Extinct Ponds: Potential for Increasing Landscape Retention Capacity?

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***Abstract*—**The restoration of extinct ponds is considered as one of ways to gain new retention capacities for water which is getting much more important issue with respect to expected impacts of a climate change. However, there are also other pressures on the landscape which must be all taken into consideration when making a decision on the possible restoration of extinct ponds. The research presented here focuses besides others on the restoration of former ponds which could be important for both the flood protection and drought impacts prevention. The first step of the methodology development for the assessment of such areas is the assessment of their present state. In this paper, the results of land use types assessment for 22 localities are presented. These results confirm the assumption that the most present land use type in such areas is the permanent grassland. However, the spectra of land use types present in extinct pond areas is very diverse and include besides others also airport areas and industry.

***Keywords*—**Extinct pond, land use change, sustainable water resources management, pond restoration.

I. Introduction

THE demands of growing population on the space for its expansion together with increasing living standard belong to the main factors affecting the landscape development dynamics. The landscape within the area of the present extent of the Czech Republic has been historically importantly affected by fish farming. The fish farming had undergone a boom in the Lands of Bohemian Crown in the Middle Ages. During the ages, a lot of ponds have been destroyed or ceased to exist by different reasons. It is referred that the total number of ponds at the end of 15th century had been about 40 000 in the area of present Czech Republic, some estimates are speaking about 70 000 ponds at the beginning of 17th century [14]. Currently, the number of pond in this area is about 21 000 which means that about one half of the former amount of ponds are not water bodies anymore and that the land use type is there other. A lot of ponds have been cancelled due to increasing demand on arable land in 17th and 18th century and turned to fields. At present, the situation has changed again and there is a pressure on the arable land to be turned to other land use type. The change consists of tenin transformation from the field to permanent grassland if the urbanisation is not considered. On the other hand, the demand for the space for expansion is getting stronger as the society is developing even faster than in recent past. Also the situation with water supply is changing which is caused besides others by the expected climate change and its impacts. It results from above mentioned that there is an important area of extinct ponds in the Czech Republic and that there is a demand for a tool which would be useful for the decision on their future use.

The research project NAZV KUS QJ1220233 “Assessment of former pond systems with aim to achieve sustainable management of water and soil resources in the Czech Republic” focuses on the assessment of extinct pond areas from the point of view of their further use. Its aim is besides others to define methodology for the assessment of areas of former ponds. Two important tasks to be solved within the project implementation are to identify extinct ponds and to be able to assess this area from the point of view of its further use. Identification of extinct ponds and the digitization is carried out using historical maps. It is necessary to do this manually due to the quality of these maps because they are originated in the middle of 19th century. The methodology for the classification of former ponds areas is based on multicriterial assessment [2]. It considers all natural conditions, safety, socio-economic criteria as well as ecology. The project has started at the beginning of 2012 and until now, the concept of the methodology has been worked out including its structure and list of criteria. One of main tasks was to define how each criterion should be assessed and how to include it in the final classification. In principle, the use of different spatial data and the application of GIS tools is there is emphasised and considered as suitable way to get objective classification. In general, the methodology needs to be formulated as the assessment of all possible future uses comparison for each present state.

In this paper, the analysis on present state of the areas of extinct ponds is presented which is the necessary first step for the assessment of the future use optimization. The emphasis is put on the possibility of the pond restoration. The restoration of extinct ponds needs to be assessed from different points of view. One of main criteria must be the evaluation of possible ecological impacts because such the conversion of the land into a pond affects the whole ecosystem not only in ponded area but also in its surroundings [4]. Ponds can affect the ecosystems in either negative or positive meaning. The negative influence on ecosystems can occur for example in case of building intensive fish pond close to habitats of amphibious organisms where the pond can be a trap for such animals. On the other hand, ponds which are considered as a habitat for amphibian organisms can be affected by an

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intensification of agriculture in their surroundings [9]. Furthermore, ponds are considered as very important resource for biodiversity mainly in case when they are not supposed for intensive farming [1], [6]. In general, the optimal way is to take into a consideration the whole catchments above the pond [11].The restoration of ponds can be also difficult in agricultural landscapes due to changed nutrient transport regime [8], [10] as well as changed regime of sediment transport. Also hydraulic and hydrologic conditions can be changed which affects the safety on one hand and nutrient regime and cycle on the other hand [7]. Hydrologic conditions can be also determining for the development of whole ecosystems [5]. The change in these processes can be very important since the time of pond extinction due to change of all the landscape and environment. As the ponds can be used also for storm water management, they can be exposed to the important load of heavy metals and other substances of anthropogenic origin [12].

Reasons mentioned in previous paragraphs together with the fact that the methodology will not be a simple procedure accent the need of the criteria which would identify the areas which are not suitable for any change and therefore which do not need to be further analyzed. This rejection criterion should be based on the present state of the area being assessed. The analysis on the present state was therefore carried out for 22 localities of extinct ponds which were focused on the land use types as well as on the area of each pond which is besides others a very important factor for the biodiversity [6]. The location of sample pond areas is shown on Fig. 1.

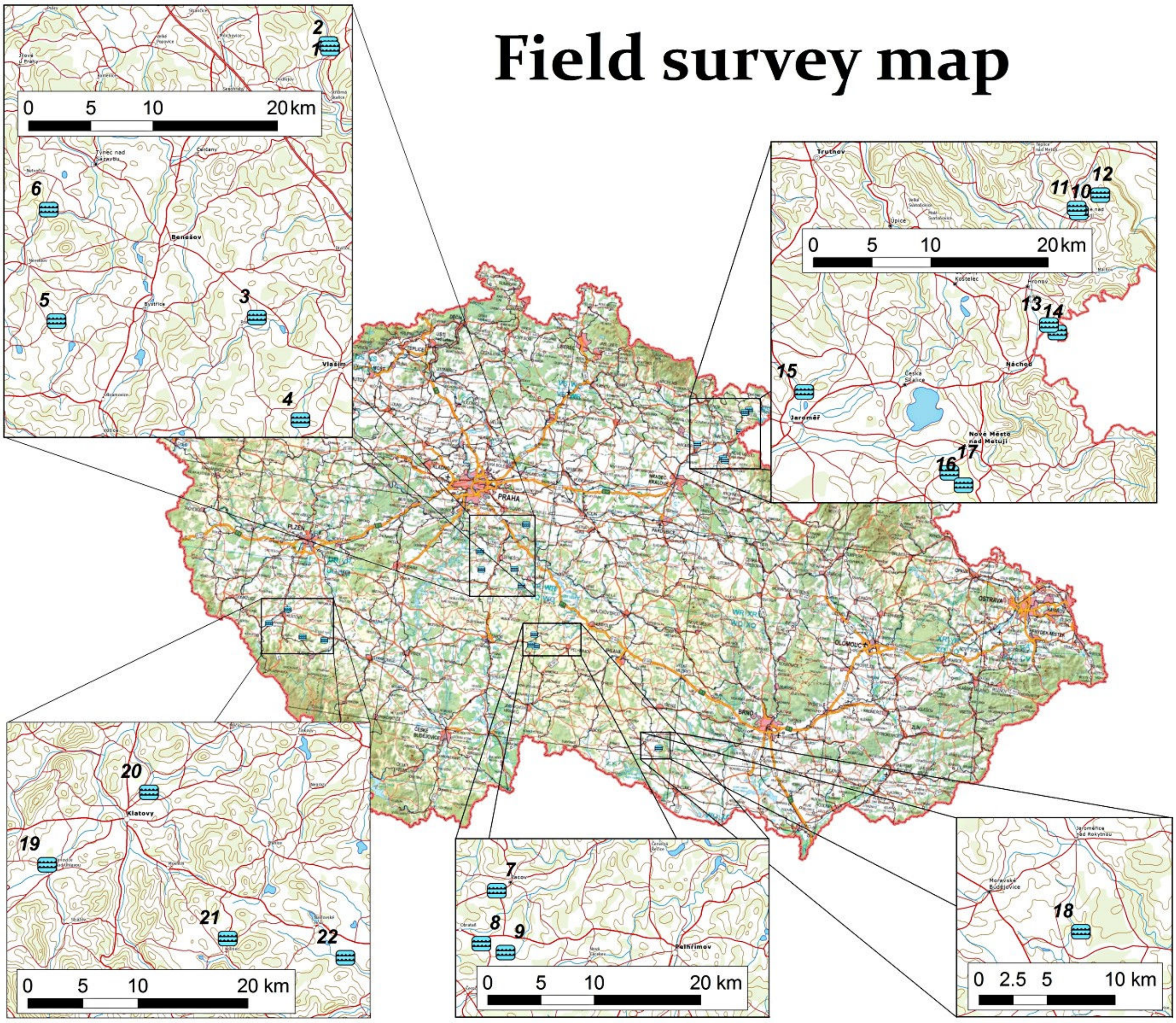

Fig. 1 Location of extinct pond areas used for the analysis

II. Material and Methods

Extinct ponds selected for the analysis are spread over the area of Czech Republic to cover different types of landscape, e.g. agricultural land, highlands, submontane areas. The occurrence of ponds in mountains is rare and therefore the mountains are not considered as the areas where the assessment would be important.

Two types of input data were used for the assessment of the present land use state of extinct pond areas. First, the CORINE Land Cover 2006 data [3]were tested for the general assessment on the most present land use type. Second, Land Parcel Identification System – LPIS [13] was used for the analysis on agricultural use of parcels registered in this database. These land use information sources are of very different resolution. CORINE Land Cover is a raster layer with the resolution 100 meters which means that it is very rough with respect to the size of areas in sample dataset. On the other hand, LPIS is polygon vector dataset with very accurate delineation of parcel borders as it is used for agricultural subsidies distribution. However, it contains only parcels for which subsidies are demanded and thus it doesn't cover all the area. Due to these facts and the fact that there was no other available land use data source, LPIS was used as a primary input and CORINE as a supplementary input for the parts of extinct pond areas which are not covered by LPIS data.

Land use was first evaluated for each data source separately and then both data sources were combined with emphasis on LPIS data. The extent of extinct ponds was depicted based on historical maps. Mainly maps of second military survey were used as a basis. The 2nd military mapping had been done in years 1836-1852.This is the oldest map source which is possible to be georeferenced with a satisfactory spatial accuracy.

Each area of extinct pond was surveyed in the field which was focused on the present state of the areas as well as on the existence of dam residues and other objects which could be used for pond restoration. Dam residues were identified in most of surveyed localities but they were in very different conditions.

TABLE I
Land use According to Corine land Cover 2006

ID	Area	Discontinuous urban fabric (112)		Non-irrigated arable land (211)		Pastures (231)		Land principally occupied by agriculture with significant areas of natural vegetation (243)		Coniferous forest (312)		Mixed forest (313)	
	m^2	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%
1	14 668							6 668	45.5	7 999	54.5		
2	70 311							8 335	11.9	9 819	14.0	52 157	74.2
3	36 356			7 201	19.8			29 155	80.2				
4	131 105			37 088	28.3			94 017	71.7				
5	158 509	6 520	4.1	92 450	58.3	53 365	33.7			6 174	3.9		
6	110 147			12 880	11.7	25 634	23.3	68 305	62.0	3 327	3.0		
7	17 258			13 674	79.2			3 584	20.8				
8	26 175					26 175	100			0	0.0		
9	44 564			44 564	100								
10	81 249	81 209	100	9	0.0	32	0.0						
11	49 851	18 859	37.8	10 843	21.7	20 149	40.4						
12	1 396	201	14.4	1 196	85.6								
13	97 929			82 120	83.9			15 810	16.1				
14	21 119					19 402	91.9	1 718	8.1				
15	181 369			13 645	7.5	89 661	49.4	78 063	43.0				
16	68 071			68 071	100.0								
17	78 829			78 829	100.0								
18	687 729			207 976	30.2					112 441	16.3	367 312	53.4
19	175 400	55 247	31.5			110 027	62.7	1 188	0.7			8 939	5.1
20	85 619			49 835	58.2	35 784	41.8						
21	61 630			51 019	82.8					10 610	17.2		
22	295 913			32 334	10.9	186 126	62.9	63 466	21.4	13 987	4.7		
Σ	**2 495 198**	**162 036**	**6.5**	**803 732**	**32.2**	**566 354**	**22.7**	**370 310**	**14.8**	**164 358**	**6.6**	**428 407**	**17.2**

Note: Pond IDs correspond to IDs shown in Fig. 1. Numbers in brackets below the land use description correspond to CORINE Land Cover land use codes.

III. Results

A. CORINE Data

First, the percentage of each land use type was calculated for CORINE Land Cover data. The results of this calculation are shown in Table I. During this analysis, also the suitability of CORINE data was assessed. The result of this assessment is such that these data can be used only in cases of unavailability of any better data. This source from the fact that each cell in the raster has an area 10 000m^2 and the pond size is often less than 100 000m^2. This means that the whole area is then represented by less than 10 cells which are rather generalized. For illustration see Fig. 2.

World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:7, No:7, 2013

The most present land use type in this case was Non-irrigated arable land - code 211 (32.2%) followed by Pastures - code 231 (22.7%) covering together more than half of analysed extinct pond areas. The rest involves Mixed forest – code 313 (17.2%), Land principally occupied by agriculture with significant areas of natural vegetation – code 243 (14.8%), Coniferous forest – code 312 (6.6%) and discontinuous urban fabric – code 112 (6.5%).

B. LPIS Data

The analysis focused first on the calculation of the proportion of analyzed area by LPIS data. The results show that parcels which are not registered in the database cover more than 43% of total analyzed area. The results of the analysis on the percentages of each culture class within extinct pond areas show, that the most present land use type is pasture (37.6%) followed by arable land (18.8%) which are again covering more than half of analyzed extinct pond areas. For detail results see Table II.

TABLE II
LAND USE ACCORDING TO LPIS DATABASE

ID	Area	Arable land (2)		Orchard (62)		Permanent pasture (71)		Other grassland (72)		Other culture (93)		Not registered in LPIS	
	m^2	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%
1	14 668					8 102	55.2					6 510	44.4
2	70 311					37 563	53.4					32 695	46.5
3	36 356	6 488	17.8			20 824	57.3					8 969	24.7
4	131 105					67 447	51.4					63 606	48.5
5	158 509	38 067	24.0			59 679	37.7					60 701	38.3
6	110 147	18	0.0			1 088	1.0					109 040	99.0
7	17 258	0	0.0									17 258	100.0
8	26 175	96	0.4			22 718	86.8					3 273	12.5
9	44 564	21 848	49.0			15 721	35.3					6 911	15.5
10	81 249											81 249	100.0
11	49 851					39 702	79.6					10 070	20.2
12	1 396											1 396	100.0
13	97 929	90 490	92.4									7 347	7.5
14	21 119					9 139	43.3					11 937	56.5
15	181 369			1	0.0	147 505	81.3					33 782	18.6
16	68 071	65 642	96.4									2 332	3.4
17	78 829	74 765	94.8									3 969	5.0
18	687 729	122 153	17.8			180 533	26.3					384 999	56.0
19	175 400					122 121	69.6			9 745	5.6	43 465	24.8
20	85 619	990	1.2									84 627	98.8
21	61 630	48 050	78.0									13 501	21.9
22	295 913					205 846	69.6	34	0.0			89 963	30.4
Σ	**2 495 198**	**468 609**	**18.8**	**1**	**0.0**	**937 988**	**37.6**	**34**	**0.0**	**9 745**	**0.4**	**1 077 601**	**43.2**

Note: Pond IDs correspond to IDs shown in Fig. 1. Numbers in brackets below the land use description correspond to LPIS codes of cultures.

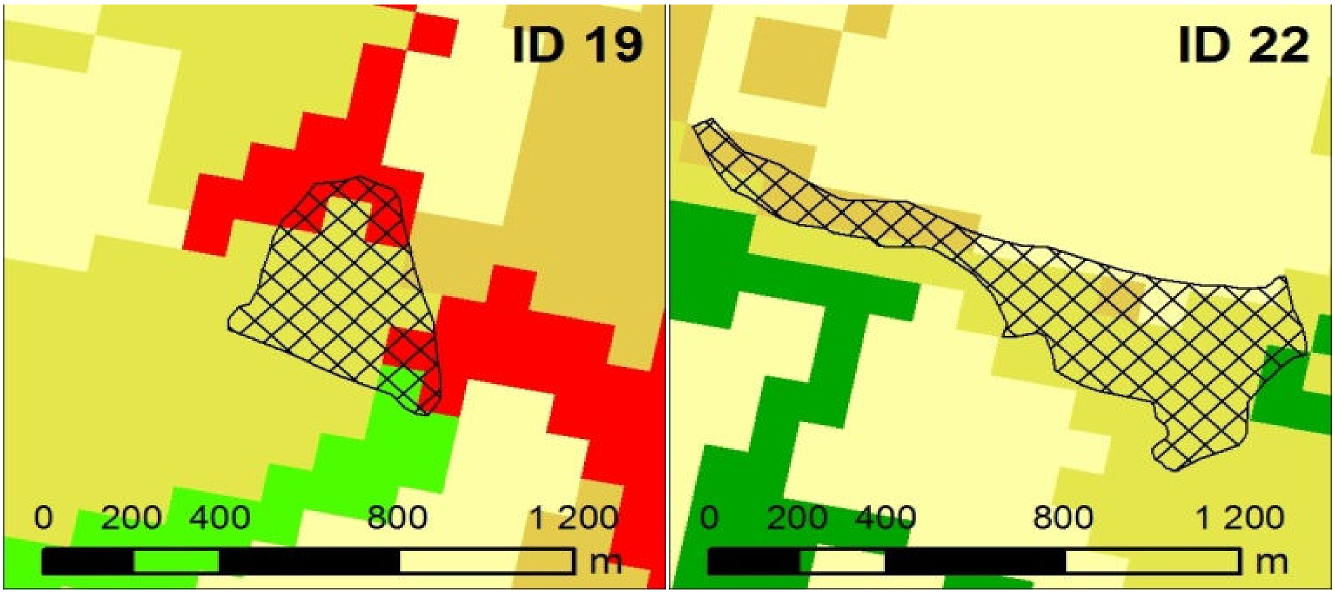

Fig. 2 Two selected extinct pond areas and its description by CORINE Land Cover data

C. Combination of the Data

The data were combined to mine the most information from available data sources. When combining, LPIS data were considered as primary. This means that the information from CORINE was used only to describe areas uncovered by LPIS data. Another issue was to define land use types suitable for combined data to make the results interpretable. These land use types were defined more general as the purpose is to define the most present land use. The final list contains only five categories.

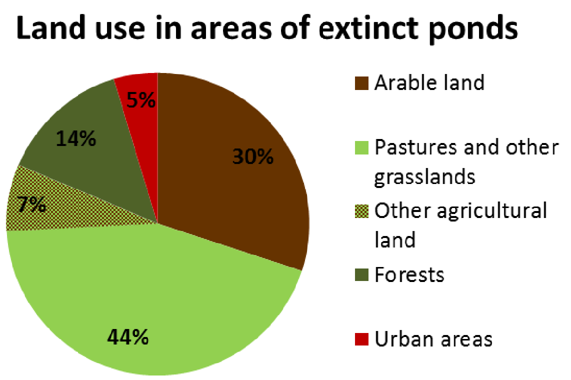

Fig. 3 Land use distribution in areas of extinct ponds within the testing sample

The results show that the most present land use type is Pastures and other grasslands (44%) followed by arable land (30%). The distribution of land use types is in detail shown on Fig. 3.

Urban areas are present on 5% of the total analyzed area which is not negligible value. This is mainly due to the fact that extinct ponds in areas which are even in very small part urbanized can be only hardly restored. The locality with ID 10 can be used as an example of extinct pond which is in present inside the town in heavily urbanized (for detail see Fig. 4).

Fig. 4 Crest of extinct pond dam and urbanization in former pond area on the left side (pond ID 10)

D. Area of Extinct Ponds

The area of extinct pond is another important factor which must be taken into a consideration when optimizing its future use. In past, the ponds of very different sizes were built. Those biggest mostly retain to present as they were important for fish production. It can be stated that the ponds which ceased to exist belong to the lower part of size spectra of ponds built in Middle Ages as shown in Fig. 5.

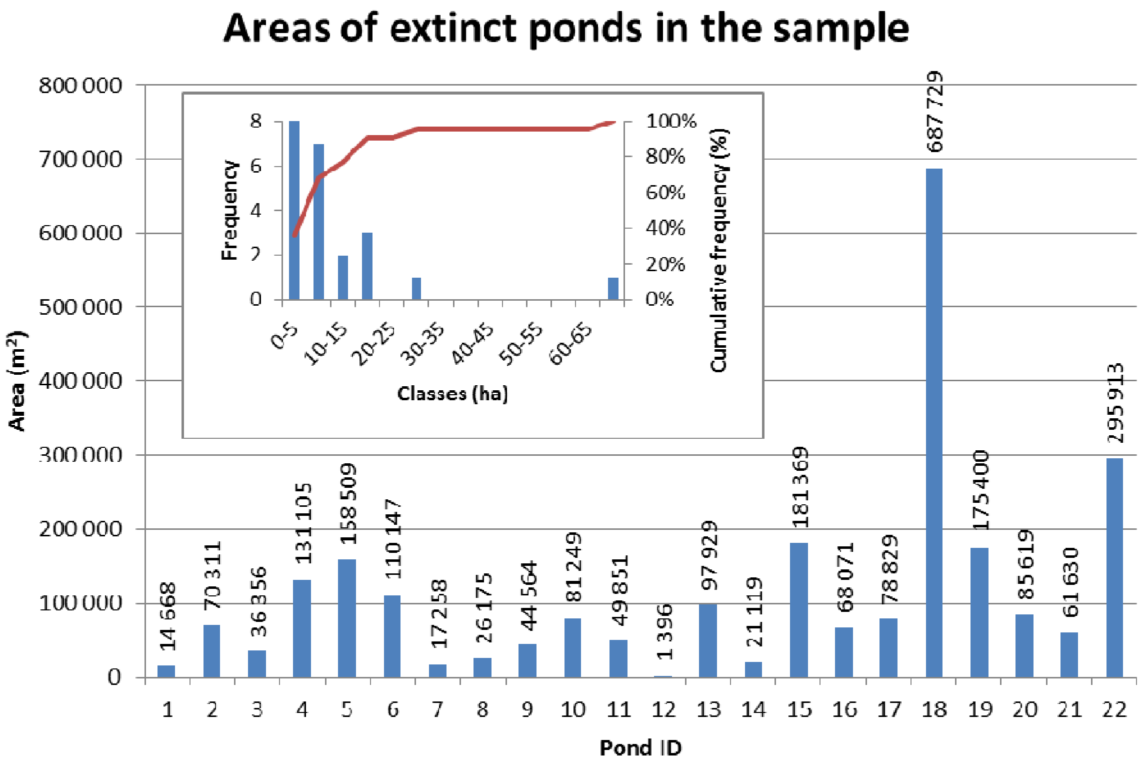

Fig. 5 Areas of ponds within the testing sample and their frequency distribution

IV. Conclusions

It was assumed that the areas of extinct ponds are in present used at most as permanent grassland which was confirmed by the presented analysis. However, the results show that there are extinct pond areas which can be excluded from the further analysis because they are now completely urbanized and therefore there is no way to change the land use. On contrary, one of assessed ponds has been rebuilt in year 2012. This was pond with ID 12.

The methodology for the optimization of extinct ponds further use will consider mainly the result which consists in the detection of land use types which are most present in such areas. Recent results show that many of extinct ponds could be possibly restored due to the present use and existence of dam residues which are often usable for construction of a new dam. This means that there could be an important potential retention capacity which could affect positively both the drought and flood regimes. However, this research must continue and focus mainly on potential volumes which would be available in case of extinct ponds restoration as well as on the assessment of other than technical criteria. These are mainly the ecological and socio-economic criteria which should be analyzed in detail. Case studies will be carried out based on the results of the initial research presented in this paper to obtain sufficient data for the methodology formulation.

Acknowledgment

The paper is based on a research undertaken within the research projects NAZV KUS QJ1220233 “Assessment of former pond systems with aim to achieve sustainable management of water and soil resources in the Czech Republic” funded by Ministry of Agriculture and COST LD11031 “Flood Characteristics of Small Catchments” funded by Ministry of Education, Youth and Sports. All the support is highly acknowledged.

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