Analysis of possible retention volumes in extinct ponds – case study for the catchment of Bystřice

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Abstract This paper presents the analyses focused on the variation of total storage volume in fishponds and other water reservoirs since the first half of nineteenth century. The study areas selected for this analysis is the catchment of Bystřice River located in eastern Bohemia (379.2 km^2). The storage volumes were calculated by two approaches: (i) the application of derived relationship between the area of fishpond and its total volume and (ii) and by the GIS application and the analysis of detail elevation data. The results show significant decrease of the storage volume after first half of nineteenth century and mild increase of the volume in recent past.

Keywords: extinct pond; landscape water retention; old maps; detail elevation data

1. Introduction

The fishponds are historically a significant part of the landscape in many parts of present Czech Republic. First of them are dated to the tenth century. The number of fishponds varied a lot since the existence of first of them. They have many functions besides the historically main one which is fish farming. Besides others, the ecosystem services should be mentioned which consists mainly in the influence on the microclimate and in the existence of habitats for many species (Pokorný and Hauser, 2002). The flood mitigation effects should be also mentioned (Lhotský, 2010).

The drought period which affected the entire area of the Czech Republic in last two years (2015-2016) has attracted both the professional and public society. It was one of the most sever events in more than last 50 years (Daňhelka *et al*., 2015; David and Davidová, 2016). It is generally agreed that there is a need to increase landscape retention capacity and retention in fishponds and other small water reservoirs is considered to be one part of this complex issue. Moreover, the water storage capacity of most water reservoirs in the Czech Republic is permanently decreasing due to increasing intensity of soil erosion processes and sediment transport.

2. Study area

For purposes of presented study, the catchment of Bystřice River was selected which is located in eastern Bohemia (see figure 1) and spreads from the lowlands along the Elbe River to Krkonoše submountain areas. The relief varies from very flat areas in the southern part to hilly areas with steeper slopes in the northern part. The total area of Bystřice River catchment is 379.2 km^2 to its confluence with Cidlina River. The catchment is drained by the Kamenice River and its many tributaries including significant presence of artificial canals. The occurrence of fishponds and other types of still water bodies is irregular. More water reservoirs are located in the lower part of the catchment while the upper part has less water reservoirs. The largest one is Třesický pond with an area 38 hectares.

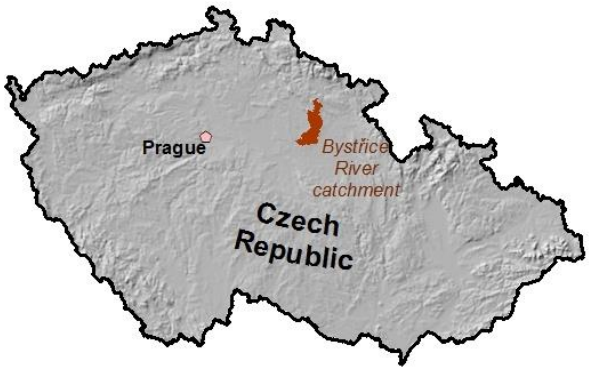

Figure 1. Location of study area

Climatologically, the area belongs to warm to moderately warm region (T2 and MT11 after Quitt, 1971) with the average temperature 8-9 °C and average annual precipitation total 500-600 mm. In the catchment, forests, meadows and arable land are all present. The presence of forests is increasing from south to north while arable land is more present in southern part. Meadows and pastures are then spread over the entire catchment with slight higher presence in the northern part.

3. Data

The data used for analyses presented in this paper consists mainly of digitized polygons of fishponds captured on

maps from different periods and of detail elevation data of the study area.

3.1. Topographic maps

The data describing fishponds in different periods were digitized from following maps:

- Maps of 2nd Austrian Military Mapping 1 : 28 800 (1836-1852)
- Maps of 3rd Austrian Military Mapping 1 : 25 000 (1876-1880)
- Czechoslovak Military Topographic Maps 1 : 25 000 (1953-1957)
- Czechoslovak Military Topographic Maps 1 : 10 000 (1988-1995)
- Czechoslovak Topographic Base Maps – ZABAGED 1 : 10 000 (2002-2006)
- Czechoslovak Topographic Base Maps 1 : 10 000 (updated version 2015)

Older maps such as maps of 1st Austrian Military Mapping created in second half of 18th century (Miškovský and Zimová, 2005; Zimova *et al*., 2006) have unfortunately insufficient spatial accuracy which avoids their referencing for purposes of digitization in a similar way.

The data were either available from previous researches as in case of ponds captured on maps of 2nd Austrian Military Mapping (Pavelková *et al*., 2016) or digitized newly for purposes of ongoing research project. The spatial accuracy of old maps decreases with the period since their creation. Thus, the very small fishponds up to 0.5 hectares were excluded from the analysis to avoid misinterpretation of the results due to the inaccurate position.

3.2. Elevation data

Fish ponds in the area of the Czech Republic are often very small and thus the accuracy of elevation data is one of key point when doing the analysis of potential retention volumes of those which ceased to exist in past. Thus, the most accurate source of elevation data was chosen which is available for the entire area of the Czech Republic which. It is the Digital Relief Model of the 5th Generation (DMR5G). This is an irregular net of points with XYZ coordinates. The density of points varies but is in general more than 1 point per 1 m^2. The accuracy is about 0.18 m in an open space and about 0.3 m in forested areas expressed as mean square error.

4. Methods

The volumes were taken from Basic Water Management Maps of the Czech Republic 1 : 50 000 for existing fishponds for which this information was available there. Then, the relationship between the water surface area and the volume was investigated (see figure 2) which was considered as a possible way to estimate volumes of existing fishponds for which the volume was unknown.

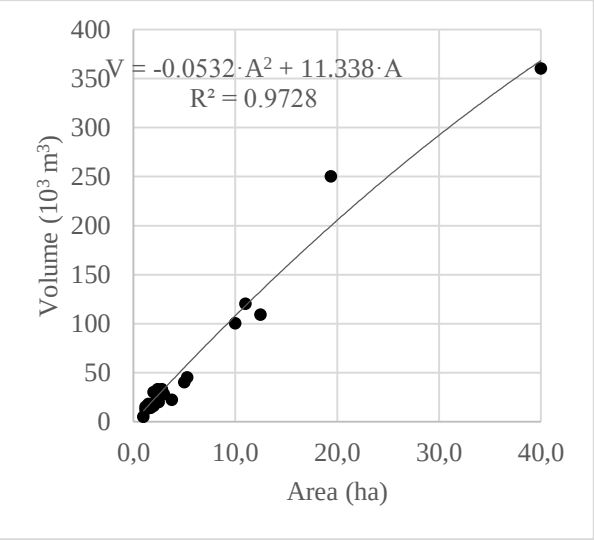

Figure 2. The relationship between the fishpond area and the volume

The detail elevation data could be used only for the investigation of those fishponds which do not exist now as for those existing the application of LiDAR is impossible to get the bathymetry. In this case, GIS tools were applied to calculate the volumes for polygons of extinct ponds. For this purpose, the elevation of former water surface needed to be estimated which was done by the analysis of elevations along the borders of pond areas.

5. Results

The volume for each fishpond and other water reservoirs were calculated using the procedure described in the chapter 4. Total storage volumes for respective periods were then calculated by summing the volumes of all water reservoirs captured on maps created in these periods.

The results show that the highest storage volume corresponds to the oldest period in focus which was the period of 2nd Austrian Military Mapping (1836-1852). This is caused mainly by the existence of three big fishponds (Chlumetzer T., Piseker T. and Gr. Kositzer T.) in this period which were located close to the confluence of Bystřice River with Cidlina River by Chlumec nad Cidlinou (see figure 3) and which ceased to exist after this period. These three fishponds had a toal volume $1332 \cdot 10^3$ m^3 and the area 2110 hectares.

The estimated total storage volume in the period of 1st Austrian Military Mapping is $4924 \cdot 10^3$ m^3 which is more than three times more than in the period less than 40 years later.

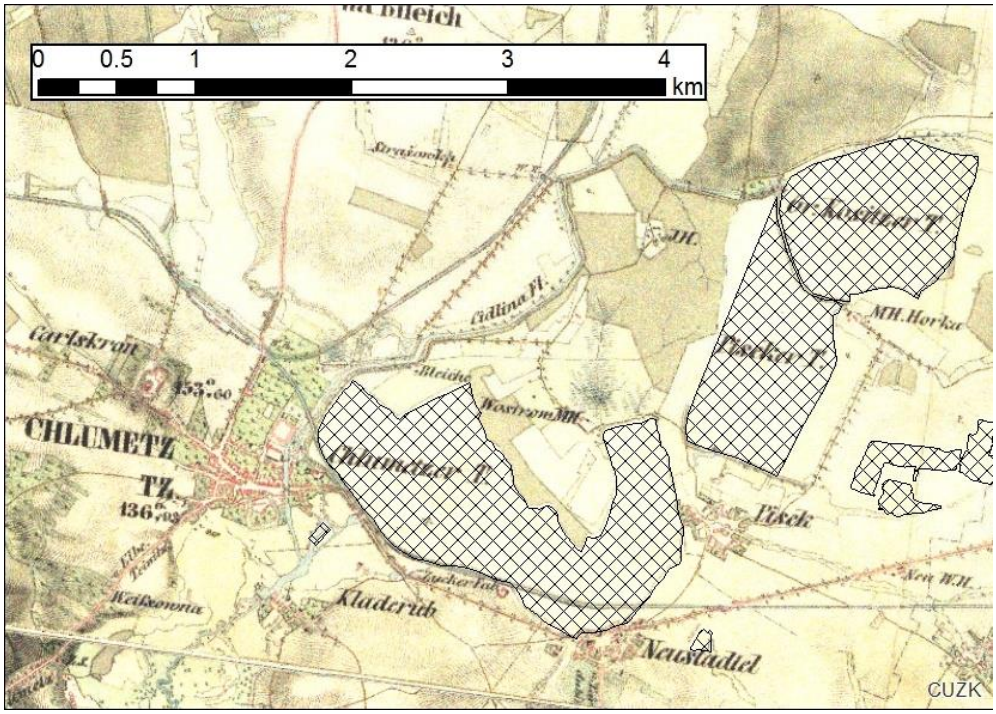

Figure 3. The relationship between the fishpond area and the volume

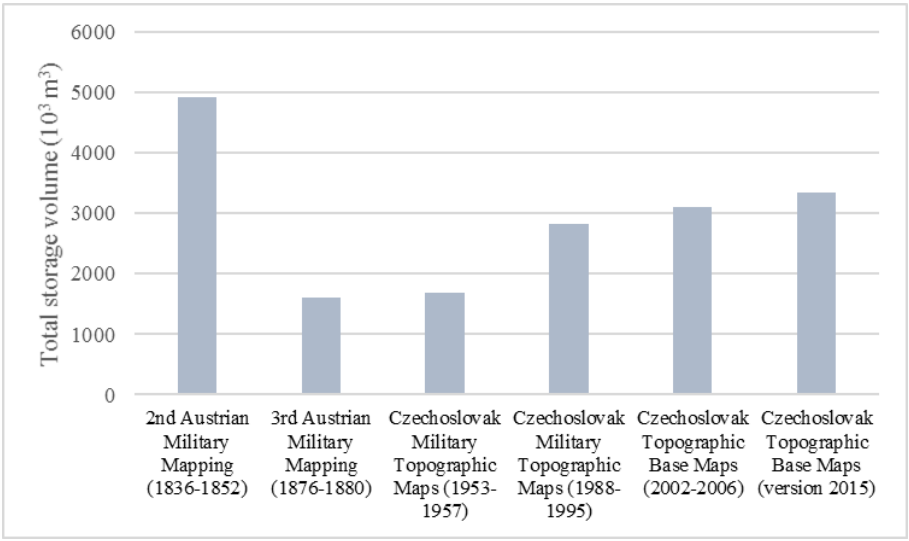

Figure 4. The total storage volumes in fishponds and other water reservoirs larger than 0.5 ha in different periods

Table 1. Storage volumes of fishponds and other water reservoirs larger than 0.5 ha in different periods

Period	Total storage volume (10^3 m^3)
2nd Austrian Military Mapping (1836-1852)	4924
3rd Austrian Military Mapping (1876-1880)	1607
Czechoslovak Military Topographic Maps (1953-1957)	1678
Czechoslovak Military Topographic Maps (1988-1995)	2817
Czechoslovak Topographic Base Maps – ZABAGED (2002-2006)	3114
Czechoslovak Topographic Base Maps (version 2015)	3341

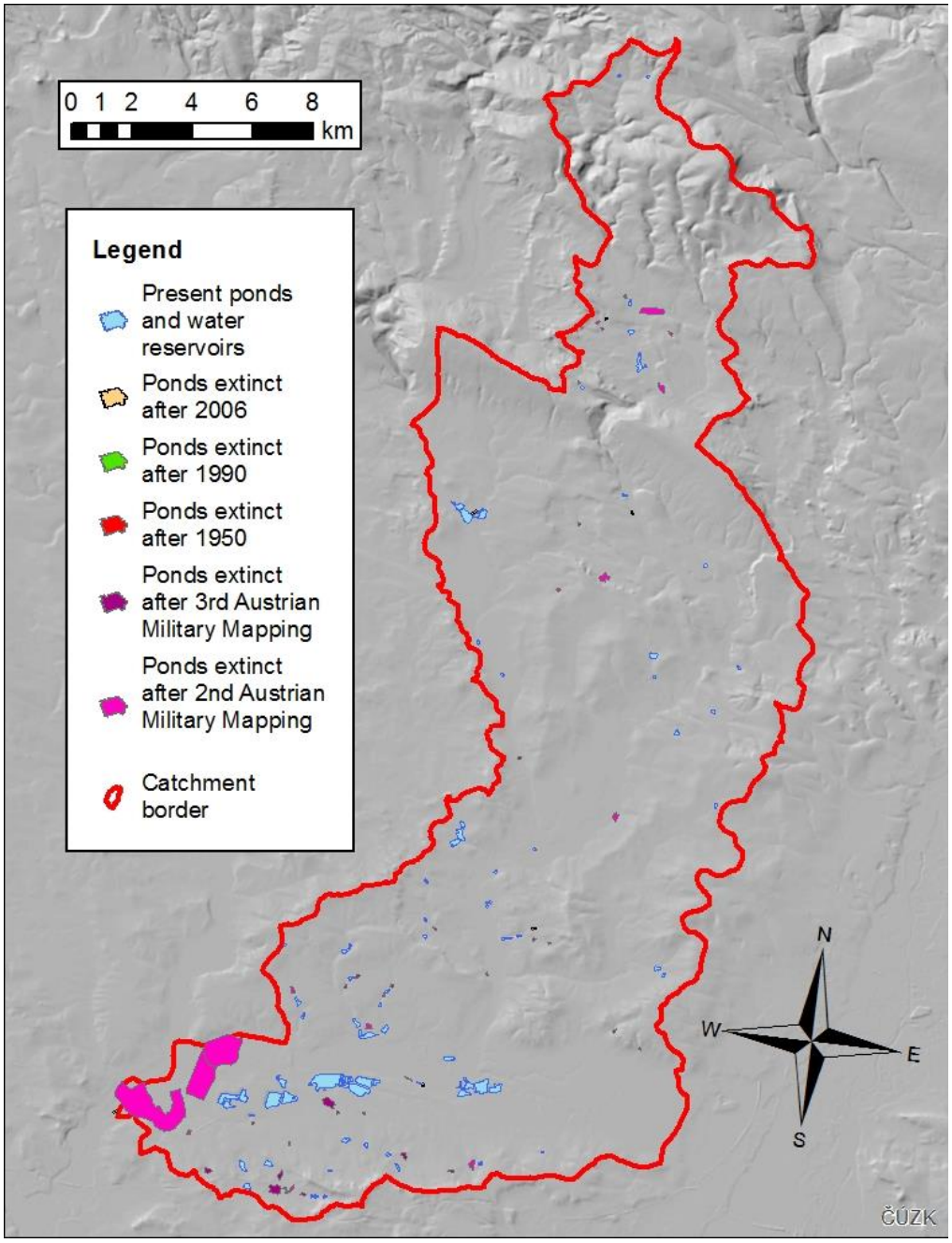

Figure 5. The distribution of ponds within the Bystřice River catchment

The results then show, that the period with lowest presence of fishponds and other water reservoirs corresponds to the end of nineteenth century and first half of twentieth century. At present, the number of ponds increases slightly together with their total storage volume (see table 1 and figure 4 for details). The map showing distribution of fishponds within the catchment with distinguished periods of the extinction is presented in figure 5.

6. Conclusion

The results of analyses presented in this paper can be concluded in several statements. First, the total storage volume of fishponds and small water reservoirs varied a lot in study area in past. The highest retention capacity was identified in the first half of 19th century among all analyzed periods. However, it can be identified by simple visual check that the number of fishponds was much higher in earlier periods. The analysis of older map resources is however difficult due to their low accuracy and will need more time to be done.

Second outcome of presented analyses is that there are many extinct ponds in the study area having an important water storage potential. Thus, the landscape water retention capacity can be significantly increased by the restoration of such ponds. This implies that the restoration of extinct ponds can be considered as one of possible tools to increase the retention of the landscape.

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