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CLIMATE RISK OF SHALLOW TOURISTIC LAKES: A CASE STUDY OF LAKE VELENCE (HUNGARY)

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Abstract. The European shallow lakes used primarily for tourism are subjected to a large amount of environmental pressure, and climate change is adding new problems and aspects to them: a complex analysis of processes and connections is necessary to make appropriate decisions and strategies. In this reseach research, using literature review and precedent analysis, it has been reviewed the climate risk of a Central European lake, as well as the natural conditions and landscape change processes determining its sensitivity. It was analysed the ecological and economic effects of the record low water levels of 2021-22, focusing on processes. It was determined which of the current land uses can be considered risky or sensitive in terms of climate change. It was found that natural processes are uniformly leading towards pre-regulation character, low water levels facilitating the regeneration of flora and fauna. However, the dominant land use is dependent on artificially elevated water levels, and therefore serious economic problems have arisen. Beaches, bathing, and angling tourism are the most vulnerable to climate change.

Keywords: *climate change, climate risk, Lake Velence, tourism development, shallow lakes*

Rezumat: Lacurile puțin adânci din Europa, utilizate în principal în scopuri turistice, sunt supuse unei presiuni semnificative din partea mediului înconjurător, iar schimbările climatice aduc noi probleme și aspecte. Este necesară o analiză complexă a proceselor și conexiunilor pentru a lua decizii și a dezvolta strategii adecvate. În această lucrare, prin revizuirea literaturii și analiza precedentelor, s-a examinat riscul climatic al unui lac din Europa Centrală, precum și condițiile naturale și procesele de schimbare a peisajului care determină sensibilitatea acestuia. S-au analizat efectele ecologice și economice ale nivelurilor scăzute record ale apei din perioada 2021-2022. S-au identificat utilizările actuale ale terenului care pot fi considerate riscante sau sensibile în contextul schimbărilor climatice. S-a constatat că procesele naturale conduc uniform către un caracter de pre-reglare, iar nivelurile scăzute ale apei facilitează regenerarea florei și faunei. Cu toate acestea, utilizarea dominantă a terenului depinde de nivelul ridicat artificial ale apei, generând astfel probleme economice serioase. Plajele, turismul balnear și pescuitul sunt cele mai vulnerabile la schimbările climatice.

Cuvinte cheie: *schimbări climatice, risc climatic, Lacul Velence, dezvoltare turistică, lacuri puțin adânci.*

1. Introduction

Mid-sized and large lakes have numerous functions, important in terms of landscape ecology and land use: they provide habitat, water for drinking and irrigation, they are the location for various recreational and touristic activities, as well as fisheries and reed farming, they are emphatic elements of scenery, they regulate local climate, etc. The increase in usage resulted in negative changes in the chemical and ecological status of lakes around the world, which will be even more drastic in most regions due to effects of global climate change. Changes in the quality or quantity of water in lakes always have repercussions on social and economic processes.

Responses of freshwater species are strongly related to changes in the physical environment: water temperature has increased lakes (up to 0.45°C per decade). Indirect changes include alteration in oxygen concentrations and thermal regime in lakes, dissolved oxygen concentrations have typically declined and primary productivity has increased with warming [1]. The amount of water stored in specific lakes may increase, decrease or have no substantial cumulative effect, the magnitude of hydrological changes that can be assuredly attributed to climate change remains uncertain [1].

Although lakes are more isolated than many other biomes [2], the evaluation of structural and functional connectivity between the body of water and the surrounding landscape has become a subject of the researchers. Several studies discuss the ecosystem services and pressures of lakeshores (many times originated in tourism), the review of [3-12] belong to the most complex approaches.

Lake Velence is known to be one of the largest shallow lakes having a surface area of 24.17 km^2 [13] (Figure 1).

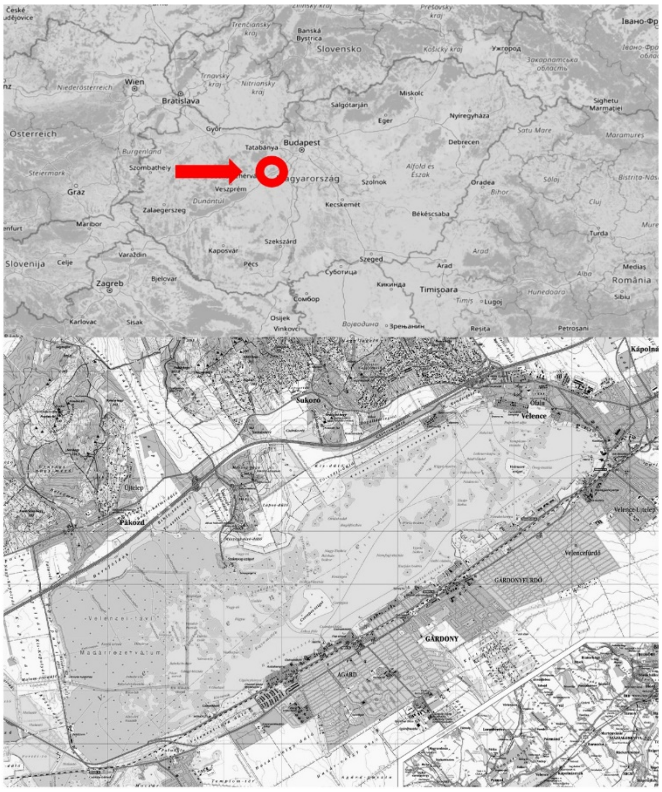

Figure 1. Location of the study area in Central Europe / Hungary; Lake Velence is surrounded by settlements mostly for East and South [13].

The western basin is mainly covered by emergent macrophytes; for the eastern one, however, open water surfaces are typical. As from the 1960's, large-scale sediment removal and lakescaping interventions were performed [14]. The dominant land use of the lake and its surroundings is tourism.

The Southern and Eastern shores of Lake Velence were developed for tourism in the second half of the 20^{th} century, creating an almost continuous urban strip [15]. In 2021-22, water levels in the lake decreased to a historic low, bringing attention to the necessity for a new paradigm regarding the use and management of the lake. Researchers have implemented different indicators to measure climate risk or risks associated with climate change [16], which should be specified to support the planning and strategy making processes related to changing challenges. The goal of this paper is to review in a complex manner the climate sensitivity of a shallow, heavily modified large lake under Continental climate, used primarily for tourism, to summarize processes and phenomena and to identify connections, further research opportunities.

2. Materials and Methods

The first step of research was a precedent analysis, the systematic investigation of the record low water levels in Lake Velence (Hungary) in 2021-22, which included the summary of negative social, economic and ecological phenomena, "symptoms", and land use problems. These topics designated the focus topics of detailed analysis.

In the second step, based on data gathered from a wide range of literature about the lake, it analysed the natural conditions and landscape change history of Lake Velence and its shoreline, identifying the a) natural and b) land use history aspects of climate risk and sensitivity.

The analysis of communication regarding the situation of the lake included the collection of Google search results for the query "Velencei-tó" (Lake Velence in Hungarian), using the first 150 total results and the first 150 image results separately (date of query: 01.27. 2023).

The third step comprised the creation of the list of land uses, activities present on Lake Velence or its shorezone (defined here as the 100-metre wide zone measured on the legal shoreline), based on results of privious studies [17-18] and field surveys (August 2022). Individual activities were divided into categories based on whether a significant and sustained change in water quality (due to bacteriological contamination of bathing water, the beach would have to be closed for at least 21 days, or the trophic state of the water, based on chlorophyll - A levels, would fall within the eu-polytrophic – 100-200 mg/m^3 – category for 21 days simultaneously at a minimum of 2 measurement sites) or quantity (water levels would fall below 50% of minimum operational levels for at least 30 days) would render them impossible. It was studied separately whether the visual unity of the lake and its shoreline, its familiar scenery, landscape aesthetic quality, and the subjective perception of landscape (primarily visual, secondarily auditory and olfactory) are significant aspects for the activity in question. If three sensitivities were present, the climate risk and sensitivity were classified as 'High,' while the presence of two and one sensitivities meant a classification of 'Moderate' and 'Low', respectively.

For further information, based on field surveys in 2019-20, it was recorded whether the activities were (or would be, in a hypothetical future scenario) restricted during a medical emergency like the Covid-19 epidemic.

3. Results and discussion

3.1. Negative phenomena, symptoms present in 2021-22

3.1.1. Base phenomenon: sustained low, or historically low water levels

Certified water level measurements have been available on the lake since 1939, using a water level gauge in Agárd.

The water level on 11 August 2022 was measured at 58 cm, the lowest value ever recorded. Since 2017, water volumes have been naturally continuously decreasing, and in 2020-21 precipitation was lower than long-term averages, leading to desiccation of the catchment area (influx is also lower) (Table 1.). In March and June 2021, rainfall was severely lower than long-term averages; therefore, the measured change in water volume was also significantly (by -80 and -100 lake millimetres, respectively) below volume change typical for this period.

Table 1

Water balance of Lake Velence divided by factors, 2011-2021. The change in water balance has been negative since [19]

(lake mm)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Precipitation	297	436	572	720	512	632	553	603	633	528	493
Inflow	375	153	434	268	310	288	205	195	153	158	158
Inflow from reservoirs	212	196	185	88	142	211	62	210	119	0	60
Evaporation	977	992	902	834	923	886	1005	929	936	930	907
Change	-93	-207	289	242	41	250	-185	79	-31	-244	-196

3.1.2. Changes in vegetation

Currently exists only empirical data about how wildlife reacted to low water levels, primarily from observations of nature conservation and water management professionals working on the lake. According to them, the following processes have been observed on the lake since 2021. As expected, lower water levels facilitate the spread of marsh vegetation, which is particularly true in a lake with limited light.

The spread of *Schoenoplectus litoralis* and *Phragmites australis* was clearly visible in the summer of 2021. *Cladium mariscus* shows extraordinary competitiveness even compared with stands of *Typha* spp.

On sandy beaches, mud vegetation began to spread, among others endemic species (*Cyperus pannonicus*) have been found. Species of salt grassland associations (e.g. *Tripolium pannonicum*) characteristic of Lake Velence's shoreline started appearing in dry areas of the lakebed as well.

These processes indicate that the lake has started shifting towards a new equilibrium, and that the changed water conditions enabled the development of conditions and a lake character resembling the pre-regulation era (higher marsh vegetation cover, smaller surface of open water).

3.1.3. Changes in fish population

Two waves of fish mortality / fishkill occurred in 2021, followed by two more similar events in 2022. Table 2. shows relevant data of these events.

Table 2

An Overview of Fish Mortality Events in 2021-2022: Impact on Open Water Species and Exotic Species [20-21]

Date	Bream, Rudd (scardinius erythrophthalmus), Roach (rutilus rutilus), Bleak (alburnus alburnus)	Aps (leuciscus aspius)	Grass Carp (ctenopharyngodon idella)	Common Carp (cyprinus carpio)	Zander (sander lucioperca)	Catfish	Other: Silver carp (hypophthalmichthys molitrix), Crucian carp (carassius carassius), Eel (anguilla anguilla)	Total
June 2021	3890	175	277	100	130	80	328	4980
August 2021	3979	20	395	50	80	1020	1126	6670
								15219*
August 2022	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1530

Note: *corrected by considering fish drifting into reed stands, eaten by birds or sinking to the bottom, rounding up.

Studies show that the chemical reasons behind mortality events - which affect approximately 5% of total fish populations, assuming 150kg/ha – were oxygen deficiency and ammonia release [20-21]. Data show that a large number of fish preferring open water and/or belonging to exotic introduced species died. On the other hand, species like *Esox lucius*, characteristic of the lake before its regulation, show only very minor fatality rates.

3.1.4. Changes in avian fauna

Bird populations of the lake reacted rapidly to changed conditions as well. However, currently only empirical observations are available about these changes, comprehensive data has not yet been published. One conspicuous phenomenon is the increase in species spending the night or the entire winter on the lake, making its character similar to the neighbouring wetlands of Dinnyési Fertő Nature Conservation Area. The high numbers of nesting *Himantopus himantopus* in the summer of 2021, unbothered by the proximity of humans, was spectacular, with birds being a constant presence on beaches as well. *Recurvirostra avosetta* also found more favourable conditions. On the other hand, the desiccation of large continuous reed marshes of the Western side of the lake caused a part of the heron population to abandon their former nesting sites, due to increased pressure from *Sus scrofa*.

3.1.5. Effects on scenery and landscape perception

Decreasing water levels made the view of the bare lakebed and mud a more dominant sight in the coastal zone. Additionally, the aforementioned spread of marsh vegetation is perceptible, transforming visual connections. The formation of dry sections of the coast and lakebed significantly changed the accessibility of water (e.g., it became far or hard to reach from certain beach stairs, while other places gained new entry points), and new points of view appeared. An important aspect of landscape perception was the smell of biological processes occurring in rapidly warming shallow waters and sediment appearing on the surface.

3.1.6. Economic and social effects

Although detailed data necessary for a thorough analysis of economic effects are not yet available, it is unquestionable that low water levels had a negative impact on the tourism and service sector, as a result of the above-mentioned processes. Additionally, separating the impact of low water levels from the effects of the Covid-19 epidemic will be challenging even with access to detailed data. However, it can be stated that several activities dependent on water volume became impossible due to low water levels: boat docks and fishing spots dried up, while beaches became unsuitable for swimming. Issues of quality and quantity often occurred simultaneously, strengthening each other – for example, rapidly warming, shallower waters facilitated the proliferation and concentration of bacteria in summer months, causing health risks for swimmers. In July 2021, *Enterococcus* numbers increased on several beaches, leading to the temporary closure of affected beaches.

Media coverage and public reactions to the previously detailed processes describe and complete the picture regarding the entire phenomenon, while also influencing tourist demand. Based on a Google search made in January 2023 (query "Velencei-tó" = Lake Velence in Hungarian), the summary of keywords in the first 150 articles/webpages within the results shows that public opinion is singularly focused on how/when the previous, artificially created system, which is difficult to maintain, can be restored. As the artificially high water levels have become familiar and seemed manageable during the decades since the lake regulation took place, local residents, stakeholders, local and national policymakers are practically only debating different alternative ways of increasing water supply (by redirecting karst water, drinking water, purified waste water, restoring water supply infrastructure etc.), adaptation to water level fluctuation and temporarily low water levels has not been widely considered. Another easily identifiable trend among the search results is the abundance of emotionally charged, strongly negative expressions („dramatic", „critical" etc.), which shows that the natural behaviour of the lake is unanimously seen by people as a serious problem, while the naturalness and ecological benefits of low water levels are barely known (Figure 2).

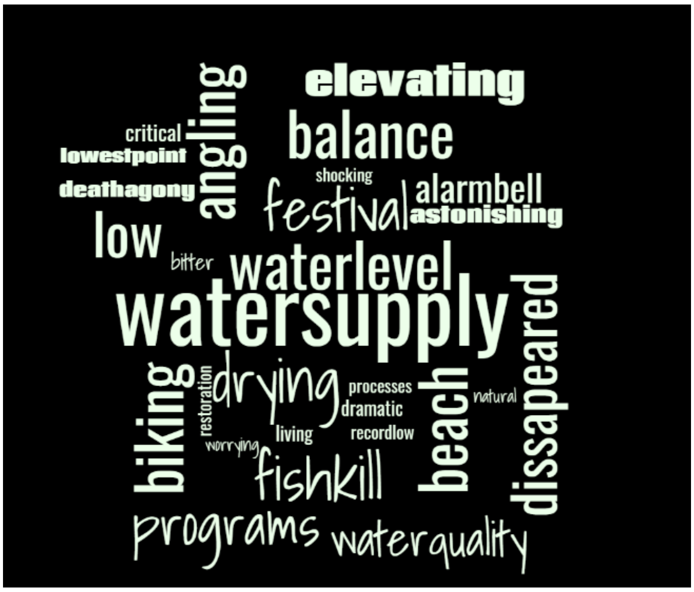

Figure 2. Word cloud based on the analysis of the first 150 results for the query „Velencei-tó": „water supply" is the most common expression.

In the case of image results, the 150 analysed images included 39 that, without a doubt, depicted the lake during the low water levels of 2021-22. According to empirical experience, the low water level also had a strong emotional impact on local communities in settlements around the lake, resulting in heated debates and a search for scapegoats.

The above symptoms especially impacted the hydrological conditions, fish population and shore usage of the lake. Using this information, as the next step it is necessary to review the natural conditions and landscape change history of Lake Velence and identify the factors determining climate risk and sensitivity.

3.2. Natural conditions

The catchment area of the lake is 602.4 km^2, extending to the Northern end of the Mezőföld plains and the Southern side of the Vértes mountains, and consists of three distinct parts. Its largest portion – 383 km^2 – is the catchment area of the Császár-stream feeding into the lake, which has a partially inactive karstic upper area (approximately 75 km^2). The second largest tributary of Lake Velence is the Vereb–Pázmándi-stream (catchment area 105 km^2), with a remaining direct catchment area of 114.3 km^2 [19]. The only permanent stream feeding the lake is the Császár-stream, but there are several small temporary streams in its vicinity as well.

The average depth of the lake is 1.45 m [13], and based on currently available data, its depth has remained similar since its formation [22]. This average depth makes it a "shallow lake" according to the classification of Dévai [23], and belongs to the "polymictic" thermal lake type.

Hungary is located in the temperate climate zone, and its specific climate classification is continental with long warm seasons. This climate type is globally characterized by significant annual variation in temperature with four distinct seasons. The Velence basin is located at the border between the climate zones moderately warm, dry and moderately warm, moderately dry. The mean annual temperature varies between 9.3 and 9.5 °C, the total annual precipitation is between 525 and 55 mm [24].

The water balance of the lake is dominated by the effects of precipitation and evaporation. In the last half century, the amount of rainfall and the factors of flow are the water balance that have significantly declined [19]. Based on its natural water circulation, Lake Velence is a semi-static lake, as it can potentially dry up in certain years [25]. In the limnologic sense, the entire lake belongs to the littoral zone, there are reed islands located throughout most of the lakebed (due to its morphology and semi-static character), and overall can be classified as a wetland-type saline steppe lake.

3.3. Landscape change history

The first major attempts at changing the natural coast conditions of Lake Velence occurred in the middle of the 19th century. The construction of the Budapest – Fiume train line (Southern Railway) between 1859 and 1861 transformed the shoreline, as it fragmented the hydrobiological littoral zone, separating Lake Velence and "Nádas Lake" (currently known as Dinnyési Fertő) [25]. The first two train stations near the lake were constructed in Dinnyés and Kápolnásnyék [26]. The possibility of draining the lake with its fluctuating water levels was considered several times to increase agricultural areas, but finally after the 1880s the decision was made to construct the drainage channel known as the Dinnyés-Kajtor channel [22]. A drainage channel had already been excavated around 1778-1787 close to the current

Dinnyés-Kajtor channel, but it fell short of expectations [22]. To regulate drainage, a weir (1903) and later a floodgate (1928) were built near Dinnyés [14]. Between 1968 and 1975, two reservoirs (Zámoly, Pátka) were created by damming the Császár-stream. After the regulation of water levels, fluctuation was reduced below 1 m (and later, after 1970, below 50 cm), reducing the shoreline. The change in shore length was reduced to ±10% at extreme water levels [14]. According to current operating regulations, the floodgate control range is +130-170 cm from the Agárd gauge (the „0" point of which is 102.62 m above sea level).
Truly significant transformations in the surrounding landscape began in the 1960s; the shore zone could be considered semi-natural until that period [14]. Under the direction of the Lake Velence Administrative Committee (1958), large-scale and complex development began, with the goal of creating a "recreational lake" [27]. Therefore, the changes were motivated by the creation of necessary conditions for recreational use, and as a basis, the improvement of water quality in the lake showing signs of advanced benthonic eutrophication. The silted-up lake, overgrown with reed and aquatic plants, was unable to meet requirements for recreational use [25].

The goals of development works were to improve water quality, to enable construction at waterfront areas, to protect banks against erosion, to create docks and quays for boats and ships, and to increase the surface of open water suitable for bathing [27-29]. 17231 m of embankment, 2056 m of breakwater piers, and 5204 m of harbour banks were constructed between 1962 and 1992, with the total length of shore protection works being 24491 m and the length of reinforced shoreline being 17.73 km. Through dredging, 9.8 million m^3 of silt, clay, and reed-root soil were removed from 15 km^2 of reed beds, with 3.8 km^2 being filled up (Papp 1995), which meant that open water surfaces became prominent instead of the former dominance of marsh vegetation.

Tourism was developed in accordance with the creation of a recreational lake, with the first wave taking place in the 1970s and 1980s, and gaining momentum in the 2000s. Data shows that between 2009 and 2017, this region developed in a far more dynamic manner than the Central Transdanubian Region as a whole, producing 300000 overnight stays annually in the commercial sector (with this data being only a third of this 10 years earlier). 96 percent of overnight stays at the lake are domestic tourists. The number of overnight stays in Gárdony increased more than one and a half times since 2005, while Velence quadrupled its number of stays. The average stay is 2.2 days [30].

Angling tourism must be noted separately: commercial fishing has been abandoned on the lake since 1974, fishery management is controlled by the National Federation of Hungarian Anglers. While the number of anglers – and therefore revenue – has been decreasing since the 1990s (with stagnation and a slight uptick around 2010), costs of fishing inspection and fish stocking are rising (partially because of the increasing costs of transportation). Revenue from fishing tickets fell by 29.5% between 2020 and 2021 [20]. While fish stocking and introduction of exotic fish species took place as early as the beginning of the 20th century, the most significant changes occurred from the 1970s onward, by stocking non-native species *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix* and *Hypophthalmichthys nobilis*, as well as mass-stocking native *Cyprinius carpio* [31].

Based on the aforementioned results, historical changes in lakeshore landscape character (scenery, landscape structure, shore morphology) were separated into four periods. The findings are consistent with the results of Papp [14] on the transformation of the shoreline, but are not limited to changes on the shoreline itself. The first period of lakeshore transformation – before intensive use – was between 1859 and 1880, including the largest changes in the extent of natural and semi-natural littoral zones and shoreline length. The second period of shore transformation was between 1880 and 1962, with regulated water levels facilitated the development of extensive recreational land use. The consequent period, between 1962 and 1992, included large-scale, planned lake regulation and recreational development. The fourth period (1992-2016) can once be characterised by independent, scattered developments. These partially involve the transformation of areas already used for recreation in earlier periods, signifying the increasing intensity of use and the decrease in open shoreline. Another notable aspect of this period is the lack of large-scale shore regulation works, with changes being focused on the transformation of former artificial embankments (e.g., creating sandy beaches, use of pilings). Certain sections of shoreline were not affected by all trends of these periods – for example, the vicinity of the rowing centre of Sukoró still looks like it did after the regulatory works were finished, while areas near the Bird Reserve are in places only affected by water level regulation. It was considered the period of the complex shoreline restoration project (2016-2023), funded by the European Union's Cohesion Fund, which includes the renewal/transformation of shoreline protection at a length of 29 km, as well as dredging (114.150 m^3), hydraulic engineering works at the mouths of streams and nature conservation-fishery management measures like the creation of spawning grounds.

Based on the above review, climate risk and sensitivity are determined by the following factors:

- natural factors of climate risk and sensitivity
    - small, water-deficient catchment area (low drainage)
    - shallow lake
    - continental climate
    - semi-static character because of the previous two (fluctuating water level, temporary desiccation)
    - dominance of macrophytes
- landscape change history factors of climate risk and sensitivity
    - water levels kept artificially high
    - increase in open water surfaces by dredging
    - embankment/shore protection works / shore engineering, alteration
    - reed management using heavy machinery
    - stocking of open-water fish species
    - waterfront development (hotels, restaurants, resorts etc.)
    - construction of docks, harbours, and beaches

3.4. Climate risk and sensitivity of land uses

The land uses and activities present in 2022 in Lake Velence and its 100-metre shore zone were evaluated, based on the level and form of climate sensitivity, summarised in Table 3. The results show that angling and activities related to beaches (bathing, swimming) are the most at risk. Several sections of shoreline become unsuitable for angling at low water levels, while negative changes in water quality have an impact by affecting fish populations (e.g., fish mortality events). Water quality has an increased importance for bathing, but observations from 2021-22 show that the disappearance of beaches suitable for swimming, the increase in silty areas negatively impacts this activity as well.

Table 3

Climate sensitivity of land uses at Lake Velence: angling, operation of beaches and bathing/swimming are most at risk

Land use / activity	Dependent on water quality*	Dependent on water level**	Dependent on landscape perception***	Dependent on pandemic restrictions****	Climate risk / sensitivity
Recreational angling	x	x	x		High
Boating, pedal boating		x	x		Moderate
Canoeing, kayaking, SUP			x		Low
Swimming	x	x		x	High
Water-skiing	x	x			Moderate
Cruiser ship traveling		x	x		Moderate
Cycling, other outdoor sports			x		Low
Residential area, hotels, resorts			x	x	Moderate
Restaurants, cafes, shops			x	x	Moderate
Cultural programs, festivals			x	x	Moderate
Reed harvesting		x			Low
Nature conservation		x			Low
Ecotourism			x		Low

Note: *definition of low water quality: due to bacteriological contamination of bathing water, the beach would have to be closed for at least 21 days, or the trophic state of the water, based on chlorophyll-A levels, would fall within the eu-polytrophic – 100-200mg/m^3 – category for 21 days simultaneously at a minimum of 2 measurement sites. ** definition of unfavourable water level: water levels fall below 50% of minimum operational levels for at least 30 days. ***definition of unfavourable effect: long-term change in the familiar scenery from frequented viewpoints, sustained or periodic unpleasant sounds or smells. ****based on the restrictions applied in 2019-2020 in Hungary.

Although this is beyond the scope of this research, it is notable that beaches are also closed during a pandemic. Activities based on original natural conditions of the lake, like nature conservation and ecotourism, are less sensitive.

Further analyses are necessary to identify effects on the service industry, but it can be established that the most typical and widespread uses of the lake (angling, bathing) are inflexible to change. In other words: currently dominant land uses require an artificially maintained water level, which is costly and resource demanding to sustain within a rapidly changing natural system, becoming less and less possible to guarantee and definitely unsustainable.

4. Conclusions

In the research, natural factors and landscape change processes was reviewed that determine the climate risk and sensitivity of a shallow Central European lake, mainly used for tourism. It was analysed the ecological and economic impact of the record low water levels of 2021-22, focusing on processes. It was determined which current land use forms can be considered most at risk or sensitive regarding climate change. The wise and sustainable use of natural resources, especially lakes, requires a major paradigm change, including education, communication, and raising awareness. The question is not how one could go against natural processes and replenish the water of a semi-static lake during a period of drought, but how one could adapt to natural conditions and water level fluctuations. This is painful to face the system is resistant to necessary social and economic changes, but the later the transitioning will start, the more disappointment will encounter before finding the right path. After the change of approach, a change in land use structure becomes feasible: the example of Lake Velence shows that long-term utilisation of our shallow lakes, vulnerable to climate change, is only possible in a flexible system that considers their natural dynamic processes (fluctuations in water level, succession, filling, etc.), their resilience, the ecological footprint, and biological capacity of the area. This requires strategic planning based on climate models and considers alternative scenarios for the entire catchment area and all settlements around the lake.

The management of the lakes and lakeshores is not only urgent because of the necessity of climate adaptation, but compliance with the Water Framework Directive of the European Union and the goals of the UN regarding the protection and restoration of biodiversity all concur on this topic. As the continuation of this research, monitoring ecological changes (flora, fauna) is necessary, as well as the data-based analysis of economic effects (tourism and service sector) and the sociological assessment of opinions and emotional reactions of local residents impacted by these processes. The possibility of integration into decision-making processes and communicability, teachability must also be a primary concern during the development of a system of indicators regarding the climate sensitivity of lakes.

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