Method of measurements

Measured data evaluation has an aim to determine how diffusion coefficients of radionuclides depend on temperature, and finally how retention capability of the container material depends on temperature. There are some radionuclides chosen for investigations: ^{60}Co, ^{110m}Ag, ^{137}Cs and ^{241}Am. Table 8 contains the main characteristics of these nuclides:

Table 8.
Main parameters of used isotopes for gamma spectrometry analysis

Index	Nuclide	Chosen gamma lines		Decay parameters			FHWM (keV)	5δ	Efficiency
		Energy (MeV)	Gamma + isotope decay probability	Decay factor (1/s)	Half life	Half life dim	DET01	keV	DET01
1	Am-241	59.5	0.359	5.09E-11	431.9	years	1.590	3.383	3.412E-02
2	Cs-137	661.65	0.8512108	7.28E-10	30.15	years	2.113	4.496	2.165E-02
3	Ag-110m	884.67	0.72584	3.21E-08	249.9	days	2.257	4.803	1.504E-02
4	Co-60	1332.5	1	4.17E-09	5.27	years	2.499	5.317	1.039E-02

Source: Depicted by the author.

In case of every isotope there, four series of leach tests have been performed for different temperatures: 10°C, 25°C, 43°C and 50°C. The following table contains the evaluated results with diffusion parameters and temperatures:

Table 9.
Calculated diffusion coefficients from leach tests performed by different temperatures

T (°C)	Diffusion coefficients (m^2/s)			
	^{110m}Ag	^{137}Cs	^{241}Am	^{60}Co
10	9.65E-12	1.15E-11	2.11E-11	9.8E-12
25	1.23E-11	1.46E-11	2.75E-11	1.37E-11
43	1.36E-11	1.87E-11	3.41E-11	1.88E-11
50	1.41E-11	2.15E-11	3.89E-11	2.17E-11

Source: Depicted by the author.

The next table contains the evaluated data for Arrhenius equation:

Table 10.
Evaluated data for Arrhenius equation related to nuclides and the waste container material (Cement c400)

Isotope name	^{110m}Ag	^{137}Cs	^{241}Am	^{60}Co
Material of cylinder	c400 cement	c400 cement	c400 cement	c400 cement
Slope coefficient (m)	–839.468	–1395.45	–1350.8	–1789.83
Intercept coefficient (p)	–22.3631	–20.2636	–19.8019	–19.0193
Correlation coefficient (R squared)	0.941053	0.995586	0.995586	0.995586
Initial diffusion coefficient D_0 (m^2/s)	1.94E-10	1.58E-09	2.51E-09	5.5E-09
Energy activation E_A (J/mol)	6967.585	11582.26	11211.62	14855.56

Source: Depicted by the author.

Finally, we are given the correct regression parameters for building temperature dependence functions for diffusion coefficients of related isotopes as follows:

Table 11.

Regression data for temperature-dependence functions of diffusion coefficients

T (°C)	Diffusion coefficients (m^2/s)			
	^{110m}Ag	^{137}Cs	^{241}Am	^{60}Co
273	8.96E-12	9.54E-12	1.78E-11	7.81E-12
278	9.47E-12	1.05E-11	1.95E-11	8.79E-12
283	9.99E-12	1.14E-11	2.12E-11	9.85E-12
288	1.05E-11	1.25E-11	2.31E-11	1.1E-11
293	1.11E-11	1.35E-11	2.5E-11	1.22E-11
298	1.16E-11	1.47E-11	2.7E-11	1.35E-11
303	1.22E-11	1.58E-11	2.91E-11	1.49E-11
308	1.27E-11	1.71E-11	3.13E-11	1.65E-11
313	1.33E-11	1.83E-11	3.36E-11	1.81E-11
318	1.38E-11	1.97E-11	3.59E-11	1.98E-11
323	1.44E-11	2.11E-11	3.84E-11	2.16E-11
328	1.5E-11	2.25E-11	4.09E-11	2.35E-11
333	1.56E-11	2.4E-11	4.35E-11	2.55E-11

Source: Depicted by the author

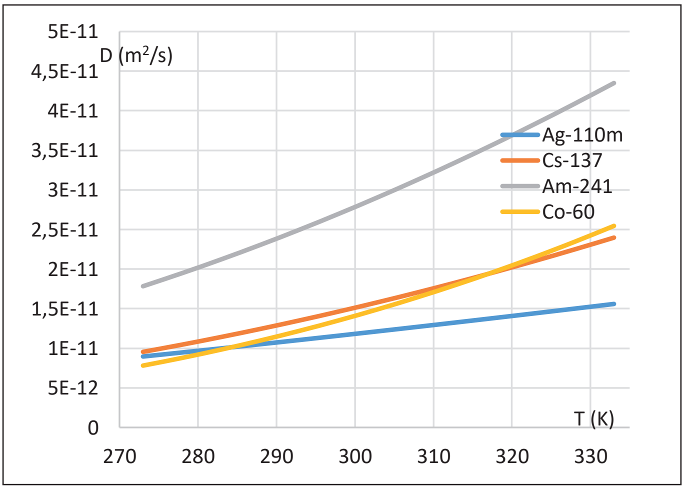

Figure 15.

Calculated temperature dependence of diffusivity

Source: Depicted by the author.

3.9. Results

The table and graph above show very important information about strong temperature-dependence of diffusivity of relevant metal ions through container material. In average climate conditions, increase of temperature by 5°C results approximately in a 10% increase of diffusivity of container material. This character of diffusion process requires a temperature of waste storage as low as possible and absence of significant temperature anomalies. Of course, the best solution of this problem would be the proper planning and design of waste storage facilities with optimal sorting materials.

4. Conclusion

At the end of the actual section, we can conclude that two thin separate aspects have been investigated from the viewpoint of temperature-sensitivity of technology:

- temperature effect on the filtering materials
- temperature effect on the waste contain capability of widely used building materials

Unfortunately, in these two cases, the temperature effect decreases the useful capability of investigated objects and the predicted global warming climate trend requires accommodation in many fields of technology.

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Ágoston Restás

The Effects of Global Climate Change on the Fire Service Organisational Point of View

1. Introduction

1.1. General overview of the problem of climate change

There are numerous studies focusing on the future effect of climate change. No doubt, most researchers agree that climate change means not only the local change of climate but also global warming. The common belief that global warming means less rain and humidity is not true. It is also a well-known fact that climate change can perpetuate longer and more serious local drought periods, conversely it can be attributed to heavier than normal rainy periods, resulting in flash floods. Such extreme weather events can be accompanied by strong winds that can cause physical damages to houses, infrastructure and to the natural environment resembling the incident which occurred on the 19th of November 2004, in the High Tatras, Slovakia.

In view of the above, we can simulate a climate change mitigation model which incorporates drought, flood, storms and vegetation fires. In Hungary alone, the damage caused by vegetation fires amounts to some million Euros every year. The production value of one hectare of forest is around ten thousand Euros. The intangible value destroyed is generally estimated at around ten times the production value. Accordingly, forests as living environments have an intangible value that certainly justifies measures to protect them from fire. The extent of the damage is increased further at the level of national economy by the cost of extinguishing those fires. We may state that global warming is increasing the frequency of extreme weather conditions meaning droughts, floods and storms. This results in an increase of protracted periods without precipitation. Consequently, we may expect increases in the number of, and the level of destruction caused by forest fires, floods and storms.

1.2. The fire service as a dedicated organisation to respond to emergencies

The fire service is a very special organisation. It is dedicated to give a first response to any life threatening problem which can adversely affect society's health and safety. Health service and ambulances are responsible organisations for the latter; the police are responsible for internal security, the army for national defence. Fire services are responsible for any other problem or unusual event that requires a quick respond.

Uniformed professions, such as fire departments but also police departments and military units, work in a unique way. These organisations possess characteristics such as a sense of duty and allegiance not found to such a strong degree in other professions. (Chatman–Jehn 1996) There is no universal or single way to describe all the aspects of fire departments, law enforcement organisations, or military units, (Soeters 2000) but some generalisations can still be made. In 2004, the fire and emergency services organisational culture came in the front and centre with the release of the *Life Safety Initiatives.* The study states that the culture of uniformed organisations has the following characteristics in common:

- They are relatively isolated from society as a whole.
- They are characterised by their strong culture that includes the use of a uniform, hierarchical command structure, promotion solely from within the existing ranks, and long-standing traditions.
- Fire departments further differ from other organisations in that they are exposed to uncommon levels of danger, work unusual schedules, require a lot from their members, and can recall staff and cancel their leaves.
- Fire department, law enforcement and military organisations have unique indoctrination procedures that inculcate their specific culture at special schools, acquainting members with the demands of the profession, as well as the special privileges that society affords them.

Some of these practices date back centuries, as military groups were some of the first formal organisations. They are also characterised by a Janusian or two-sided organisational culture –one that has both emergency response/combat (hot) and nonemergency response/noncombat/administrative (cold) aspects and functions to the work. (Brian 2016)

Climate change also requires cultural changes that mean to be more active with higher effectiveness in society. For these reasons, fire departments do not only have to respond to the challenges but also to prepare themselves for a more meaningful role. As it was detailed above, climate change can be attributed to storms, floods and droughts and vegetation fires. This study will focus on how fire services as dedicated organisations optimally respond to these challenges.

2. Challenges for Fire Services in Case of Storms and Floods

2.1. General overview of the problem of storms and floods

Floods are typical for a slowly developing disaster; however, in most cases storms can also be well-predicted. Based on weather forecast, we can get information about serious windy and/or rainy periods many days or sometimes even 1–2 weeks before their beginning. Today, weather services can foresee the severity of the rain in very good detail. It means that services can predict the expected time of the beginning of rain, the potential affected area, the term of raining, the expected amount of water, the power and the direction of the wind, etc.

Responsible authorities such as local and territorial governments with responsible services like disaster management, civil protection and fire service should be able to prepare the community for the disaster events. Authorities and services have to know the *flood history* of the territory they are responsible for, so in a *normal case,* i.e. not facing extremities, they should manage this kind of disaster with good quality. In this case, *normal* means the severity of the floods is not higher than experienced periodically by the authorities, services and communities. Usually, the communities living in floods prone areas have indigenous knowledge on how to respond to flood disaster events.

Land use planning can be regarded as a long term prevention solution towards floods. For example, local authorities refusing permission for citizens to build houses on flood plains.

Based on flood history, the government usually builds flood lines at the critical sections of the rivers, in many cases along the whole river trials to protect not only the settlements but also the growing areas. It is very important to keep these flood lines in good condition to be able to hold the water pressure during the flood disaster event. Bad flood lines condition means higher risk of both flood line break and water jet. Both cases generate more workload for fire services and higher financial loss for the government.

In case of a flood line break, disaster management, civil protection and fire services can have a special task to evacuate citizens from the threatened or flooded area making previously made protection work and service efforts for nothing.

Floods have a typical kind of appearance, that is flash flood. It occurs quickly and in almost all cases it comes together with storms. Comparing flash floods to the slowly developing *normal* floods, they have totally different features. It occurs suddenly and even if the affected area of flash floods can be limited, the effect can be much worse than that of rain. Usually, it is not only a heavy rain but many times it goes together with local storms. The rain or storms last for a relatively short time but in this term the intensity can vary drastically. (Teknős 2017)

2.2. Answers to challenges

Floods call for specialised functions from the fire services. It is very important to notice that the main and mostly made task of firefighters takes a relatively short time period. The work load of extinguishing house or building fires, rescuing those trapped in confined areas or responding to accidents takes relatively shorter periods compared to responding to floods.

Based on the above, at disaster management level or fire service level floods generate a different type but surely longer workload than is usual for firefighters which requires a higher quality level of staff organisation. Moreover, this special task requires also different instruments and devices like transportation capability, motor boats, innovative tools like drone applications, logistic and social background facilities but also special training. Based on these, we can notice that the basic standard of managing flood disasters is beyond the narrow interpretation of the fire service task range meaning that the fire service has to strongly and continuously cooperate with other authorities like local or regional governments, services of civil protection and disaster management.

Depending on the structure of the country disaster management system, for optimising the required resources, managing different types of disasters or other emergencies, fire services can be involved as a part of the country level disaster management organisation. This allocation can optimise not only the human and technical resources of the different services but it can also reduce the costs of managing of even any other kind of emergency on state level.

One of the main features of disasters is that its elimination requires more resources than fire departments have. Another similar feature is that firefighters are never adequate to respond completely to a disaster, therefore, cooperation with other services is required. Voluntary firefighters as well as police officers, health service, civil protection and soldiers are also involved in responding to emergency situations, therefore, high level communication and organisation is strongly required for the effective management. Therefore, focusing only on the fire department is not enough, in case of floods, large scale storms and vegetation fires, the government is required to provide comprehensive disaster management. In 2012, Hungary's emergency management levels were boosted in order to respond better to climate change related challenges.

3. Challenges for Fire Services in Case of Forest Fires

3.1. General overview of the problem of forest fires

From the fire service point of view, it is quite clear that the biggest problems caused by droughts are the forest and vegetation fires. In a study published earlier by the author, (Restás 2018) it was explained how global climate change could affect the frequency and the intensity of forest fires. The frequency of forest fires will likely be higher; however, in developed countries, this will be kept in line with well-chosen preventive measures. Still, the intensity of forest fires will be clearly higher, so fire brigades face a very serious problem.

The following general problems are well known and may be characterised by the current system of vegetation fires and forest fires:

Climate change with global warming is accepted as a fact. It can be justified by a number of literature and by the previously published paper of the author. (Restás 2018) Based on these, we can state that both the number and the duration of drought periods will increase. (Heizler 2002) The amount of precipitation in the Carpathian Basin is not expected to change significantly, but its distribution is already there. Many times rains will occur in shorter time but in larger volumes, or in more concentrated areas than previously. (Hargitai 2003) Opposite to this, the drier periods may be longer, which may lead to higher levels of dryness of the vegetation, as well as to the better conditions of ignition, combustion and fire spread. (Mika 1988; Vidal et al. 1994)

The burning forest generates large amounts of carbon dioxide into the air, which makes the balance of greenhouse effect worsen in the atmosphere. According to international data, 20% of the carbon dioxide emissions into the atmosphere can be attributed to forest fires (GFMC).

It can be seen from previous studies that fire seasons can be predicted with relatively good suitability rate based on the meteorological conditions and previous firefighting experiences. (Chandler et al. 1983; Bussay 1995; Bryan 2003) Nevertheless, the effectiveness of the current preventive measures (such as the prohibition of fire-ignition in open places) can be strongly questioned in the light of the most widespread wording. (Nagy 2004)

Both national and international experiences confirm that the rate of human intervention is decisive for fire ignition, reaching even up to 80–99%. (Leone–Lovreglio 2003) By improving the effectiveness of preventive measures and improving civic discipline, this ratio can be significantly reduced. Based on the study and classification of the reported fires, it can also be stated that, in many cases, the person reporting the fire could have been supported the fire control before the arrival of the first intervening firefighting units.

In case of intentional or negligent fire, the person causing the fire does not have any interest to report the fire to the fire service or to extinguish it before the arrival of the first unit. Fire report depends on many factors and circumstances. For example, it is very important whether the person who first noticed the fire, is interested or not in reporting the fire. Other examples are the competencies or ability that the person who detected the fire has. Even if the next example is becoming more and more scarce and irrelevant, it has to be stated. Traditional landline telephony is predominant in the populated environment, while the use of mobile phones in the event of fire-causing groups may not be general. In some places, network coverage does not allow the use of mobile phones to report the fire. This latest one may hinder the signals of the tourists.

In the current system, the fire department is informed about any forest fire only from the signalling person. If there is no citizen notification, there is no fire alarm for the fire service. (Restás 2004) This process can be interpreted as a passive fire detection system for the fire service.

Based on the recorded data on vegetation fires, naturally – mostly in case of grass or bush fires – it can be seen that a significant part of them is considered a worthless fire by firefighters or experts, while everybody knows that for suppressing it, significant resources are needed. From an economic point of view, we should give up the followed process that means a fire event can have no damage or costs.

During suppressing grass or bush fires whose value is obviously less than that of forest fires, the potential vulnerability of citizens increases due to the absence of firefighters from the home city.

This is unacceptable, as in many cases, firefighters are being used to kill forest fires with fire engines that have been created for so-called *urban fires* and not forest fires. While these fire engines with the staff are at the scene of forest fires, people in a populated environment potentially face a higher risk because in case of an urban fire, intervention can only begin with less or with later arrived resources due to the absence of vehicles from the home department.

There are many fire brigades with no special fire engines for suppressing the vegetation fires, therefore, they use their fire engines worth about 500,000 €. By doing so, fire trucks are unnecessarily amortised; on the other hand, the effectiveness of these assets is unacceptable in case of forest fires. When a fire brigade approaches the fire front on dirty or forest roads, the level of wear and tear on cars is growing, while this truck can even fall in a trap in the forest.

In order to save the condition of the fire trucks, firefighters sometimes walk several kilometres to the fire front, which causes a considerable time loss. This increases the fire size, which is also a disadvantage to effective intervention. Meanwhile, the time of walking to the fire front and back to the truck further increases the potential risk of citizens. To approach the fire front with an appropriate vehicle would be very important to help the early commencement of firefighting, as well as to raise the alert level in time and to save the physical force of the staff.

The high number of simultaneous fires requires simultaneous use of all fire trucks in the area. Many times it is not only one car that is alarmed and is going to fires. At the same time, applications mean that fire brigades can be very far from each other, which leads both to a delay in arriving to the intended place and to a significant reduction in effectiveness and efficiency. Moreover, this may further induce an increase in the alarm level. In such cases, the otherwise logical so-called assistance plan is virtually crashing. It also happens in these cases that the head of the firefighting unit in need of help – because of the late arrival of the assistance – does not order the reasonably higher alert level.

If the assistance plan is crashing regularly, the commanders cannot count on it in case of necessity – be it a forest fire or city fire – therefore, they try to find alternative solutions to keep their ability at a minimum level that sometimes may not be legal or ethical. For avoiding this, we might also suppose that the commander of smaller units sometimes protects his own site from higher fire risks with a special process. That means, he coordinates the work of his firefighters in such a way that the fire suppression will not happen as quickly as possible, it is still executed within a planned time, to be able to keep their own units in their own area.

The above behaviour is logical for the protection of the community concerned, but in a wider context, at a larger territorial or national level it is not only unethical, but certainly ruthless. Additionally, this attitude can also result in an avoidable economic damage. Even if this behaviour is questioned by the author and surely also by the higher decision-makers, it should be taken into account that unit commanders have a high level responsibility, and that this behaviour at their decision-making level is logical and also that this situation is the result of an evolutionary process.

To address the problems discussed above, the fire service can apply multiple solutions, such as significant human resources and technical development at the professional fire brigades or dislocation optimisation with stronger support for the voluntary movement like voluntary fire brigades and civil protection. But a more professional management introducing the prohibition of setting open fires is also a tool. Even if the above-mentioned possibilities are an everyday practice in the hand of the higher decision-making levels but looking at the results, we can see that they are used only with moderate success; therefore, we can call them a conservative treatment.

The key elements to solve the above problems are therefore not in the continuation of the application of traditional methods. Problems must be addressed in a complex way that is to be found in conjunction with the state of art. There is a need to find and adapt methods and technologies – that are already used effectively in other topics – to make forest fire management more effective. The methods used elsewhere need to be investigated and, if the results are positive, they have to be used for improving fire prevention and fire suppression.

Based on a deeper review of the above issues, it can be noticed that a significant part of them is generated from each other. Without further analysis, it can be seen that the characteristics of the initial intervention of the fire brigade have a significant impact on subsequent consequences. By developing an integrated environmental monitoring and alarm system, many of this self-generating problem can be solved or can be reduced significantly, and overall, effective management can be achieved.

The detailed description of the basic problem is analysed in two directions. One draws conclusions from the nature of the spread of fire, while the other analyses the process of fire.

3.2. The key factors of effectiveness

The so-called fire curve can be examined with the so-called damage-time function. (Restás 2012) The vertical axis represents the magnitude of the damage value; the horizontal indicates the passage of time. In general, this function is based on a closed space. Assuming a free fire spread, the function first shows a steep rise and then the curve flattens with the burning of the combustible material. If the combustible material runs out, the fire itself spontaneously falls, the curve is interrupted.

In examining the question of efficiency, we generally take into account the return on investment and the time of recovery. During firefighting, it makes sense to talk about efficiency, but its explanation differs from the classical interpretation. During firefighting and other interventions, the efficiency is objectively measured by the magnitude of the saved value, which is very difficult to measure, or the amount of damage caused by the fire, that should be as low as possible. A firefighting intervention can be called efficient if the available resources are used to maximise the value of the saved forest while the resulted damage value is as small as possible. (Restás 2004)

To understand the essence of the organisation effectiveness of the fire service and to get relevant results, it is necessary to analyse the fire curve in case of forest fires. Naturally, as a first step, we have to make the following assumptions regarding the study:

- the forest is homogeneous at the study area
- meteorological conditions are constant and stable, like temperature, humidity, etc.
- there is no wind
- the studied area is flat

Based on the above assumptions, it can be seen that, the fire curve goes up exponentially to infinity. The intensity of the curve's steep is determined by two different factors: the first one comes from the mathematical formula calculating the area of circle which is nothing else than the circle radius. The other one comes from the speed of the spreading fire; however, it is not independent from the first one, therefore it is nothing else than the changing rate of the circle radius. Very simply, the burnt area depends on the speed of fire spread which is changing exponentially in time. The higher the rate of the spreading fire, the bigger the area burnt by the fire.

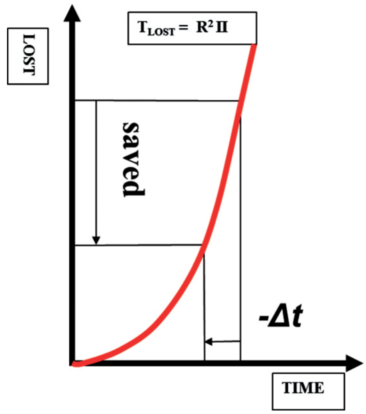

Figure 1.
Damage – Time function analysis

Source: Drawn by the author.

With the given assumptions, it can be seen that the burning time could take forever. Fire service is responsible to terminate any fires; in this case, it is responsible to break this exponentially raised curve that means to stop the fire. If the fire service can stop the fire earlier, the burnt area also reduces exponentially. It is easy to find some basic statements:

- the smaller is the area of burning, the easier it is to terminate it
- quick fire report means smaller burnt area
- quick fire response means less requirements in resources to suppress the fire
- reducing the response time with any Δt means that the burnt area and the damage caused by the fire, decreases exponentially

Based on the above we can conclude that fire services should get information about the forest fires as soon as possible to limit the burnt area and to reduce the resources required to terminate the fire. Summarising the above, quick fire report could raise the effectiveness of the intervention of the fire service.

3.3. Summarised problems of fighting against forest fires

At a big scale, forest fire disaster management or fire service faces many problems. The first problem is that, in many cases only one or two fire brigades are not powerful enough, or do not have enough staff members to suppress the fire with their own resources. It means that help from other fire services is required which causes time delay in the beginning of the suppression and it also means more resources to suppress the fire as it was explained in more details before.

Another problem is that, in most cases, a fire brigade begins to control the fire with hand tools instead of water, because, water resources are usually very limited in the forested areas especially in drought periods, when fire risk can be extremely high. Usually, drought periods mean fire seasons, too.

The other reason for using hand tools instead of the more effective water is that, the places of fire, in many cases, are too far from the roads on which traditional fire engines can reach the fire front and could support the fire brigades with water supply. (Bodnár 2017) Nowadays, fire services use more and more fire engines specially optimised to suppress forest fires instead of traditional fire trucks optimised to suppress so-called city fires. The palette of these vehicles is wider and wider, it can be featured from the small size pick up, which carries only some hundred litres of water, to a huge size fire truck, with the capability of up to more than ten thousand litres of water.

Even if the capability of small size vehicles in carrying water is very limited, they still have the advantage of moving much more effectively on a rough terrain. The author's experiences show that many times, it is more valuable than the water itself. This value is underlined if we take into account the statement mentioned above, that is, in most cases fire brigades must use hand tools instead of water.

From the point of view of effectiveness, to use hand tools or water depends not only on the water supply but also on the fire intensity. Hand tools can be effective enough in case of low fire intensity when firefighters can be at a so-called "step distance" from the fire front. According to the literature, a normal personal protective equipment that firefighters must use during any intervention is able to protect a person against heat radiation up to 500 kWm^{-1} fire intensity; however, using a special personal equipment, this value can go up to 700 kWm^{-1} but not higher. Based on everyday practice, in many cases, the fire intensity is below 700 kWm^{-1} which means that using only hand tools can be an effective method to suppress fires without even using water. Based on the above we can conclude that, simple but very mobile vehicles, like pick up can carry the staff of a fire brigade and can be an effective vehicle for the fire service.

Continuing the above logical method, we can find other useful mobile vehicles. For example, quad systems can also be a very good solution; their structure were built to carry goods on very difficult rough territories. Depending on the type of quad, the gravity point of the usefulness can move from the bigger transport capacity to the moving capability in extremities. Fire services can find the balance between these capabilities from carrying more extinguishing materials like water or carrying more persons with hand tools.

Based on the author's experiences, the effectiveness of using hand tools is drastically reduced if the fire intensity rises. The maximum speed of the fire suppression per staff can be as high as the maximum walking speed of an equipped firefighter, that is about 1 $msec^{-1}$. In this case a firefighter can suppress the fire with pulling easily his special hand tool on the grass with a walking speed that has a minimal fire intensity. In this case firefighters can reach up to 3,600 $mhour^{1}$ of terminating the fire front. In higher fire intensity, just pulling the hand tools on the surface is not enough, the staff must spatter the vegetation which takes time and makes the extinguishing process slower. The higher the fire intensity is, the slower the extinguishing process is. The extinguishing process falls down to zero, when with spattering the fire front, the staff cannot suppress the fire because of its high intensity, or the intensity itself is so high that the personal protective equipment cannot protect the staff from heat radiation. In both cases hand toll effectiveness ends.

We could also study that case when both methods, it means spattering the fire front and using water, are at hand for the staff to suppress the fire. Decreasing the fire intensity by spattering the fire front is a slower procedure, however, firefighters can move ahead in extinguishing it. Even at a higher fire intensity, the staff can be effective using water, however, it takes costs compared to using hand tools. It should be a tipping point when the effectiveness of using water with direct cost balances the effectiveness of using hand tools without direct cost.

4. Answers to Challenges: Integrated Vegetation Fire Management

4.1. General program overview

Summarising the above, the analysis of firefighting ascertains a number of statements. The fire department becomes aware of the report through someone noticing the fire. The reporting individual's subjective assessment considerably influences the time of notification. The notification is independent of the fire department, the link between the report and the time of lighting is often simply the reporting individual's subjective assessment. Fire departments currently endeavour to increase the rapidity of reporting through the method of awareness-raising. Following the report, the fire brigade reaches the location of a fire, or at least approaches it, with the minimum delay in accordance with its operational order. This time period cannot practicably be lowered, and thus it can be considered as being objectively set and minimal. Approaching the fire on foot could waste a lot of time if there was a suitable path that was more rapidly negotiable by a cross-country vehicle. That is dependent on the technical tool, a vehicle. At the scene of the fire, the first task is reconnaissance, which is simply gathering sufficient information to facilitate effective firefighting. The effectiveness of the reconnaissance can be measured by the efficiency of the firefighting. A sufficient amount of quality information is needed for that. The first job is to establish the extent of the fire. A burning area of only 300 metres radius represents a walk of nearly 2,000 metres. Accounting for the configurations of the terrain, the obstructive effects of plantation and equipment, exploration on foot may extend in time considerably. Conclusions drawn from the firefighting procedures are as follows:

- the time that has passed before a fire is reported does not depend on the fire department, but does lead to a delay in intervention
- the time from the report to arrival at the location cannot objectively be reduced
- reaching the location on foot results in delayed intervention
- investigation on foot extends in time and results in a delay in the commencement of effective intervention

Both the analysis of the damage – time function and the firefighting procedure show that effective firefighting depends mostly on the time factor. Rapid intervention calculated from the point of lighting appears firstly in reduced damages and secondly in reduced costs for deploying forces and equipment.

Based on the above, fire services have to focus on the key element of the success, that is directly or indirectly the time factor. It means the new approach requires an integrated system which consists of different parts such as:

- a fire risk assessment module with effective legislative instruments to be able to prohibit fire lighting in dangerous fire seasons
- an early warning system to detect fire as quick as possible
- an appropriate logistic system with mobile deployment control and support unit
- static decision support unit
- dynamic decision-support unit
- complementary elements (e.g. training module, financial module including insurance opportunities)

The detail of the first element, that is the fire risk assessment module of the integrated vegetation fire management system was explained in a previous study, therefore, the author focuses now mostly on other units, such as the early warning system, logistic and mobile control unit and the decision support units.

4.2. Early warning fire detection unit

Depending on the geographical features of the given area, for a quick fire detection, a centralised tower based or a networked camera system should be installed. There are examples even in Hungary of how to create a centrally installed forest monitoring and fire-detecting unit. (Restás 2006) With this system the duty officer will be able to detect any fire or smoke within a very short period from a fire ignition, and before it would be reported by telephone by anyone. Based on this system, fire services can detect the forest fires before the civil report which obviously means higher effectiveness than the traditional procedure.

The cameras, which have appropriate resolution, can also be able to generate automatic signals or alarms, depending on their settings. The accuracy of both automatic alarm signals and personal detection will deteriorate in proportion to distance, but even at the edge of the area to be monitored, a circle with a 13–17 km radius around the tower can be defined which will have to comply with the perceptual threshold of 160 m^2. This size shall ensure, both on the detection and on the alarm side, that under normal conditions the first responders unit arriving to extinguish the fire will be confronted by a vegetation fire that they are able to extinguish using their own resources. With this solution we are able to eliminate the civil subjectivity of reporting fire. The fire department does not wait for civil report but searches fires by active way. We can say it is an active cognizance.

The geographical features can allow fires to be detected within a short period from their start, either by direct visual observation of hillsides, or indirectly in the valleys by detecting the smoke rising from occluded hillsides. In mountainous areas, fires in valleys and in lower-lying areas can be detected by detecting pillars of smoke. When the smoke rises over the ridge of the hill occluding the area, it can be detected by one of the cameras. The relatively small height differential between ridges and the lowest points of valleys in Hungary, it will allow even the pillars of smoke from small fires to be detected, despite the mixing of air and the resultant “thinning” of smoke.

4.3. Logistic system with mobile control unit

The mobile deployment control and logistic support unit can be the system's second module. Once a fire is detected, it is crucial that the site is reached as soon as possible in order to perform precise reconnaissance of the fire, and to commence extinguishing it using the appropriate tactics. At present, since the roads are not negotiable by fire-engines, fires are often accessed on foot over distances of several kilometres, on some occasions with a fire-hose, which carries the risk of the hose being damaged as detailed in this study before. The above considerations justify the use of a vehicle with strong all-terrain capabilities to access scenes of fire. The vehicle would also allow the traditional and modern equipment that is widely used in international practice to be transported to the scene. (NAGY 2004) Both small size pick-ups and medium range fire trucks can be effective depending on the previous practice and the size of the fire. As detailed before, quads can also be effective vehicles carrying the staff quickly in extremely rough areas.

4.4. Static decision support unit

Appropriate information is a precondition for tactically correct intervention, which presupposes accurate reconnaissance performed by the leader of the firefighting unit. As areas are usually accessed from the direction of valleys, a good overview of the area affected by the fire is generally not available. Walking around the fire is time-consuming and, in case of a larger area under flame, the leader of the firefighting unit is evidently physically too close to the fire to be able to make the correct decision concerning the type of intervention based on an assessment of both the fire and its environment. International practice has produced a few examples for establishing fire spread models. (CHANDLER et al. 1983; BRYAN 2003)

The above data-series can determine the parameters of the fire spread if summarised with a mathematical algorithm (spread prediction model). (FINNEY 1998; ROTHERMEL 1983) This is the static fire spread calculation that can be displayed for the firefighting leader on a digital map (3D – terrain model) on an on-site laptop. If we also summarise the parameters of the current weather conditions (temperature, humidity, speed and direction of wind), then the anticipatable fire spread in accordance with the situation at the time can be seen. All the data that may be represented in a map shall be stored in digital format. User-friendly programs will also allow the risk levels of the area to be displayed in real time. Hence, instead of estimates concerning the spread of the fire based on previous experience, the likely spread of the fire can be determined on the basis of real, objective data.

4.5. Dynamic decision support unit

Once firefighters are on the scene, the first important task is reconnaissance. Reconnaissance comprises of data collection and orientation required for defining the tasks associated with the saving of lives and the extinguishing of the fire, along with their safe implementation; it extends from the fire report until the supplementary work is concluded.

The above problems can be solved using a tool that can rapidly provide accurate information about the entire fire zone. The use of personal reconnaissance from the air is a logical solution. Air reconnaissance is efficient because obtaining an overview of several hundred or even thousand hectares of forest allows intervention measures to be coordinated. Without air reconnaissance, coordination of measures can only be based on the information circulated between the commanders of individual units at various locations. But the assessment of the gravity of their individual situations by commanders located at various sites may be completely subjective and not made in relation to the other sites. Air reconnaissance helps to eliminate subjectivity in such judgements and to rank the individual sites in relation to the others. Air reconnaissance may also eliminate the effects of terrain topology that otherwise hinder or prevent visual access to the area concerned. Our task is to find a solution that allows us to take advantage of the benefits of air reconnaissance in case of smaller fires, as well.

We can retain the benefits of air reconnaissance at a relatively low cost if the visual inspection by the staff is replaced by the acquisition of image data. The replacement of the staff inspection by machine data acquisition does not reduce the efficiency of reconnaissance or prevent the facilitation of more efficient firefighting. In short, machine reconnaissance can support the achievement of the criteria required for a greater efficiency to a similar degree. And it does not require manned aircraft!

Maximum efficiency is best supported by making the corresponding efforts as early as possible. That problem could be solved by a drone being operated by the fire service. The relatively low flight performance requirement reflects the preference for a really small drone that can provide efficient support for the reconnaissance activities of even the smallest firefighting unit rather than a drone with excess capacity. Excess capacity is unnecessary as the requirements of efficient reconnaissance can even be met by a single image from a suitable perspective. As fire spreads relatively slowly, a second flight can furnish precise information to the firefighting commander.

If we can find a drone that can be used by even the smallest fire brigade, a number of incidental benefits will also accrue that would not be furnished by a larger drone. They include the fact that once the drone is used in the field, the everyday practice of the smallest unit would provide support for the viability of the drone in a very short time. The frequent calls that fire brigades receive in dry periods would allow a tremendous quantity of experience to be collected. Drones with large flight potential are only deployed in emergencies of a magnitude that is relatively rare. As a result, the experience of their application would be of an inferential nature rather than one of statistical certainties. On the other hand, the use of small drones of limited capabilities would provide a quantity of data sufficient for statistical analysis in a relatively short time.

5. Drone Applications Especially Developed for Forest Services

5.1. The process of using drones supporting forest fire management

After the fire brigade receives the fire report, a single section sets off for the scene of the forest fire. In a terrain of medium articulation, topological conditions do not allow the area to be viewed as a whole, but, based on the smoke, the firefighting commander believes that thorough reconnaissance is in order. Therefore, the commander defines the point of control and the small drone is prepared for flight. In effect, the preparation for flight should take less than 10 minutes.

Based on the visible smoke, the commander of the firefighting unit can give a rough estimation of the extent of the fire. As an example, due to terrain conditions, the direction of spread and the extent of the fire cannot be assessed with proper accuracy. The laptop transported on the vehicle is used to display a digital map of the area. With a special pencil, the commander could draw a curve starting from and returning to the point of control. Alternatively, some points may be defined, which would be connected to obtain the flight path, this time as straight sections connecting the turning points. The drone, which would be connected to the laptop, would convert the flight path to the digital map stored in its own memory.

Experience indicates that it is not difficult to draw a curve that is certainly significantly larger than the actual extent of the fire. This will ensure that the drone flies around the fire in the way the commander or any other dedicated member of the staff would have to walk around it. Using its built-in GPS unit, the drone flies along the specified flight path, transmitting images from its digital and thermal cameras to the screen of the laptop. As a result, the firefighting commander can see perspective images of the area affected by the fire in real time. If possible, the precise image and thermal data transmitted by the drone would be mapped onto the digital map displayed on the screen of the laptop. From the moment of launch, the drone supplies data continuously, therefore within the first few minutes it provides information of a quantity and quality that provide effective support for the decisions of the commander of the firefighting unit. One such element of decision support is that even before the drone returns, it is possible to establish the extent of the burning area and to request the assistance of further units. This saves a significant amount of time. Also, as it was already mentioned, the amount of damage prevented is proportional to the square of any amount of time saved.

Another example of decision support: if we are able to manage the entire area in a complex manner, it may well be the case that protecting the area where the fire is currently most intense is the most important task. It is possible that our forces need to be concentrated or optimised in a location other than that furnished by the initial assessment. While firefighting is in progress, the fire continues to spread in the areas where no countermeasures are taken, and indeed it may meet natural obstacles or barriers. A river, a wider road or glade may stop the fire as a natural barrier, so taking firefighting measures at a distance of 100 or 200 metres from such a natural barrier can only be considered efficient if we have plenty of resources and equipment, which are not needed elsewhere. On the other hand, it is also possible that in a direction which currently has low parameters for spread and is thus assessed as lower priority, there lies a much more valuable area, such as a highly protected plant community, a habitat of protected animals, or perhaps an area of vegetation with higher parameters for spread.

The above examples show that the most efficient intervention is not necessarily the same as intervention at the point where the fire is the most intense. In order to make the best decision, the area of the fire must be managed in a complex manner, together with its environment. The above considerations lead to the conclusion that we should always attempt to extinguish forest fires in order to consume the smallest possible quantity of resources.

5.2. Experiences of using drones supporting forest fire management

Using drones, the fire services should take into account the following statements based on the author's experiences:

- For a minimum efficiency, it is not necessary to use coloured cameras. Naturally, a coloured and infrared camera is much better but a black and white camera is also able to give firefighters enough information. Coloured pictures might seem a good idea but sometimes it simply provides too much information for the mind.
- High technologies are not necessary. It is much more important to give a user-friendly technology for the firefighters.
- After launch, below 2–3 minutes, firefighters can have enough information to choose a good solution to managing the fire.
- It is not necessary to fly more than 500 metres' altitude above the fire. Naturally, it assumes not very articulated territories. This altitude is fit to the most parts of Europe to use simple drones supporting forest fire management. The maximum altitude can be 1,000 metres depending on other air traffic.
- Analysing the pictures taken at different times, firefighters are able to predict the spread of fire and to see how the characteristics of the fire changes.
- The author's practice evidences that drones are very useful tools supporting the fight against forest fires but only in those cases when they are used at the scene of fires by the first responders as soon as possible. All this means that drones have to be managed by nobody else than firefighters.
- The efficiency of drones in case of fire monitoring is evident; however, for a quick fire detection its efficiency is not yet determined. It seems that for fire detection, the tower based early warning system is in most cases more effective.
- If firefighters have such a big affected area that it is not possible to manage it by their small drones, then they have to ask for help. In this case they have a chance to support the fire management by any staff aircraft.

Based on the above we can see that the application of drones for effective use is relatively well developed. Fire services should use it.

6. Drone Development and Training Program for Fire Services

Any high technology is worth nothing in the hand of untrained workers; however, fire managers know that with enough practice and creativity, many times, even from the simplest device, the staff can make an appropriate and professional tool on the scene. Therefore, it is very important to appropriately train firefighters in using special tools, such as drones. Based on the above, the author developed a 3-step program for fire services to develop this opportunity and to train firefighters using different drones for being as effective as possible.

6.1. The first step: Basic level

The aim of the first step is to find or create a cheap but good enough drone, so that firefighters have a chance to use drones without any fear of crashing or losing it.

Plane/equipment: the material of the drone should not be easy to break (its wings should be from latex or plastic) but easy to replace. The drone carries a cheap camera, visible only enough at this stage. This drone should be ground controlled only to get enough practice in controlling. The flight capability can be limited, it can have about 15 minutes' flight time, within a circle of about 1 km radius and about 500 m altitude. Advantage: firefighters can get used to this technology, without fear from using the drone. Firefighters get lots of experience during training flights but also in real intervention situations and within a short time. Disadvantage: this solution has limited capabilities, i.e. it provides moderate quality information. It is only ground controlled and it requires at least 2 users.

Training: before using real drones, firefighters can be trained by a drone flight simulator program which spares time in real training. In a short time, the selected firefighters are ready and trained. The whole program takes no more than 30 hours.

6.2. The second step: Intermediate level

The aim of the second step is to find or create a drone with autonomous flight capabilities specialised for supporting interventions like fighting against forest fires or floods.

Plane/equipment: carried by jeep, measuring maximum up to 50 x 50 x 50 cm. They can be fixed- or rotary-wing ones to carry them easily in case of a fix wing plane; however, the capabilities of rotary-wing drones seem very good today. Good quality visible/thermal camera with zoom. They are ready for autonomous flights and require only limited ground control. They should be lunched within 2 minutes. Flight capacity: 30 minutes' flight time, within a circle of 3–5 km radius and 800–1,000 m altitude. Advantage: full intervention support. They can provide high quality information with user friendly technology. Disadvantage: the first drone can be expensive.

Training is required from professionals to be able to use the maximum capabilities of the drone. It takes only some hours.

6.3. The third step: The complete system

The aim of this step is to create a mobile and integrated drone base. It can be used in any type of intervention. This can be a complete system with fixed- and rotary-wing drones but balloons can also belong to the system. Balloons can be used as a static monitoring point in case of long term interventions. This compact system is to be carried in a little truck but its capability is higher than what a small fire brigade requires, therefore suggested for service at higher organisation or management level.

Advantage: ability to support any intervention from little accidents to large scale disaster management, not only fighting against forest fire (e.g. at chemical accidents, floods and storms drones can be attached with special sensors). Disadvantage: the whole system can be expensive. Several hours needed to start the use of drones. The system effectiveness is accentuated in case of long term interventions. Extensive background support needed.

Training requires professionals; however, self-training is also required from motivated firefighters.

7. Summary

Integrated vegetation fire management involves numerous applications that have an innovative character in firefighting. The system does not condemn the principle of fire extinguishing in the traditional way, it is complementary to it. It is an initiative that emerged to tackle climate change problems. Its effectiveness has to be judged on economic rather than emotional grounds. The program is not a cost-free system; it could not possibly be. If we accept that the efficiency of the current system is not optimal for fighting vegetation fires, then the reserves of the system simply not ought to be, but must be exploited. The analysis and its conclusions demonstrate that the premise of effective firefighting depends on the quickness of the first responders. As long as a time-reserve, unexploited in the current system, exists prior to the initiation of firefighting, using it is more than a possibility, it is an obligation.

The area monitoring and fire detection unit installed on the tower ensures, from the perspective of recognisance and alarm, that the unit arriving for action will face a vegetation fire that it can fight with its own forces. The mobile deployment control and support unit ensures an optimal approach to the fire and that the static and dynamic decision support unit will reach the location. The tried and trusted principle of air-reconnaissance can be available to even the smallest fire department through the use of the drone. Traditional reconnaissance does not offer information neither quantitatively nor qualitatively appropriate to standards of the modern era. Drones, suited to the demands of fire departments that can also be used by small fire departments, significantly contribute to solving that problem. The dynamic decision support is able to provide initial data for static decision support. Thus, instead of an estimate of fire spread based on previous experiences, the fire's actual scale and spread can be objectively defined.

The application of the integrated vegetation fire management is expected to result in increasingly effective interventions, which can achieve a growth in the size of preserved forest areas, as well as a decrease in the area of territory destroyed. The costs of development and application need to be judged on the basis of economic considerations, and seen as effective if returns are brought at the state economy level. The requisition of firemen may diminish, and the need for help may frequently be avoided. In the absence of superfluous requisitions, the potential risk to the general public diminishes in a higher degree of fire-security.

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Andrea Farkas

Challenges for Agriculture and Water Management in the UN Sustainable Development Goals (2016–2030)

1. Introduction

The United Nations accepted 17 Sustainable Development Goals and detailed 169 Targets for the 2016–2030 period. (SDG 2015) Sustainability is used in its widest understanding, so the Goals comprehend all environmental, societal and economic problems as aspects of sustainability. The co-chairs of the preparation were Csaba Körösi (Hungary) and Macharia Kamau (Kenya).

Let us list the 17 Goals as originally compiled in the SDG 2015:

Goal 1. *End poverty in all its forms everywhere*

Goal 2. *End hunger, achieve food security and improved nutrition and promote sustainable agriculture*

Goal 3. *Ensure healthy lives and promote well-being for all at all ages*

Goal 4. *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*

Goal 5. *Achieve gender equality and empower all women and girls*

Goal 6. *Ensure availability and sustainable management of water and sanitation for all*

Goal 7. *Ensure access to affordable, reliable, sustainable and modern energy for all*

Goal 8. *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*

Goal 9. *Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*

Goal 10. *Reduce inequality within and among countries*

Goal 11. *Make cities and human settlements inclusive, safe, resilient and sustainable*

Goal 12. *Ensure sustainable consumption and production patterns*

Goal 13. *Take urgent action to combat climate change and its impacts**
**Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.*

Goal 14. *Conserve and sustainably use the oceans, seas and marine resources for sustainable development*

Goal 15. *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*

Goal 16. *Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels*

Goal 17. *Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development*

Since the Goals are not arranged in any logical structure, János Mika and Boglárka Tóth (MIKA-TÓTH 2017) provided a meaningful classification of the 17 Goals. In the followings, the below listed classification of the 17 Goals will be used. (The Groups will be marked by their numbers and brief characterisations.)

- *Primary needs of humans* (2. Food, 3. Health, 6. Water and 7. Energy)
- *Equality between humans* (1. No poverty, 4. Education, 5. Gender equality and 10. Reduced inequalities)
- *Efficient, sustainable production* (8. Economic growth, 9. Innovative industry, 12. Responsible consumption and production, 13. Climate action)
- *Landscapes in danger* (11. Cities, 14. Life in water and 15. Life on land)
- *Worldwide cooperation* (16. Peace and justice and 17. Partnerships)

From among the 169 targets, 126 targets have measurable, numeric indicators to be reached by a specific year (usually 2030). These targets are indicated as number.numbers. The remaining 43 targets are denoted with a combination of a letter and number. These targets promote awareness, institutional or financial actions for improving the state of the issue.

Let us cite examples for both related to Goal 1:

"1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day."

"1.b Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions."

Reducing poverty will help us to achieve other Goals and targets, as well.

One should note that the SDG was initially recommended as a document reflecting the important 5P for mankind: *people, planet, prosperity, peace, partnership,* (SDG 2015, 2.) but these concepts do not consequently accompany the document. The first two groups of the above classification, i.e. the basic needs (No. 2, 3, 6 and 7) and the equity group (No. 1, 4, 5 and 10) deal really with *people.* The next two groups, the production (No. 8, 9, 12 and 13) and the zones in danger (No. 11, 14 and 15) fit to *prosperity* and *planet,* but *peace* and *partnership* are related to the smallest group, cooperation (No. 16–17).

The present paper intends to select all targets related to agriculture (food production) and water management, as basic resources of mankind. The third branch of supply, the energy is missing, since this had already been published earlier. (MIKA-FARKAS 2017) Note that in Chapter 15 (MIKA-FARKAS 2018) further information on the SDG (2016–2030) can be found.

These targets are grouped into four sectors of agriculture (arable crops, horticulture, forestry and grassland farming, animal husbandry) and water management (sub-surface waters, rivers and lakes, oceans, water quality) accepting that some targets may affect more than one sector.

After selecting the SDG targets, an additional sub-chapter is also presented, including characterisation of drought, i.e. a common phenomenon in agriculture and water management, a key figure, the Whittaker-diagram, to assess climate change effect on natural vegetation and finally some key fact from a post-SDG survey issued by the United Nations, as well.

2. Targets of the SDG Related to Agriculture

In the followings those targets are listed in the below grouping, which are relevant to *agriculture.* Number.number and number.letter type targets are equally considered. All tasks of agriculture are classified into four branches as already mentioned above. They are arable crops, horticulture, forestry and grassland farming, animal husbandry. Tables will indicate which target is related to one or more of these classes.

2.1. Primary needs of humans

The most important goals are to fulfil basic needs of humans which are still not completely resolved in many regions of the world. Table 1 indicates which branches of agriculture the nine targets of this group contribute to. The four branches considered are arable crops, horticulture, forestry and grasslands, animal husbandry.

Table 1.

The relevant targets from among primary needs of humans, classified into four sectors of agriculture

Target	Arable crops	Horticulture	Forestry, grasslands	Animal husbandry
2.1	+	+		+
2.3	+	+		+
2.4	+	+	+	+
2.5	+	+	+	+
2.a	+	+		+
2.b	+	+		+
2.c	+	+		+
3.9	+			+
7.2	+		+	

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

2.1 "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round"

2.2 "By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons"

2.3 "By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment"

2.4 "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality"

2.5 "By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed"

2.a "Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries"

2.b "Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round"

2.c "Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility"

3.9 "By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination"

7.2 "By 2030, increase substantially the share of renewable energy in the global energy mix"

2.2. Equality between humans

Equal possibilities and rights form the next group of the Goals, including access to quality education and gender equality. Table 2 exposes the three relevant targets contributing to the four branches of agriculture.

Table 2.

The relevant targets from among equality between humans, classified into four sectors of agriculture

Target	Arable crops	Horticulture	Forestry, grasslands	Animal husbandry
1.4	+	+	+	+
1.5	+	+	+	+
5.a	+	+	+	+

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

1.4 "By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance"

1.5 "By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters"

5.a "Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws"

2.3. Efficient, sustainable production

The next group is the efficient but sustainable production, including Goal 13 (climate change), as well. The latter is the only environmental problem which is tackled in a separate goal not only in those domains affected by the problem. Table 3 sorts these targets with respect to the branches of agriculture they contribute to.

Table 3.
The relevant targets from among efficient, sustainable production, classified into four sectors of agriculture

Target	Arable crops	Horticulture	Forestry, grasslands	Animal husbandry
8.1	+	+	+	+
8.4	+	+	+	+
9.3	+	+	+	+
12.2	+	+	+	+
12.3	+	+		+
12.4	+	+		+
12.b	+	+		+
13.1	+	+	+	+
13.2	+	+	+	+

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

8.1 “Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries”

8.4 “Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead”

9.3 “Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets”

12.2 “By 2030, achieve the sustainable management and efficient use of natural resources”

12.3 “By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses”

12.4 “By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment”

12.b “Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products”

13.1 “Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries”

13.2 “Integrate climate change measures into national policies, strategies and planning”

2.4. Landscapes in danger

In geography and environmental sciences, we often define several types of landscapes. The SDG solves this problem very efficiently, distinguishing three types only: cities, underwater world (oceans) and lands. Table 4 collects the ten agriculture relevant targets of this group according to their contribution to the four basic branches of agriculture used also above.

Table 4.

The relevant targets from among landscapes in danger, classified into four sectors of agriculture

Target	Arable crops	Horticulture	Forestry, grasslands	Animal husbandry
11.a	+	+	+	+
14.4				+
15.1			+	
15.3	+		+	
15.5	+		+	+
15.6	+	+		+
15.7			+	+
15.8	+		+	
15.9	+	+	+	+
15.a	+	+	+	+

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

11.a "Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning"

14.4 "By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics"

15.1 "By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements"

15.3 "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world"

15.5 "Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species"

15.6 “Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed”
15.7 “Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products”
15.8 “By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species”
15.9 “By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts”
15.a “Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems”

2.5. Worldwide cooperation

Finally, there are two Goals which list those conditions mostly fulfilled by a kind of cooperation, without which realisation of the other 15 Goals would be questionable. Concerning agriculture, one finds only one target which is related to agriculture, as indicated in Table 5, and listed by its full text, below the table.

Table 5.
The relevant targets from among worldwide cooperation, classified into four sectors of agriculture

Target	Arable crops	Horticulture	Forestry, grasslands	Animal husbandry
17.18	+	+		+

Source: Drawn by the author.

17.18 “By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts”

In Summary to agriculture, let us state that 13 Goals comprehending 32 targets are found to be related to agriculture. This is 19% of the total 169 targets of the SDG (2016–2030).

3. Targets of the SDG Related to Water Management

In the followings those targets are listed in the below grouping, which are relevant to *water management.* Number.number and number.letter type targets are equally considered. All tasks of water management are classified into four branches as already mentioned above.

They are sub-surface waters, rivers and lakes, oceans and water quality. Tables will indicate which target is related to one or more of these classes.

3.1. Primary needs of humans

Table 6 indicates to which branches of water management do contribute the 12 targets of this group called basic human needs. The four branches considered are sub-surface waters, rivers and lakes, oceans and water quality.

Table 6.

The relevant targets from among primary needs of humans, classified into four sectors of water management

Target	Sub-surface waters	Rivers and lakes	Oceans	Water quality
2.4	+	+		
3.3		+		+
3.9		+		+
6.1	+	+		+
6.2	+			+
6.3		+		+
6.4	+	+		
6.5	+	+		
6.6	+	+		+
6.a	+	+	+	+
6.b		+		+
7.2		+	+	

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

2.4 “By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality”

3.3 “By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases”

3.9 “By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination”

6.1 “By 2030, achieve universal and equitable access to safe and affordable drinking water for all”

6.2 "By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations"
6.3 "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally"
6.4 "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity"
6.5 "By 2030, implement integrated water resources management at all levels, including through trans-boundary cooperation as appropriate"
6.6 "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes"
6.a "By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies"
6.b "Support and strengthen the participation of local communities in improving water and sanitation management"
7.2 "By 2030, increase substantially the share of renewable energy in the global energy mix"

3.2. Equality between humans

Table 7 shows the five targets contributing to the main branches of water management.

Table 7.
The relevant targets from among equality between humans, classified into four sectors of water management

Target	Sub-surface waters	Rivers and lakes	Oceans	Water quality
1.4	+	+		
1.5		+	+	
4.7	+	+	+	+
4.b	+	+	+	+
10.7		+		+

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:
1.4 "By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural

resources, appropriate new technology and financial services, including microfinance"

1.5 "By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters"

4.7 "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development"

4.b "By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries"

10.7 "Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies"

3.3. Efficient, sustainable production

Table 8 shows the nine targets contributing to the main branches of water management.

Table 8.
The relevant targets from among efficient, sustainable production, classified into four sectors of water management

Target	Sub-surface waters	Rivers and lakes	Oceans	Water quality
8.9		+	+	
9.1	+	+	+	+
12.2	+	+	+	+
12.4				+
12.8	+	+	+	
12.a	+	+		+
13.1		+	+	
13.2		+	+	+
13.3	+	+	+	

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:

8.9 "By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products"

9.1 "Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all"
12.2 "By 2030, achieve the sustainable management and efficient use of natural resources"
12.4 "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment"
12.8 "By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature"
12.a "Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production"
13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries"
13.2 "Integrate climate change measures into national policies, strategies and planning"
13.3 "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning"

3.4. Landscapes in danger

Table 9 shows the six targets contributing to the main branches of water management.

Table 9.

The relevant targets from among landscapes in danger, classified into four sectors of water management

Target	Sub-surface waters	Rivers and lakes	Oceans	Water quality
11.1		+		+
11.5		+	+	
14.1			+	+
14.3			+	+
15.1	+	+	+	
15.5	+	+		

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:
11.1 "By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums"
11.5 "By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations"

14.1 “By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution”
14.3 “Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels”
15.1 “By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements”
15.5 “Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species”

3.5. Worldwide cooperation

Table 10 shows the two targets contributing to the main branches of water management.

Table 10.
The relevant targets from among worldwide cooperation, classified into four sectors of water management

Target	Sub-surface waters	Rivers and lakes	Oceans	Water quality
17.6	+	+	+	
17.7	+	+	+	+

Source: Drawn by the author.

The official phrasing of the relevant targets is as follows:
17.6 “Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism”
17.7 “Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed”

In summary to water management, let us state that 15 Goals comprehending 34 targets are found to be related to water management. This is 20% of the total 169 targets of the SDG (2016–2030).

4. Additions to Agriculture and Water Management

4.1. Drought as a major problem for both sectors of economy

Among the extreme meteorological events, droughts are possibly the most slowly developing ones that often have the longest duration, and at the moment the least predictability among all atmospheric hazards. Due to these characteristics, particularly their temporal character, droughts cannot be compared with other weather and climate extremes such as floods, winter storms, frost, etc. which also contribute significantly to the weather affected annual loss. The major hydrologic hazards (e.g. flood and drought) are consequences of precipitation extremes. While floods may have mostly local economic impacts, the impacts of drought usually influence large regions and almost the entire economy. There are many definitions of drought.

Meteorological drought is often identified with atmospheric drought and defined simply with below mean precipitation amounts, sometimes combined with other parameters e.g. air temperature, humidity and wind velocity. As a matter of fact, the general term drought is not identical to precipitation deficit, but rather it is usually the consequence of below normal precipitation. Drought is by definition a regionally extensive deficiency in precipitation. Briefly, all other definitions of drought are related to the effect or impact of below normal precipitation on agricultural, water resources, social and economic activities. More precisely, atmospheric drought is a state of the atmosphere (not an instantaneous but an integrated state for a longer period of time) that results in less than average (for that period) precipitation amounts and/or below normal atmospheric humidity.

Agricultural drought occurs when the available soil moisture is inadequate to meet the evaporative demand. It can also occur, if meteorological anomalies take place during the plant specific time period (vulnerable stages of plant development) with regard to water availability. In addition to lack of precipitation, other contributing factors may increase drought severity such as low humidity temperature and winds. Drought results in considerable crop yield losses (e.g. more than 10% of the average yield).

Hydrological drought occurs when river flows or stored water in lakes, groundwater, reservoirs and aquifers fall below some critical levels resulting from a long-term deficiency of moisture. Conditions for hydrologic drought are built over extended periods of time. It takes a longer time for reservoirs or streams to become depleted which corresponds to longer replenishing periods.

Frequency or intensity of an extreme event can generally be enhanced under climate change in two cases. Either the whole distribution is shifted, with no change in the variance, when the extremes of this direction become much more frequent, but those from the other side become less frequent. In case if the variance of the distribution changes with no shift in the mean, when frequency of extremes on both sides changes in the same direction. Of course, in a real change, parallel occurrence of the two versions is the most likely.

Figure 1 indicates a subjective but rather global picture on what extreme events are considered to be common in different areas of the world concerning agricultural damages. Though the survey represented by the figure was collected over a decade ago, its results are still actual as climates of the answering localities could not change too much during this time. About the Global Warming Hiatus in continuous warming of the near-surface layers in 2002–2013, one can read in the present volume in János Mika's paper.

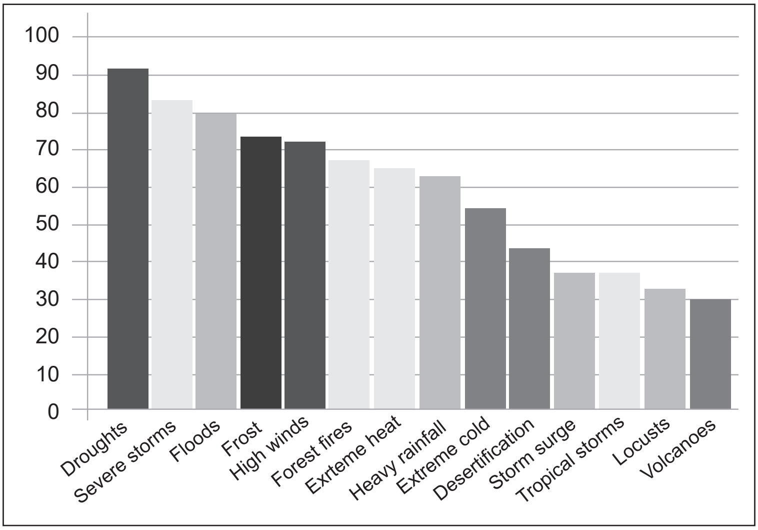

Figure 1.

Percentage of countries reporting agricultural impacts from the listed extreme events

Source: Shivakumar et al. 2005

The immediate meteorological causes of drought involve a number of factors. A stable high-pressure air-mass with descending air and low humidity is relatively free of clouds. If this air mass stagnates or moves slowly across an area because of atmospheric circulation patterns, the region over which it lingers will receive substantial sunshine and generally dry air with little or no rain. Once established, this condition has a tendency to persist, resulting in drought. Although drought is a phenomenon of shorter time scales, the frequency of drought can vary on decadal or longer scales, especially at low latitudes.

"There is not enough evidence to support medium or high confidence of attribution of increasing trends to anthropogenic forcings as a result of observational uncertainties and variable results from region to region. Combined with difficulties described above in distinguishing decadal scale variability in drought from long-term climate change we conclude [...] that there is low confidence in detection and attribution of changes in drought over global land areas since the mid-20th century." (IPCC AR5 2013, 913.)

4.2. The Whittaker-diagram to assess climate impacts on natural vegetation

The challenges for adaptation of natural vegetation are illustrated in the well-known Whittaker-diagram describing the main ecosystems in the temperature–precipitation system of coordinates (Figure 2). What can living organisms do during climate change? Three things basically: to tolerate the changes, to leave the place (very slowly by the plants) and to die.

When climate of a given location reaches the margin of the separate types of vegetation, plants find themselves in marginal position. There are most endangered species and the most culminant tasks for planned adaptation.

This is a key to establish whether or not a modified climate still corresponds to the given vegetation type, earlier dominant in the region. The only thing that should be known is the expected change in the main climate variables, i.e. annual mean temperature and precipitation.

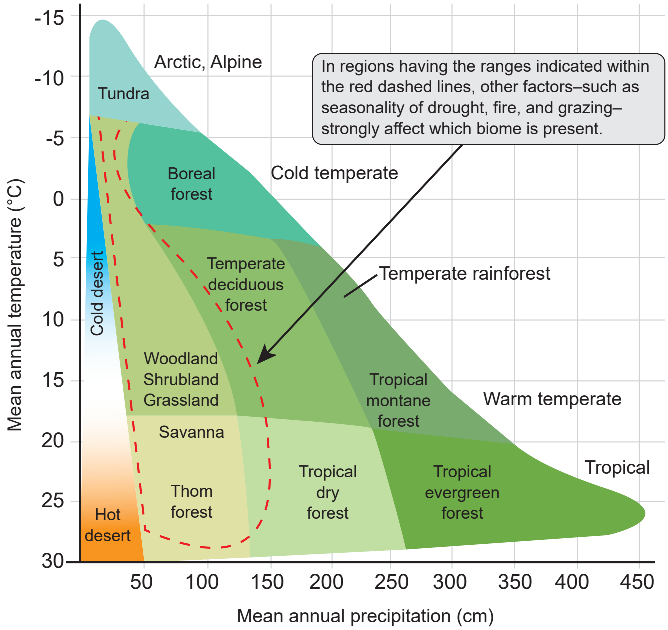

Figure 2.

The Whittaker-diagram of the present vegetation-cover in terms of the annual mean temperature and precipitation

Source: MIKA s.a.

4.3. Worldwide challenges of agriculture and water management in a post-SDG survey

Finally, let us present a few consequences established by post-SDG statistics (UN SDG Report 2016) related to agriculture and water management. Concerning food production, this document establishes that:

"The proportion of the population suffering from hunger declined globally from 15 per cent in 2000–2002 to 11 per cent in 2014–2016. However, nearly 800 million people worldwide still lack access to adequate food. (Figure 3, left panel.)

One in four children under the age of 5 had stunted growth in 2014 – an estimated 158.6 million children.

The share of overweight children under the age of 5 increased by nearly 20 per cent between 2000 and 2014. Approximately 41 million children in this age group worldwide were overweight in 2014; almost half of them lived in Asia."

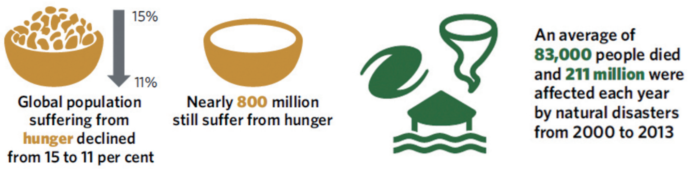

Figure 3.

Illustrations for hunger and natural disasters

Source: UN SDG Report 2016, 4, 9.

Concerning climate change it is worth emphasising the following statements of the UN SDG Report (2016):

- "…Urgent action is needed not only to combat climate change and its impacts, but also to build resilience in responding to climate-related hazards and natural disasters.
- In April 2016, 175 Member States signed the historic Paris Agreement, which sets the stage for ambitious climate action by all to ensure that global temperatures rise no more than 2 degrees Celsius.
- An average of 83,000 people died and 211 million were affected each year as a result of natural disasters occurring from 2000 to 2013. (Figure 3, right panel.)
- In 2015, only 83 countries reportedly had legislative and/or regulatory provisions in place for managing disaster risk."

Concerning water management, it is worth emphasising the following statements of the UN SDG Report (2016), selected illustrations of which are seen in the left panel of Figure 4.

- "In 2015, 6.6 billion people, or 91 per cent of the global population, used an improved drinking water source, compared with 82 per cent in 2000. However, in 2015 an estimated 663 million people were still using unimproved sources or surface water.
- Between 2000 and 2015, the proportion of the global population using improved sanitation increased from 59 per cent to 68 per cent. However, 2.4 billion were left behind. Among them were 946 million people without any facilities at all who continue to practise open defecation.
- Water stress affects more than 2 billion people around the globe, a figure that is projected to rise."

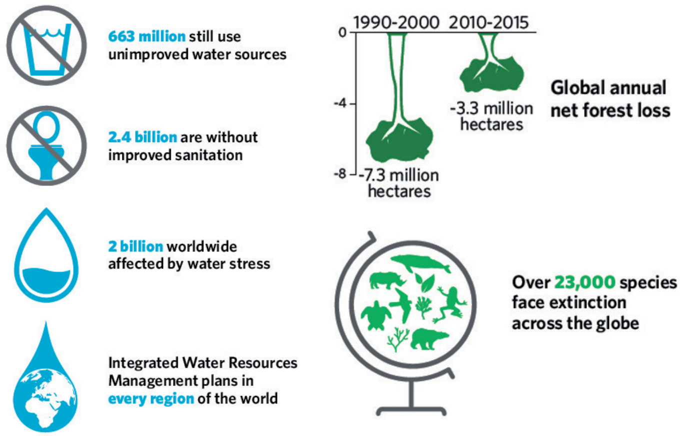

Figure 4.
Illustrations for water and biodiversity

Source: UN SDG Report 2016, 6, 10.

Concerning water management, it is worth emphasising the following statements of the UN SDG Report (2016), selected illustrations of which are seen in the right panel of Figure 4.

- "Global net loss in forest area declined from 7.3 million hectares per year in the 1990s to 3.3 million hectares per year during the period 2010–2015.
- The percentage of global terrestrial, inland freshwater and mountain key biodiversity areas covered by protected areas increased from 16.5 per cent to 19.3 per cent, 13.8 per cent to 16.6 per cent and 18.1 per cent to 20.1 per cent, respectively, from 2000 to 2016.
- As of 2015, over 23,000 species of plants, fungi and animals were known to face a high probability of extinction. Human activities are causing species extinctions at rates three orders of magnitude higher than those normal throughout the Earth's history."

4. Conclusion

In 2015 the UN adopted the Sustainable Development Goals (2016–2030), which contains 17 goals and also including 169 targets of the upcoming tasks of mankind. 13 goals, with 32 targets (19%) are expounded as linked to agriculture according to the author. These targets are grouped into four main sectors of agriculture (arable crops, horticulture, forestry and grassland farming, animal husbandry). Most of the targets (7 and 8) are related to Goal 2 and Goal 15, and also the role of agriculture is significant in four targets of Goal 12. Concerning the main branches of agriculture, arable crops and animal husbandry is supported by 29 and 28 targets, from the overall 32 agriculture relevant targets. Somewhat less support is provided for horticulture (24 targets) and for forestry and grassland farming (20 targets).

For water management the numbers are as follows: 15 Goals comprehending 34 targets (20%) are found related to water management. Obviously, all the eight targets are relevant from Goal 6, whereas four targets are taken from Goal 12. Concerning the main branches of water management, rivers and lakes are supported by 30 targets, from the overall 34 relevant targets. Considerably less support is provided for other branches of water management, i.e. 20 targets for water quality, 19 for sub-surface waters and 18 targets for the oceans.

Finally, note that there are 11 targets which are relevant for agriculture and water management at the same time. Four targets (12.2, 12.4, 13.1 and 13.2) come from the *Efficient, sustainable production* group of the Goals. Three doubled targets (2.4, 3.9 and 7.2) come from among *Primary needs of humans,* whereas 2–2 targets of *Equality between humans* (1.4 and 1.5) and of *Landscapes in danger* (15.1 and 15.5) affect both agriculture and water management.

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János Mika – Andrea Farkas

The Role of Meteorology and Climatology in Realisation of the UN Sustainable Development Goals (2016–2030)

1. Introduction

The General Assembly of the United Nations (UN) accepted the 2030 Agenda for Sustainable Development including 17 Sustainable Development Goals (SDG 2015) and 169 detailed targets. These goals spread over all natural, human and economic aspects of sustainability all over the world. The 17 established Goals, comprehended in Figure 1 are not ordered into any logical structure. One may suspect that the Goals of physical needs, key resources and landscapes in danger are intentionally mixed with those of technological and institutional character in order to present all the Goals as one unit.

Figure 1.

Icons of the Sustainable Development Goals (2016–2030)

Source: SDG 2015

In the followings, we recommend a fairly unequivocal classification of the 17 Goals. Please, see SDG (2015) or the text within the groups below for the full wording of the Goals.

- Primary needs of humans (2. Food, 3. Health, 6. Water and 7. Energy)
- Equality between humans (1. No poverty, 4. Education, 5. Gender equality and 10. Reduced inequalities)

- Efficient, sustainable production (8. Economic growth, 9. Innovative industry, 12. Responsible consumption and production, 13. Climate action)
- Landscapes in danger (11. Cities, 14. Life in water and 15. Life on land)
- Worldwide cooperation (16. Peace and justice and 17. Partnerships)

The above set of the problems, mankind should solve in the next 15 years, is much wider than the initial thoughts on sustainability. (e.g. GOODLAND-DALY 1996) In the above set of problems, Goal 13, Climate action is problematic to select into any of the groups. The polemic is caused by the fact that climate change is the only environmental problem of the SDG, which is tackled as a separate Goal. All the other problems, like reduction of biodiversity, changes in nitrogen cycle, ozone depletion, etc. are considered in connection with their effects on the vulnerable spheres, or human health. Another aspect of this Goal is that the Paris Agreement, i.e. another UN document deals with several aspects of climate change. Hence, this Goal does not include all related activities of adaptation and mitigation.

The above listed 17 Goals contain 169 Targets. The larger part of the Targets are quantitative objectives, mostly related to 2030, their number is 126. Another part of the targets point at organization tools, as preconditions of the objective targets, encountering 43 such Targets. As a rule, the quantitative targets are marked by numbers and the preconditions by letters.

The aim of our study is to present those Targets in which meteorology should play an important role. Though, this aim was reflected by the World Meteorological Organisation in 2016, pointing at 11 related Goals and providing general scopes of the WMO. The present study aims more in four aspects:

- Until the original document lists the Goals without any logical structure, our paper classifies the 17 Goals into five groups, i.e. as Primary needs of humans, Equality between humans, Efficient, sustainable production, Landscapes in danger, Worldwide cooperation.
- The paper considers 22 Targets of 16 Goals to be relevant for meteorology.
- These Targets are marked according to the four main branches of meteorology, requested to meet the challenges. They are air-chemistry, climate information, climate change and weather forecast.
- The relevant Targets are also grouped according to the type of meteorological information, i.e. as average conditions of key information, average conditions of additional information, prediction for short-term actions, prediction for long-term planning, education and awareness rising. The required activities are also illustrated by selected figures.

2. Goals with Relevance to Meteorology

The WMO issued a short communication concerning SDG, (WMO 2016) pointing at the 11 Goals and generally characterising the activity of the WMO and the national meteorological services.

The present paper differs from it in four aspects:

1. It defines a logical structure of the 17 Goals, which is not provided by the Report itself.
2. It tackles the challenges at the target level, marking 22 targets as related to meteorology.
3. The challenges are grouped according to the four branches of meteorology, requested to meet the challenges. They are air-chemistry, climate information, climate change and weather forecast.
4. The related targets are also grouped according to the utilisation of meteorological information, i.e. classified, as average conditions of key information, average conditions of additional information, prediction for short-term actions, prediction for long-term planning, education and awareness rising.

The branches of meteorology contributing to the targets are presented in the tables, as follows: Air-pollution (AP), climate information (CI), climate change (CC) and weather forecasts (WF). References on these branches of meteorology are provided in the conclusion. Before listing the targets, note that there is only one Goal in target of which we could not find any task of meteorology: *Goal 5. Achieve gender equality and empower all women and girls.*

2.1. Primary needs of humans (4 Goals, 5 relevant targets)

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Target 2.4 "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality."

Goal 3. Ensure healthy lives and promote well-being for all at all ages. Target 3.6 "By 2020, halve the number of global deaths and injuries from road traffic accidents." Target 3.9 "By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination."

Goal 6. Ensure availability and sustainable management of water and sanitation for all. Target 6.4 "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity."

Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all. Target 7.2 "By 2030, increase substantially the share of renewable energy in global energy mix."

Table 1.

Meteorological contribution to targets related to primary human needs

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 2.4		+	+	+
Target 3.6				+
Target 3.9	+			+
Target 6.4		+	+	
Target 7.2		+		+

Source: Drawn by the author.

Reading along the lines of Table 1, contribution of meteorology can contribute to them as follows. Sustainable food production (Target 2.4) requires use of climate information (not only the means, but also interrelated spread along them and frequency distribution, including extremes). As between the year 2030 and the origin of available climate information, there are several decades; projections of regional climate change are also useful.

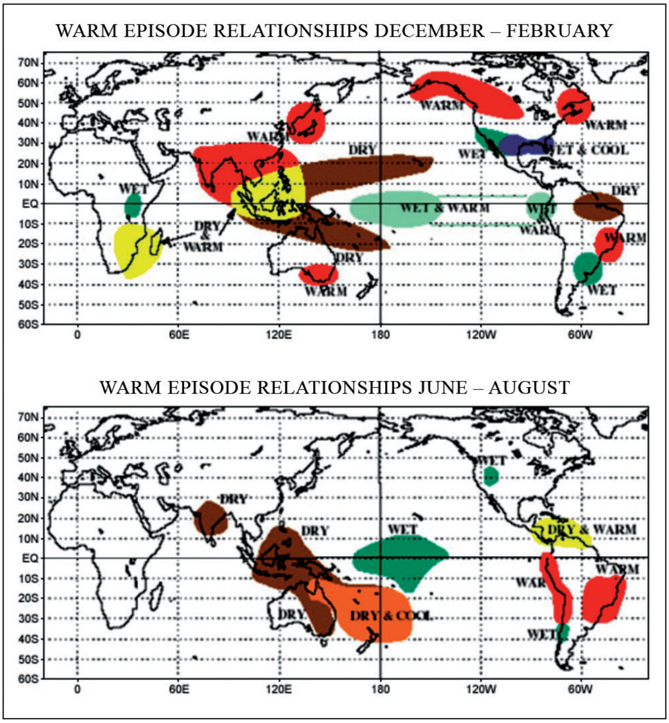

Figure 2.

Empirically established regional climate anomalies related to El Nino episodes

Source: NCEP-NOAA, USA www.climate.gov/news-features/featured-images/global-impacts-el-ni%C3%-B1o-and-la-ni%C3%B1a

Finally, long-term weather prediction, not impossible at the lower latitudes, in connection with the El Nino La Nina fluctuation (see Figure 2) is also useful, whereas in everyday agricultural practice, even the weather forecast for several days ahead are also useful. Against the accidents (Target 3.6) adequately tailored and distributed weather forecast on road conditions and visibility are especially useful. For decreasing illnesses of chemical origin (Target 3.9), air chemistry knowledge is obviously required. Besides that, climate information on usual and extreme conditions for accumulation of various pollution types is of value. Finally, weather prediction of e.g. smog conditions are especially needed for sick people and their doctors. Against water scarcity (Target 6.4) both climate information and climate change regional projections are of unavoidable use. To increase the share of renewable energy (Target 7.2), climate information is useful to assess the potentials, and weather prediction of e.g. actual wind energy are relevant.

Figure 3 shows the number of events, fatalities, total losses and insured losses from all natural hazards, expressed in 2013 values, from all natural hazards in EEA member countries cumulated over the period of 1980–2013. Hazard categories are meteorological events (storms), hydrological events (floods, mass movements), climatological events (heat and cold waves, droughts and forest fires), geophysical events (earthquakes, tsunamis, volcanic eruptions).

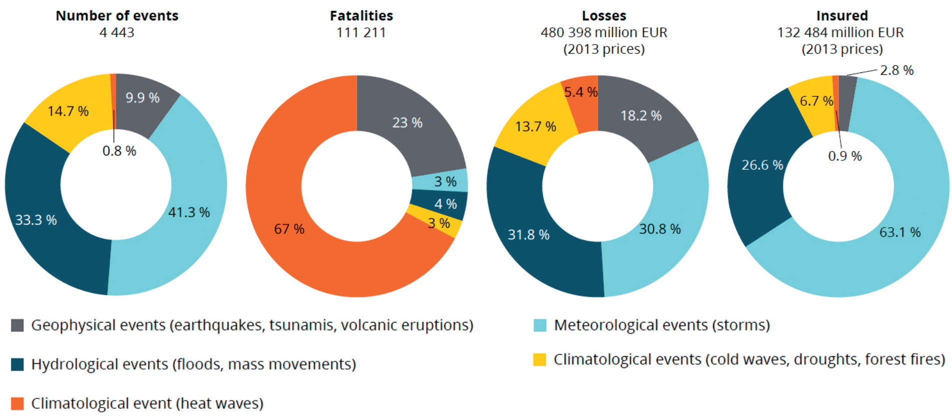

Figure 3.

Number of events, fatalities, total losses and insured losses from all natural hazards cumulated in 1980–2013 expressed in 2013 prices

Source: EEA 2017, Fig 5.3.

2.2. Efficient, sustainable production and climate change (4 Goals, 7 targets)

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Target 8.9 "By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products."

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Target 9.1 "Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all." (Table 2.)

Table 2.

Meteorological contribution to targets related to efficient production

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 8.9		+		+
Target 9.1		+	+	
Target 12.2		+	+	
Target 12.4	+			+
Target 12.8	+	+		
Target 13.1		+	+	
Target 13.3		+	+	

Source: Drawn by the author.

Goal 12. Ensure sustainable consumption and production patterns. Target 12.2 "By 2030, achieve the sustainable management and efficient use of natural resources." Target 12.4 "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment." Target 12.8 "By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature."

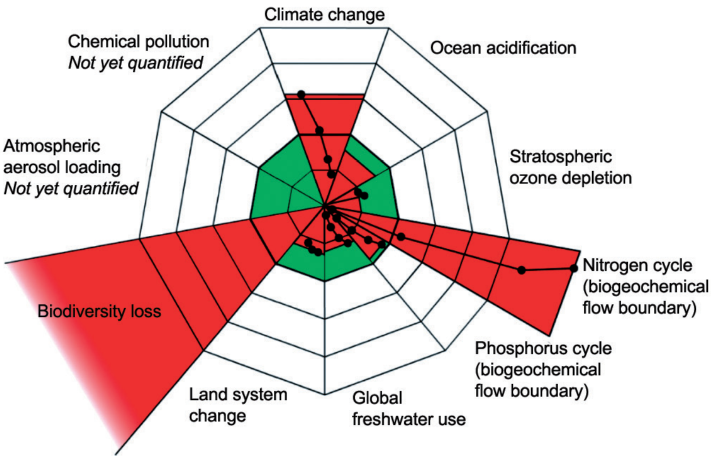

Figure 4.

Most important environmental problems of the world. The green area denotes a "safe operating space" for development. The red sign indicates the current situation for each process. The dots indicate the evolution by decades from the 1950s.

Source: Global Energy Assessment 2012, Fig. TS-6.

Let us illustrate Target 12.8 by Figure 4 indicating that the environmental problems, biodiversity loss and changes in the nitrogen cycle, e.g. nitrogen leaching have already caused irreversible changes in nature. Climate change is of serious concern, whereas regarding chemical pollution and atmospheric aerosol loading, we are not able to judge the size of the problem due to lack of satisfactory measurements.

Goal 13. Take urgent action to combat climate change and its impacts. Target 13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries." Target 13.3 "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning."

In this group of Goals one may inquire why we can see only two targets of Goal 13, i.e. climate change listed as a meteorology-relevant one. But having read it in the SDG (2015), one should understand that climate change is a much wider problem even at the level of the sustainability targets, and a wider set of the targets has no meteorological aspects.

2.3. Landscapes in danger (3 Goals, 5 targets)

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable. Target 11.5 "By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations." Target 11.6 "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management."

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Target 14.3 "Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels." Target 14.5 "By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information."

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Target 15.3 "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world." (See Table 3.)

Table 3.

Meteorological contribution to targets related to the landscapes in danger

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 11.5	+	+		+
Target 11.6	+	+		+
Target 14.3	+		+	
Target 14.5	+	+	+	
Target 15.3		+	+	

Source: Drawn by the author.

As an example of possible information let us have a look at Figure 5 surveying all weather-related extremes at global scale. As these landscapes are threatened by degradation at long time scales, a most important contribution by meteorology is detailed climate information including smart interpolation. In some respects, even climate change can play a role in planning.

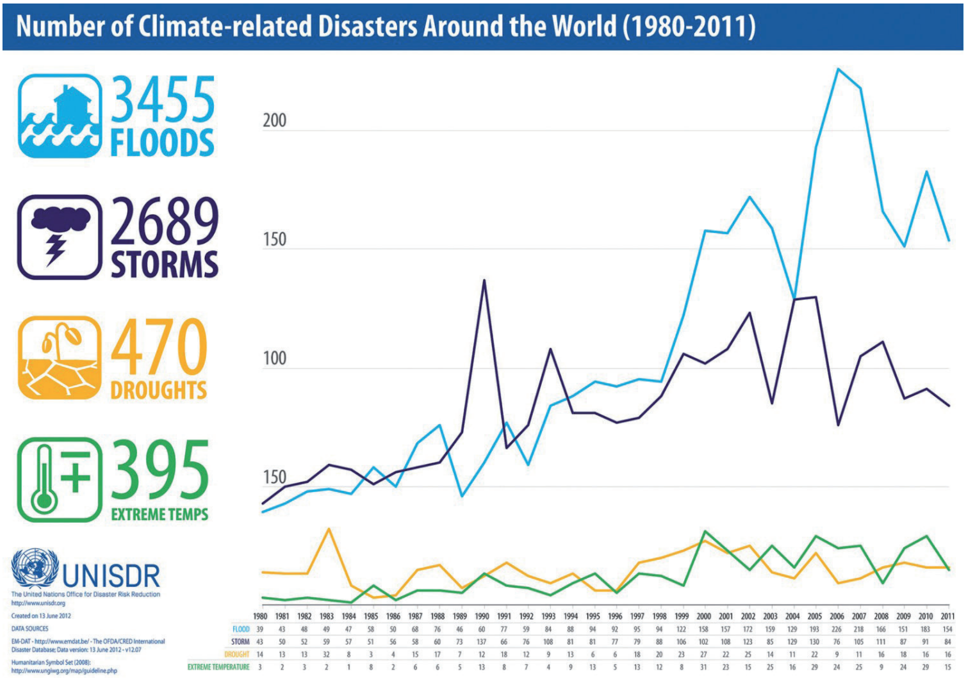

Figure 5.

Global time series of characteristic extremes of atmospheric origin

Source: SEINFELD–PANDIS 2016

2.4. Equality between humans and Worldwide cooperation (5 Goals, 5 targets)

Goal 1. End poverty in all its forms everywhere. (Table 4.) Target 1.5 "By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters."

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Target 4.7 "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development."

Goal 10. Reduce inequality within and among countries. Target 10.7 “Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies.”

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. Target 16.10 “Ensure public access to information and protect fundamental freedoms, in accordance with national legislation and international agreements.”

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development. Target 17.7 “Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.”

Table 4.

Meteorological contribution to targets related to equality between humans and to worldwide cooperation

	Air pollution (AP)	**Climate information (CI)**	**Climate change (CC)**	**Weather forecasts (WF)**
Target 1.5		+		+
Target 4.7	+	+		
Target 10.7		+	+	+
Target 16.10	+	+		+
Target 17.7		+	+	

Source: Drawn by the author.

Not intended to explain all relevant cells of Table 4 let us emphasise only the full cells on Target 4.7, i.e. education for sustainability. Everything, potentially provided by contemporary meteorology, can significantly contribute to key questions of sustainability, i.e. limited resources, pollution and environmental risks. It is important that existence and availability of these pieces of information should be distributed in all forms of education.

In this set of Goals, relevance of meteorology is not so obvious. Climate change projections play an important role to attract the decision-makers’ attention to the problem. The ozone depletion is another example limited by the Montreal Protocol and its amendments. Public access to climate and weather information would also be of key importance. Finally, cooperation between countries coordinated by the WMO serves as example to Target 17.7, including exchange of operational data, numerical predictions and instruments.

3. Sorting the Targets According to Use of Information

Besides the classification of the targets according to branches of meteorology, applied in Section 2, another possibility is to consider the way how meteorological information is utilised. The five classes might be as follows: Average conditions concerning the key information, e.g. renewable energy potential or urban air pollution (AKI); Average conditions which are of additional importance, e.g. climatic conditions of freshwater supply or conditions of migration from and to the given regions or countries (AAI); Prediction of weather for short-term actions e.g. prediction of harsh weather or smog conditions (PSA); Prediction of weather or climate to initiate long-term actions, e.g. low-latitude climate prediction in El Nino or La Nina episodes, or general climate predictions for forest management (PLA) and, finally, Education and awareness rising concerning e.g. climate change or sustainable technology (EAR).

These five aspects of utilisation could have been presented as four separate tables, possibly with further explanation. But let us limit to one comprehensive table containing just the numbers of the already known 22 meteorology relevant SDG Targets (Table 5). The text of the Targets can be read in Section 2. Table 5 provides the classification of the 22 meteorology-relevant Targets to the above classes. One target is often sorted to two, sometimes to three ways of utilisation.

Table 5.

Sorting the 22 meteorology relevant targets according to the type of utilised information

Type of use	Basic human needs	Production+ climate change	Landscapes in danger	Equity & Cooperation	ALL SDGs
Average conditions as key information (AKI)	3.9, 7.2	12.4	11.6, 14.3	17.7	6
Average conditions as additional information (AAI)	2.4, 6.4	8.9, 9.1 12.2	11.6, 14.5 15.3	1.5, 10.7 16.10	11
Prediction for short term actions (PSA)	2.4, 3.6 3.9, 7.2	8.9, 12.4 13,1	11.5	1.5, 10.7	10
Prediction for long-term planning (PLA)	2.4, 6.4	9.1, 12.2 13.1	14.3, 14.5, 15.3	10.7	9
Education and awareness rising (EAR)	2.4, 7.2	12.8, 13.3	11.5	1.5, 4.7 17.7	8

Source: Drawn by the author.

4. Conclusion

In the paper we provided information on the Sustainable Development Goals (2016–2030) with special emphasis on those targets which are relevant to meteorology. From the 17 Goals there was only one without such relation. Ca. 13% of the 169 targets were identified as having relevant meteorological aspects. Most targets (18 from the 22) request climate information (CI). Climate change (CC) and weather forecast (WF) can be attached to 11–11 targets. A slightly smaller number, 9 targets can be supported by information on air pollution (AP).

Perhaps, the brief description of the use of meteorology in the related Targets is not always easy to understand. Therefore, we provide some key references to the above branches of meteorology in three main groups: basic sources on scientific background and on surveys of key impacts.

For air pollution (AP), a good scientific comprehension is recently published by John H. Seinfeld and Spyros N. Pandis (Seinfeld–Pandis 2016) in the new edition of their former monography. For health consequences of high pollution, see the review by WHO (2014), and specifically for indoor and outdoor effects of particulate matters Siponen et al. (2015). Problem of topography as a contributor to high pollution events together with other factors is tackled by Wallace et al. (2010). Carbon-dioxide pollution causes not only climate change but also acidification of the oceans. (e.g. Fabry et al 2008) Perhaps the ecological effects of ocean acidification would not be linear: after a threshold, the impact could become amplified. (McNeil–Matear 2008)

Concerning climate information (CI), there are classical world-wide climate surveys. (Landsberg 1969–1984) There are numerous climate books in national or continental edition, based on observations at the macro-climatic scale. Spatial interpolation of these point-wise observations is the key problem, though nowadays the so called re-analysis is also available. Its point is to apply dynamical models of the atmosphere to fit the data physically, (Uppala et al. 2005) not just by various functions of spatial co-ordinates. For smaller scales (Oke 1979) provides information on climate near the surface in the boundary layer of the atmosphere. Another key point is to create univariate indices from a set of weather variables to describe the effect of the environment on the living matters, e.g. temperature and precipitation indices, (Klein Tank–Können 2003) or drought indices. (Alley 1984; Dunkel 2009) A complete book has already been devoted to climatology of the weather extremes with several world-wide maps of their occurrence and trajectories. (Burt 2007) The same task is even more important, when considering the impact of weather on human heat balance, often mentioned as heat stress. (Matzarakis–Mayer–Iziomon 1999; Kalkstein–Greene 1997) Human comfort is a key part of selecting touristic destination, hence thermal indices are sometimes used to describe and compare touristic destination sites. (de Freitas 2003) Satellite technology brought new possibilities to characterise plant development (Hayes–Decker 1996) and to estimate global energy-exchange between the various domains of the climate system. (Kiehl–Trenberth 1997)

Climate change (CC) problems, including science, adaptation and mitigation are comprehended by the consecutive Assessment Reports (e.g. IPCC 2013, 2014a,b,c) and the occasional Special Reports (e.g. IPCC 2011, 2012) by the IPCC. In addition to them we would just point at certain developments in climate change science. Multivariate statistical tools have been developed and applied to characterise spatio-temporal developments of climate. (von Storch–Zwiers 1999) Possible tipping points leading to irreversible changes beyond this point (Broecker 1991; Wood–Vellinga–Thorpe 2003; Lenton et al. 2008) Possibility of such tipping points makes rather questionable the so called GAIA hypothesis (Lovelock 1972) postulating the ability of the biosphere to keep the optimal environment around itself. Another principal problem with this hypothesis is that its validity could have been validated for much slower processes of the distant past. (Lovelock–Margulis 1974) Another global threat, already observed, is the rise of the sea level (Church–White 2006; Cazenave–Llovel 2010) most likely inter-connected with the warming of ice packs. (Pritchard et al. 2009; Apllegate et al. 2015) Further key scientific aspects of global climate change, pointing at the impact and vulnerability, is the behaviour of the extreme events, (Tebaldi et al. 2006) and extreme atmospheric motions. (Knutson 2010) Most likely, these questions cannot be resolved without regional climate models which compute the processes by fine resolution in the region of interest. (Christensen et al. 2007; van den Linden et al. 2009; Jacob et al. 2014)

A huge number of climate impact studies has been published world-wide. Concerning the SDG targets, we would emphasise those which estimated the expected changes in air and environmental pollution due to the changes in atmospheric mixing, as well as of required emission. (Ma–Hung–Macdonald 2016; Nadal et al. 2015) Plants are also rather sensitive to climate change (Prentice 2001; Gray et al. 2016) Human health is strongly exposed not only to the everyday fluctuation of weather but also to the possible trend-like changes, especially if they are also expressed in the increase of extremities. (e.g. Patz et al. 2005; Hajat et al. 2014; Wu et al. 2016) The accumulated information has already been enough for editing books on complex changes at various geographical sites, such as the mountain environment (Beniston 1994) or the cities. (Stone 2012) Complex financial balance of adaptation in comparison with those for mitigation of the changes has also been established. (Stern 2006)

Weather forecast (WF) is always based on professional understanding and often model simulation of the weather processes. At the very beginning of combined computer-human weather prediction, the so called model output statistics was a key innovation. (Glahn–Lowry 1972; Klein–Glahn 1974) This means that having the future circulation patterns predicted, the weather parameters were statistically determined in connection with given circulation patterns of various spatial first and second-order differential characteristics, e.g. gradients or Laplace operators of the pressure or geo-potential patterns. Parallel to these computations, physical conditions of further developing could have been established for the extreme objects, such as blocking anticyclones (Tibaldi–Molteni 1990) and tropical cyclones. (Emanuel 2007) Similar empirical analyses have also been comprehended in connection with climate change. (Mika 2013) For consequences of weather extremes, we would like to emphasise only the health impact of the so called heat-waves which is much higher than the normal diurnal mean temperature. (Chagnon et al. 1996; Smith et al. 2013) The point is that the human body can be relaxed if the night is relatively cool. E.g. 40°C during the day and 15°C at night are much better for our human heat balance, than 35°C in the afternoon and 20°C as an overnight minimum.

In the other classification, presented in Section 3, the altogether 44 targets, reported in one, or the other types, means exactly 2.0 ways of utilisation types in average. The five types were represented by 6–11 Targets, i.e. 0.3–0.5 cases in average. The most popular way of utilisation is the average additional information (AAI, 11 relations), followed by prediction for short-term actions (PSA, 10 relations), prediction for long-term actions (PLA, 9 relations), education and awareness rising (EEA, 8 relations) and average key information (AKI, 8 relations).

At the end of the paper we would remark, again, that the 17 goals and 169 targets are officially announced by the UN Sustainable Development Goals (2016–2030). The Structure of the Goals is the result of this paper. The identified 22 Targets related to meteorology, as well as their assigning both to the four branches of meteorology (AP, CI, CC and WF), as well as the same for assigning them to the types of information for utilisation (AKI, AAI, PSA, PLA and EAR) are also the results of this paper.

At the end of this paper, one can conclude that the various branches of professional meteorology can substantially contribute to the overwhelming majority of the UN Sustainability Goals. At the same time, these contributions are mostly focused on 1–3 Targets of each Goal.

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Dear Reader,

thank you for your interest towards the problem of global climate change and the challenges it can cause. We know that this hazard is absolutely actual and concerns billions of people. Because of the quickness of the process's changes it is very difficult to be up to date. Please regard this book or collection of studies as a snapshot on a two-year research teamwork organised at the National University of Public Service dealing with different related adaptation problems and possible solutions. You can find very different essays about specific areas such as climate modelling, state and forecast of climate change consequences, human and ecosystems aspects and climate sensitivity, reliability of certain technologies, tasks of disaster management, security technologies and public media. We also made some international overview presenting the similar or different effects in some European countries. Our investigations are based on literature analysis, on-site examples, historical data evaluation, data analysis, using of GIS systems and making of interviews.

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