Konference Mladá věda
Univerzita Tomáše Bati ve Zlíně

Drought risks in the Czech Republic and a proposal for their mitigation in a selected region

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ABSTRACT
The article focuses on the threat of drought in the cadastral area of Luhačovice and deals with the evaluation of basic meteorological and hydrological variables, such as air temperature, precipitation rate, flow on the Luhačovice stream, and groundwater level within the study area. One chapter of the article contains a description of the area of interest in which the research was conducted. The next chapter is focused on the evaluation of the history of air temperature and precipitation totals from measuring stations, from these data is then calculated Lang's rain factor, drought intensity index.

KEYWORDS
Lang's rain factor, drought intensity index, microregion, Quitt's climate classification.

1. INTRODUCTION

The water component of the environment has multifunctional functions and properties. By default, conflict potential is encoded in it. Water management facilities and services for the supply of drinking water to the population are subject to a critical infrastructure regime. Water is a strategic factor in competitiveness, requiring monitoring, and risk analysis. The decision-making process is multidimensional and highly controversial. The objective threat is climate change and landscape change. Water in nature, even though it is a thing without an owner, can be perceived as a human right as well as a commercial commodity, depending on the circumstances. It is becoming clear throughout the world that we can no longer take the sources of water, or its simple provision for the supply of the population, for granted. The area where the Czech Republic is located has historically always been considered self-sufficient in terms of water - both due to the local rivers and due to regular rainfall. However, there are currently growing concerns that the current approach to water management will not stand in the future. This awareness is a necessary prelude to changes in agriculture, landscape care, water recycling and, ultimately, changes in the administration and management of the entire system. [1]

Drought is an integral part of climate change, which has affected and will affect the environment and national economies in all countries. Drought and water scarcity can cause economic losses in key water-using industries and at the same time can have environmental impacts on biodiversity, water quality, habitat loss, soil erosion, degradation, and Lang's rain factor, drought intensity index, microregion, Quitt's climate classification. Some of these impacts may be of a short-term nature and conditions will soon recover, but others may be permanent. [2]

In the Czech Republic, water in the form of atmospheric precipitation is the only source providing water in our territory, because the Czech Republic is a landlocked country and no major river flows from abroad.

Currently, the occurrence of drought in the Czech Republic and drought, in general, is a very discussed topic, which needs to be given considerable attention. Drought is manifested by slow onset and an impact that is difficult to comprehensively define. Drought can be classified as a natural threat as well as floods. While, for example, floods and torrential rains receive relatively much attention in our climatological literature, drought as the opposite extreme has been in the background until recently and remains a little-studied natural threat.

2. GEOLOGICAL CONDITIONS

The subsoil of the Luhačovice Highlands is built mainly by flysch rocks of the Rača unit of the Magura mantle group. Only in the southern part of the area are the rocks of the Bystrice unit of the Magura mantle group applied in a narrow strip adjacent to the White Carpathians. The Rača unit is, among other things, formed by rocks of the Luhačovice strata of the Zlín Formation, which reaches a thickness of around 2000 m. In its stratum sequence, sandstones and claystones alternate irregularly. Claystone inserts have a thickness from 3 cm to 20 m. Clayton's are dark gray, green-gray, scaly, and non-calcareous. Sandstones occur in positions 1cm to 6m thick. They are mostly gray-green and bluish-gray, fine to medium-grained, glauconitic, calcareous, massive, and relatively abundantly layered. In some places, they contain a considerable amount of feldspar grains. [3]

There is a Luhačovice spring structure in the area, which is characterized by the existence of an anticlinal zone of the Luhačovice layers in the northeast-southwest direction. The axis of the mentioned anticline runs north of Obětová hora, through Malá Kamenná to the valley of the spa area Luhačovice. The most significant fault in south-eastern Moravia is the non-technical fault, which in the Neogene period conditioned the ashes it outcrops in the Nezdenice-Bánov area. The spring structure is a part of a geological structure in which mineral water is formed, which then circulates, accumulates, and springs. Here, mineral water also acquires its specific properties. The post-volcanic manifestation of the radial fracture in the Luhačovice area is the juvenile outcrop.

It adds some important tributaries to its course:
Horní Olšava - a right tributary, flows in the village of Slopné
Hájový stream - a right tributary, it flows behind the village of Slopné
Olše - a right tributary, flows in the village of Dolní Lhota
Petrůvka - left tributary, just before the Luhačovice reservoir
Pozlovický stream - right tributary, in front of Luhačovice
Černý / Ludkovický stream - right tributary, in Biskupice

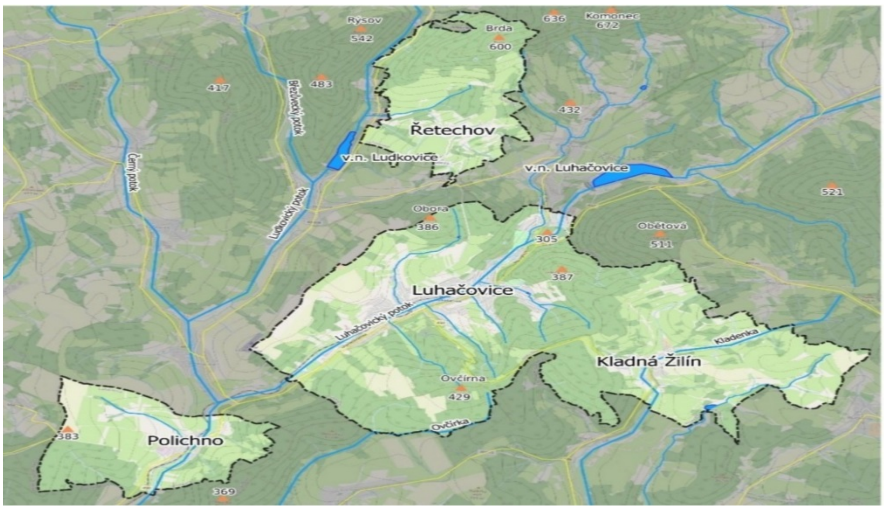

Figure 1 Map of the cadastral territory of the city with marking of watercourses (own elaboration)

On this stream, above the village of Luhačovice, below the confluence with the Petrůvka stream, there is a swell of the Luhačovice reservoir. Below the dam, the stream flows through the spa valley towards Biskupice, until it becomes a right-hand tributary of the Olšava river in the village of Újezdec (216 m above sea level). The length of the stream is 24 km and the catchment area has an area of 143 km^2. The long-term average flow for the period 1981–2010 in the final profile is 1.07 m^3 / s. The number of the hydrological order (CHP) of the sub-basin is 4- 13-01-101. The runoff maximum is here in spring and the minimum in summer. Watercourses in the area of interest are upright, regulated and there is little room for their revitalization. [4]

For hygienic and aesthetic reasons, the Luhačovický stream is regulated by a system of weirs during the flow through the spa area, which ensures permanent coverage of the entire riverbed with water. The weirs themselves then aerate the water, which contributes to improving the biological quality of the water. The riverbed is cut into its alluvium to a depth of 1 - 3 m. The hydraulic connection between the water in the stream and groundwater is variable in the longitudinal profile of the stream in Luhačovice and depends on whether the river is cut into sandy gravels or impermeable clay clays. [4]

Flows on the Luhačovice brook are affected by the valley reservoir above Luhačovice, but the total controllable volume of the reservoir does not allow long-term accumulation of large amounts of water. However, significant fluctuations in the flow in the Luhačovice creek in the spa area during the year, thanks to the regulation of the flow by openable weirs, are manifested only by slight movements of the flow level, usually up to 5 cm. It can therefore be said that these measures keep the level of the surface flow stable in terms of influencing groundwater and thus creating favorable hydraulic conditions for the protection of natural mineral resources. [4]

1) Active water circulation zone
2) Zone of difficult water circulation

In the flysch zone of the Western Carpathians it is possible to set aside:

The zone of active water circulation is characterized by rapid water exchange in the underground (low water age) and low total water mineralization. The zone is practically bound to the massif above the level of the local erosion base. In the mode of this zone, the annual course of atmospheric precipitation and air temperatures is reflected. The typical environment of the active circulation zone is the upper part of the Luhačovice layers, which are exposed in the anticline in the Luhačovice spa. The deeper zones of this formation no longer have free communication with the surface and the waters stored in them have the character of a zone of difficult groundwater circulation. [4]

3. SPRING STRUCTURE

The rock environment in which the mineral waters of Luhačovice are formed is a characteristic alternation of psammitic and pelitic, or psephitic marine sediments. In this environment, claystone from insulators and sandstone sites with limited collectors. It was here that the alternation of the two types of sediments created favorable conditions for the preservation of relict marine syngenetic waters. Sandstones to fine-grained conglomerates from Luhačovice layers, which also have very good fracture permeability. In the case of claystone, these are only partial insulators. [5]

4. CLIMATE CONDITIONS

According to Quitt's climate classification, the area belongs to the MT9 class, which is characterized as moderately warm with a long, warm, dry to slightly dry summer, a short transition period with mild to moderately warm spring and mildly warm autumn, short, mild, dry with short the duration of the snow cover. Although the town of Luhačovice lies at an altitude of 250 meters and the peaks of the surrounding hills reach a maximum altitude of 672 meters (Komonec peak), thanks to the slope and woodland, there is a noticeable mountain character. [6]

Table 1 Characteristics of the MT9 subarea [6]

Observed phenomenon	**MT9**
Number of summer days	40-50
Number of days with avg. temp. higher than 10 ° C	140-160
Number of days with frost	110-130
Number of ice days	30-40
Number of days with snow cover	60-80
Number of clear days	120-150
Number of days cloudy	40-50
Number of days with precipitation greater than 1 mm	100-120
Precipitation in the growing season	400-450 mm
Total precipitation in winter	250-300 mm

5. ANALYSIS OF DRY RISK IN THE LOCATION OF LUHAČOVICE

Evaluated drought indicators:

Drought in the area of the town of Luhačovice is assessed based on selected hydrological and meteorological indicators, such as:
- Air temperature
- Total precipitation
- Water level on Luhačovice creek
- Water flow at the inflow of the Luhačovice reservoir
- Water flow at the inflow of the Ludkovice reservoir
- Groundwater level in the Biskupice specific well
- Level status in wells of natural healing resources
- Land use
- Drinking water consumption [7]

5.1. Air temperature

A significant effect on the evaporation is the increase in temperature, which has been constantly rising since 1980. By 2010, its rise was of the order of one degree Celsius. This size seems small but has increased the size of the territorial evaporation by about 20%. This was reflected in some river basins by a significant reduction in the basic runoff to around 1/3. [7]

In the cadastral territory of the town of Luhačovice there is one meteorological station of the CHMI. Specifically, this station is located in the city of Kladná-Žilín at an altitude of 329 m. GPS coordinates of the station are 49.0831 ° N, 17.7907 ° E. This station has been processing data since 2010. Therefore, freely accessible annual average data were used for sufficient time variance. air temperatures and precipitation totals of the Czech Hydrometeorological Institute for the entire Zlín Region, which include measurements since 1961. [7]

5.2. Precipitation totals

The average annual total precipitation for the period 1961-1990 is 786 mm in the Zlín Region, but since 2011 no exceptionally higher total precipitation has been recorded, rather these years are below average in terms of precipitation. Besides, there were more years with minimal totals. The least precipitation (below 600 mm) fell in the years: 1973 - 562 mm; 2003 - 581 mm; 2015 - 580 mm; 2018 - 563 mm. For precipitation, the problem is more in the distribution of precipitation during the year. In recent decades, especially in the summer, precipitation has prevailed, which is short-term and more intense, hence with larger totals, but this is not reflected in the total annual total. [8]

5.3. Lang's rain factor

Lang's rain factor is a climatological index that expresses the conditions of natural irrigation of the landscape, namely the relationship between atmospheric precipitation and air temperature. The calculation of the Lang's rainfall factor is based on the ratio of the annual total precipitation to the average temperature. The main disadvantage of the method is that it does not take into account the distribution of precipitation and temperatures during the year. [9]

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Calculation of Lang's rain factor:
f = R/t
R – average annual total precipitation [mm]
t – average annual air temperature [°C]

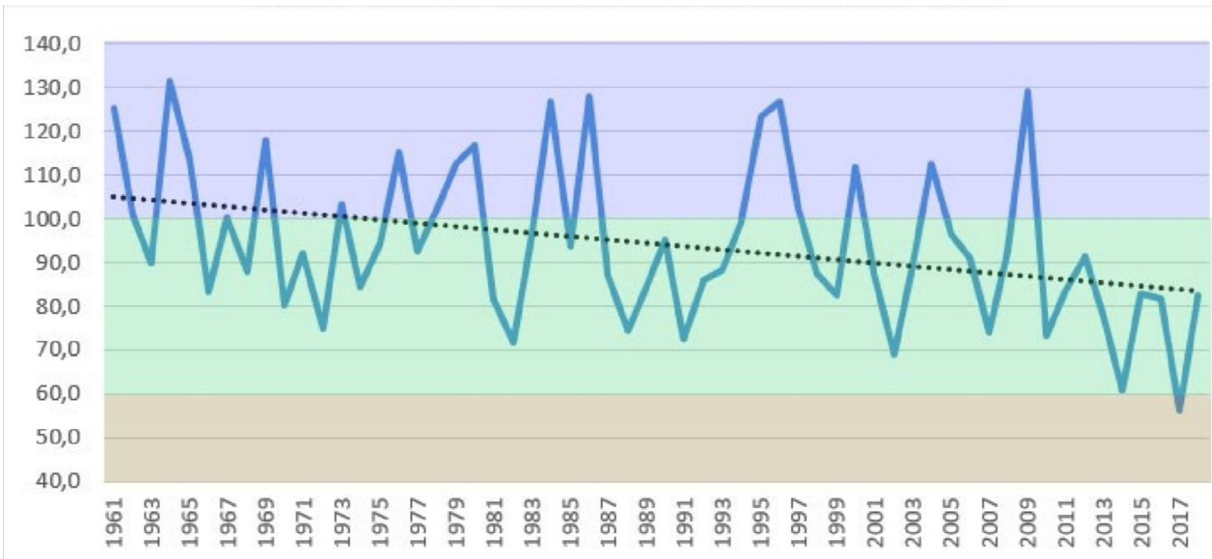

Figure 2 Course of Lang's rain factor for the territory of the Zlín Region [9]

The graph shows the development of Lang's rain factor in the Zlín region in the years 1961 - 2019. The blue part of the graph: per humid region, green: humid region, brown: semiarid region. The link between the trend is declining here, which means that this area is moving towards increasingly dry conditions. The decrease in the precipitation index is mainly due to the increasing average air temperature. The driest years with the result of a very low index are 2014 (61.1) and 2017 (56.3), which in the case of 2017 is considered to be a semiarid area. These years, including 2002 (69.7), can be described as dry. [10]

Flows of Luhačovický brook (Šťávnice)

To determine the period with minimum flows, and thus the hydrological drought, it is necessary to monitor flows in natural waters and record these data. In the Czech Republic, the limit value determining hydrological drought is considered to be the value of the flow Q355, ie the flow reached or exceeded 355 days a year. [11]

LG Polichno Reportable profile

The Polichno measuring station is relatively new, it was put into operation on 27 June 2016. The dry state (Q355) is defined here by a flow rate of 0.09 m3 / s. The flows are affected by water management activities at the Luhačovice waterworks and the Ludkovice waterworks. [11]

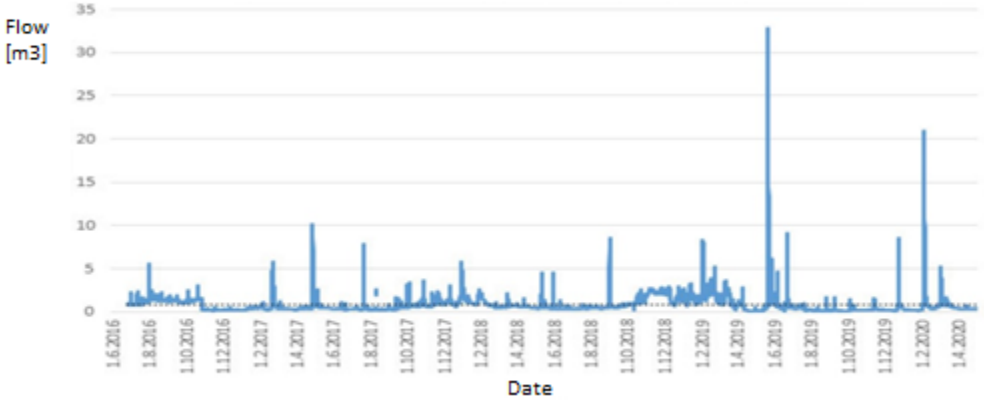

Figure 3 Flow on Luhačovický brook in the LG Polichno reporting profile [11]

Due to the short time horizon of the measurement (46 months), sudden high flows are evident from the data output of the reporting profile, which was the most intensive during the measurement on 22 May 2019. The level on that day reached a maximum of 191 cm on the LG Polichno reporting profile, ie the 2nd degree of flood activity, almost the 3rd degree of flood activity (from 200 cm). It was a flash flood, which was caused by torrential rains that day, which were able to create this condition within a few hours. The curve of the linear flow trend is stably almost horizontal, slightly decreasing. The graph shows some sudden fluctuations in flow caused by torrential rains. [11]

The state of drought (Q355) occurred here during the measurement period once in the period from 1 May 2019 to 15 May 2019, then a week later (22 May) there were intense torrential rains, which caused the state of the second degree of flood activity, but even so, the flows were, after the situation stabilized, still very low for the rest of the year, approaching the drought, except for short rainfall, the flow increased for a short time, but then the situation decreased again. [11]

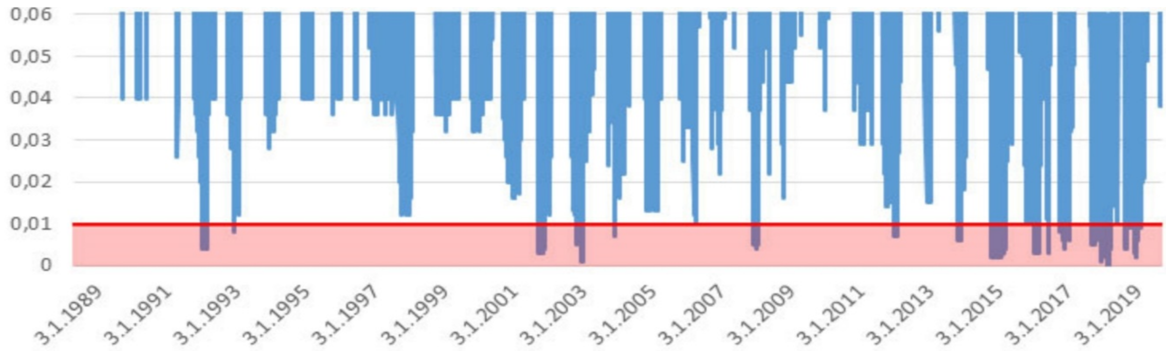

Figure 4 Flow on Ludkovický brook in the reporting profile of VD Ludkovice tributary - drought [11]

6. SWOT Analysis of the selected region

As part of the preparatory work for the elaboration of the proposed measures, a strategic analysis of significant areas of drought threat in the city of Luhačovice was prepared using the SWOT method. The areas covered in this chapter were assessed, namely: development of temperatures, precipitation totals, conditions on watercourses, development of groundwater level, drinking water consumption, and land use. The factors most frequently occurring and with the most significant influence on the development of individual areas are shown in the following graphic expression.

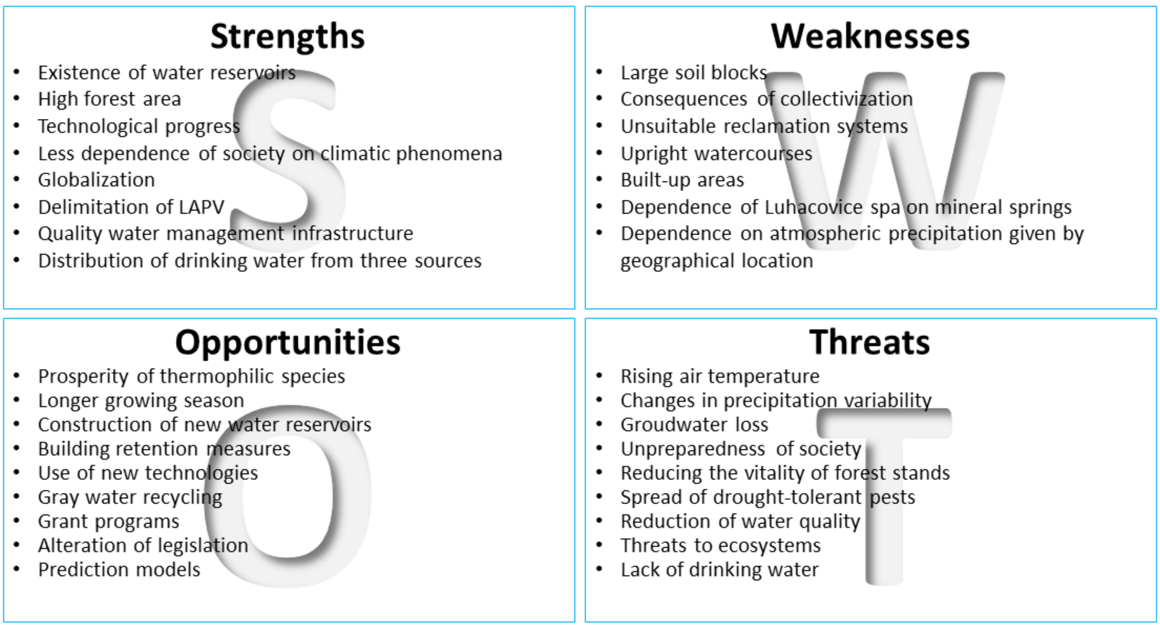

Figure 5 SWOT analysis of the area from the point of view of drought (own processing)

7. PROPOSAL FOR MITIGATION MEASURES

There are three ways to deal with the effects of climate change. Take mitigation measures, apply adaptation measures and the third option is to do nothing. The most convenient and cheapest third option would, in the long run, lead to the devastation of the landscape, a decline in the quality of all ecosystem services, and, consequently, a reduction in economic performance across sectors. IPCC Triangle Diagram - Fourth assessment report describing the relationship between mitigation, adaptation, and inactivity. The corners of the triangle represent 100% of each of these three options. The areas in the center of the triangle represent a combination of approaches. There are also relative costs associated with mitigation and adaptation. The inaction option is associated with high costs related to the impacts of climate change. [12]

Mitigation is meant as prevention in the sense of mitigating or slowing down a threat.
Adaptation serves to cope with the effects of the threat. Essentially any modification that leads to a reduction in vulnerability can be considered as an adaptation measure. In general, however, both ways are needed to reduce the impact of a threat.

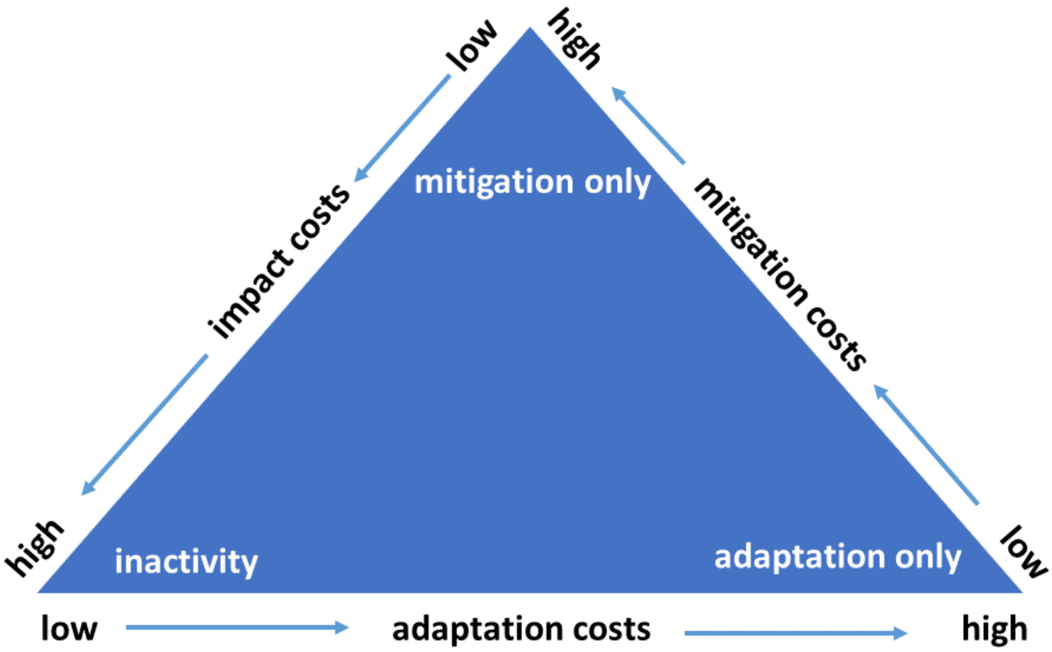

Figure 6 Triangle diagram (Source: IPCC)

Appropriately designed protection measures in the landscape always perform several functions (anti-erosion, flood protection, drought protection, but also environmental protection) fundamentally supporting the protection of landscape systems and restoration in places of previous disturbances caused mainly by human activity. Appropriately designed flood and erosion control measures also have a very positive effect on protection against the effects of drought, because the overall protection of river basins pursues the following basic objectives:

- encourage water infiltration into the soil as much as possible (but only where there is no threat of waterlogging nearby objects),
- limit the possibility for the outflow to be concentrated in the streams, ie. encourage its dispersal,
- slow down and safely drain the surface runoff so that it does not acquire entrainment forces capable of carrying away the soil,
- extend the water retention time in the catchment area.

The T. G. M. Research Institute of Water Management has prepared a Catalog of nature-friendly measures for water retention in the landscape. The catalog defines the following seven types of measures:

- area measures on agricultural land,
- biotechnical measures,
- small water reservoirs,
- measures in forests,
- measures on watercourses and floodplains,
- agroforestry measures,
- rainwater management.

These basic types are then divided into 26 types of measures. The catalog included measures that proved to be suitable for retaining water in the landscape. [13]

8. IMPROVING COUNTRY RETENTION

Theoretically mentioned in strategic concepts and documents (eg Strategy for Adaptation to Climate Change in the Czech Republic, National Action Plan for Adaptation to Climate Change, Concept of Drought Protection for the Czech Republic. Act No. 254/2001 Coll., On Waters, §27 mentions that owners are obliged to ensure that water conditions do not deteriorate (runoff, soil abstraction), improve the retention capacity of the landscape - lack of enforcement Improve landscape retention is necessary for better water management. If more water is retained in the landscape, agriculture will not be as much depending on the weather, the soil and water will be healthier, and if the landscape is more varied with wetlands, nature-friendly floodplains of streams and rivers, orchards, or renewed tree planting, it will provide refuge for animals, plants and people in times of drought. more habitable. [14]

Small water reservoirs with a water accumulation function, retention reservoirs with a small permanent reservoir, dry reservoirs, and partly also irrigation and seepage elements have a fundamental influence on the extension of water retention in the river basin. The optimal solution for the landscape as a whole is a comprehensive approach to solving the problem of drought, ie. propose a combination of suitably complementary all types of measures. From the results of the analytical part, we can state an increase in air temperature in the Zlín Region since 1961 on average by 2 ° C. From the analysis of precipitation totals data, we can state the occurrence of below-average to average precipitation years in the Zlín Region since 2011, but the long-term trend of precipitation totals since 1961 is constant. From the data on air temperature and precipitation totals, the Lang's rain factor is then calculated as an index of drought assessment, which has a demonstrably declining trend, based on which we can assess the territory of the Zlín Region in 2017 as a semiarid area. [15]

9. DISCUSSION

Based on the research, all indicators indicate that the Luhačovice area is drying out, water in watercourses is declining and the groundwater level is declining, which is currently at its minimum for the period of data provided, ie since 1981. The air temperature is rising, areas and drinking water consumption is increasing. Luhačovice has an advantage in its landscape potential with a large number of forests that retain water in the landscape, yet they have not escaped the "bark beetle calamity" of large-scale spruce deaths. To a large extent, the local forests have been transformed in favor of spruce monocultures. The influence of forest and forest management on the water regime of the landscape is so fundamental in the conditions of the Czech Republic that water management in forests should become a full-fledged part of forestry activities in the future.

From the data on air temperature and precipitation totals, the Lang's rain factor was calculated as a drought assessment index, the calculation of which has a strong decreasing trend, so far the Quiet area can be classified as humid, but if development continues with this trend, the area will soon be evaluated as semiarid. The Zlín Region already achieved this evaluation in 2017. [16]

Recent years have shown that there is a need to raise awareness of the drought issue, as this threat can have critical consequences. There is a need to study and correct mistakes that have occurred in the past and to learn from them, such as the systematic straightening of watercourses, landscape drainage, development of areas supporting the rapid runoff of rainwater, and inappropriate agricultural techniques that worsen soil retention capacity. It is also necessary to take into account the existing forecasts and adjust your actions in the field of water management in the landscape and households accordingly. New legislation should be proposed that takes more account of the importance of the water component of the environment. The situation has already begun to be addressed by the Czech Republic and its active authorities. The forthcoming amendment to the Water Act should bring the necessary definition of the issue of drought and water scarcity, as well as the introduction of legislative procedures and the necessary regulations. This amendment should also give rise to the obligation to draw up a plan for managing drought and water scarcity. Due to current developments, it is necessary to implement mitigation measures already at this time. When creating new landscaping or constructions, it is necessary to create landscaping that improves the retention of rainwater in the landscape. There are many ways to prepare for and cope with drought, you just need to put them into practice judiciously.

ACKNOWLEDGMENTS

This research was supported by the Internal Grant Agency of Tomas Bata University in Zlín, project IGA / FAI / 2021/002 and Institute of Security Engineering, Faculty of Applied Informatics.

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