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Original Research

Retrospective Evaluation of the Extent and Spatial Changes of Realized Hydromelioration Systems

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Abstract

Hydromeliorations cover a wide spectrum of activities aimed at more intensive and efficient use of land for agricultural production. In the Czech Republic (CR), agricultural land drainage has been implemented not only in lowlands in the vicinity of the lower reaches of watercourses but, to a large extent, in the central and upper reaches of watercourses in water spring areas. Drainage using systematic drainage systems was at its prime in the 1970s and 1980s. Its general implementation in Europe is hardly comparable. The database kept by the Agricultural Water Management Administration (AWMA) includes records on nearly 1,084,800 ha of drained land lots in the CR. However, this data is far from final. In a number of cases, the systematic drainage systems are close to the end of their service life. To search for and document the existing hydromelioration measures, it is necessary to make maximum possible use of supporting data, including original design documentation. Our article is dedicated to hydromelioration measures of the systematic drainage type constructed during the 20th century. In historic terms, these measures have a major impact on the landscape structure and related landscape functions.

Keywords: hydromelioration, agricultural land drainage, systematic drainage, design documentation

Introduction

Agricultural land drainage has an impact on the environment and hence on the landscape through changes made in space and time. Such changes are characterized by Spalinget and Smit [1]. These authors used the conceptual model of the agricultural land drainage effects on the environment to show that drainage changes the water regime. It also contributes to changes in the spatial distribution of pollutants and increases their concentrations in relation to the source, to their transfer from agroecosystems to aquatic ecosystems, and contributes to changes in the landscape structure (spatial fragmentation).

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Focusing on landscape changes in western south central USA, where wetlands have been drained on a massive scale by straightening river courses, the authors draw attention to degraded bank ecosystems and their transformation into an unstable and "simplified" aquatic environment, which calls for permanent [2]. Langhammeret and Vilímek [3] classify the extent of systematic drainage as one of the key indicators (besides long-term changes in the use and changes of the landscape cover, shortened river networks and river training). The EU's Water Framework Directive commits European Union member states to achieve at least good surface water status by 2015. Water quality in the rivers is influenced by the development of the whole catchment [4]. Jelínek [5] notes that hydromelioration measures were basically limited to drainage and watercourse training from the 1950s.

Defenders of drainage systems note that drainage in itself does not only have negative features, but the causes of swamping must always be identified and an appropriate drainage system selected. Even the "redundant" water in the landscape is of irreplaceable importance (floodplain forests, wetland ecosystems) [6].

Between the end of the 19th and 20th centuries, a large-scale melioration system was constructed, which entirely changed the character of the landscape [7].

Vašků [8] draws attention to the fact that at the beginning of the 20th century the term of hydromelioration included all reclamation, water management, and cultural-technical activities. The AWMA records covering only the drainage measures from 1959-89 show that in the Czech Republic there is 1,084,800 ha of land with drain-pipe drainage systems (of which 1,065,000 ha use systematic drainage amounting to 98.2% of the total surface of drained land plots); 14,166.6 km is covered by small watercourses and 11,712.4 km is covered by drainage canals (of which 7,203.5 km are open canals and 4,508.9 km closed canals, i.e. laid in pipes). Experts on hydromelioration agree that besides the previously mentioned recorded scope of drain-pipe drainage systems there is at least another 450,000 ha of drained agricultural land that has not been registered for various reasons [8]. The more detailed information on individual drainage systems (e.g. design documentations) has not been digitized. This documentation is stored in the AWMA archives and is not always complete. Without it, any purposeful action with regard to the existing drainage systems is virtually impossible [9]. Local failures or complete malfunctioning of the drainage (due to changed land management conditions, progressive erosion, unskilled or neglected maintenance, structural element aging, etc.), results in quantitative and qualitative changes in the water regime of entire river catchment areas [10].

Besides the aforementioned effects and technical problems related to drainage systems that keep gaining importance, the design documentation for these drainage structures is also a complicated issue. In 2011, the AWMA as an administrator of the central drainage system documentation was cancelled. Currently the agenda administered by the former AWMA is allocated to several organizations: it is partly administered by the state-owned companies of river management boards and Forests of the Czech Republic, and a greater part is in the hands of the Land Fund of the Czech Republic.

In 1990 the land ownership was changed by law while applying a principle that the drainage is physically a property of the landowner. During the privatization process, this principle was laid down in Act No. 92/1991 Coll. [11] on the transfer of state ownership to other entities, by which the state waived the previous investments and passed these investments on to the owners. At the same time, the state practically ceased to update the records of these water-related structures (see §12 of Regulation No. 139/2002 Coll. [12], and Annex 1 (4) and (2) of Regulation No. 7/2003 [13]).

Most of the modern drainage systems (since 1960) have failed to respect the division based on ownership. The drainage system always affects several land plots. Furthermore, these old systems are often overlapped by new systems, which make the situation even more complicated [10]. The fact remains that drainage is a major stabilization factor for the agricultural use of land and forms a substantial part of our agricultural landscape. The aging of the drainage systems is accompanied by phenomena such as the development of local swamps and water gushes on the surface [10].

Experimental Procedures

To perform the analysis of the drainage systems, a total of four model localities were selected (Fig. 1). The localities differ in terms of land use conditioned by different natural conditions and location within the CR. The common feature of all these localities is their history-based formation by agricultural activities. The areas represent landscapes intensively agriculturally farmed under different geomorphological conditions of the Dolnomoravský úval Graben – selected cadastre near Hustopeče and the Bohemian-Moravian Highland – the Žejbrostream basin, the areas along the water resource protection zone – the Maršovský Brook adjacent to the Hubenov reservoir and the area subject to special nature conservation and landscape protection regime – selected cadastres of the Železné hory Mts. Protected Landscape Area (PLA). The localities cover areas ranging from 40 to 140 km^2.

The crucial source of information on the implemented drainage system is the AWMA archives. These archives keep the design documentation for structures. A polygon drainage layer with the most important attributes (structure district number and year of construction) was applied for all the localities as the basic and, in principle, only source of digital data developed for the whole of the CR). Another source of information was archive documentation, i.e. design documentation that could be found in the AWMA archives in relation to the relevant localities and agricultural entities farming on the affected drained areas. The success rate in obtaining the necessary supporting data varied: complete design documentation was not found in any of the cases, in the locality of Hubenov no design documentation at all could be retrieved.

Fig. 1. Model locations in the Czech Republic.

Besides its very existence, another crucial characteristic is the form and condition of the design documentation. The quality depends on the age, i.e. the year of the hydromelioration measures implementation. In the analyzed localities, the construction period ranged from 1911-90 and the form of the design documentation (Fig. 2) experienced considerable changes in the course of nearly 100 years.

The analysis of the hydromelioration structures took place in several steps:
- collection of input data – design documentation and digital vector layers (AWMA) of the hydromelioration measures
- transfer of the design documentation into a digital format (scanning)
- transformation of the scanner design documentation into a coordinate system
- analysis of AWMA data layer and created vector layer (according to design documentation) in the GIS environment

The transfer of the scanned documents into the coordinate system is a basic process that is crucial for evaluating the informative value of the supporting data. This is also related to the necessity of obtaining corresponding supporting data enabling the superimposition in the coordinate system. For the relevant model localities, the historic data and map documents were collected and processed from the period of stable cadastre (1st half of the 19th century), from the 1950-60s, and from 2009. The data is the starting point for locating the hydromelioration measures in the coordinate system and for the analyses.

It was necessary to transfer the information contained in the raster-format projects into a digital vector layer compatible with the already existing drainage polygon layer processed by the AWMA. The vector layer of the drainage systems was superimposed over the design documentation raster in the form of polygons defining the shape and size of the plotted structures. Two digital vector layers were available for follow-up analyses: the drainage level according to the AWMA records and the actual drainage layout in the form of the developed vector layer showing the drained area according to the plotting in the design documentation.

Results

According to the initial supporting data – AWMA records, the localities of Hustopeče and Železné hory Mts. feature the lowest drainage rate (12.0 and 12.6% of the total area). In the locality of Hustopeče, this situation is mainly due to natural conditions predetermining the area for implementing hydromelioration measures related to irrigation rather than drainage. What is also worth mentioning is the fact that a large part of the hydromelioration measures was implemented here as early as the beginning of the 20th century. In contrast, the PLA of Železné hory Mts. with less than 13% of the drained area can still be called an intensively drained area (given the high proportion of forest communities and low proportion of agricultural land). Regarding the status of the strictly protected area, it would be desirable to eliminate oversized and improperly implemented drainage systems and bring these pieces of land closer to their natural conditions. The highest drainage rate is achieved in the model locality of Žejbro (almost 29% of the land), which is conditioned by the character of the land and major over-sizing of the measures. Compared to the Žejbrostream basin, the Hubenov water

Fig. 2. Example of the archive document related to the hydromelioration measure (design documentation) – locality of Javorné.

reservoir catchment area is much less affected by the hydromelioration measures (approx. 13% of the total area) (Fig. 3). In terms of water resource protection, this is a positive circumstance.

In the district of Hustopeče, principally all drainage (64%) was implemented before the year 1960. Compared to this, the remaining 3 model localities show a similar course of implementation. Before the considered period, a minimum number of measures was completed in the individual localities. In the district of Hubenov, only 5% of measures were implemented before 1960. In Žejbro, it is 11%. As regards the Železné hory Mts. PLA, it is 11.5% of drainage structures. The model localities, with the exception of Hustopeče, were exposed to a wave of relatively modern drainage system implementation (Fig. 4).

As regards the number of drainage systems implemented in the individual years (Fig. 5), the model locality of the Žejbrostream basin is dominant. During 1979 a total of 84 drainage measures were implemented here (based on the AWMA records). The maximum number of the measures implemented in the individual years in Hubenov, Žejbro, and Železné hory Mts. range from 40 to 70.

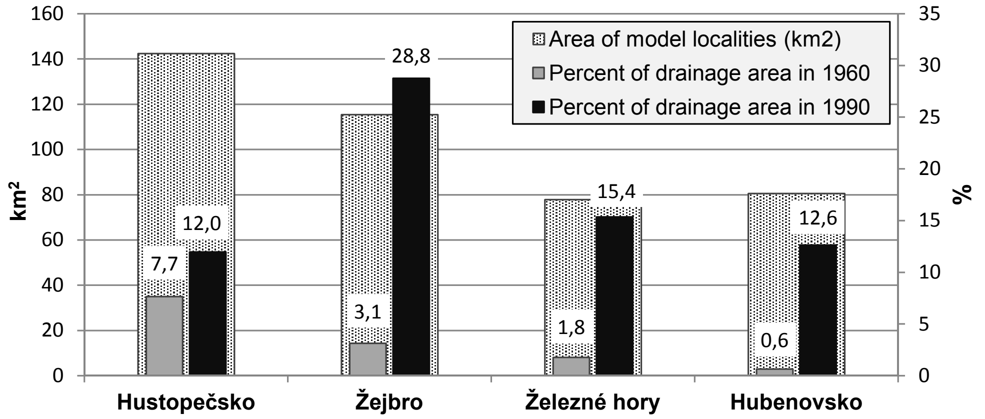

Fig. 3. Drainage in the individual model localities (comparison in percent as related to the total area of the model localities); Source: AWMA.

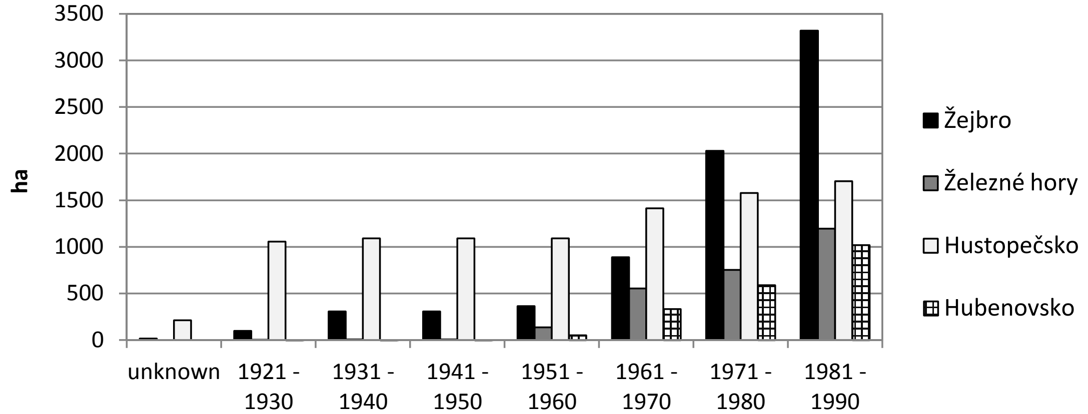

Fig. 4. Development in the size of drained areas in the model localities over decades; Source: AWMA.

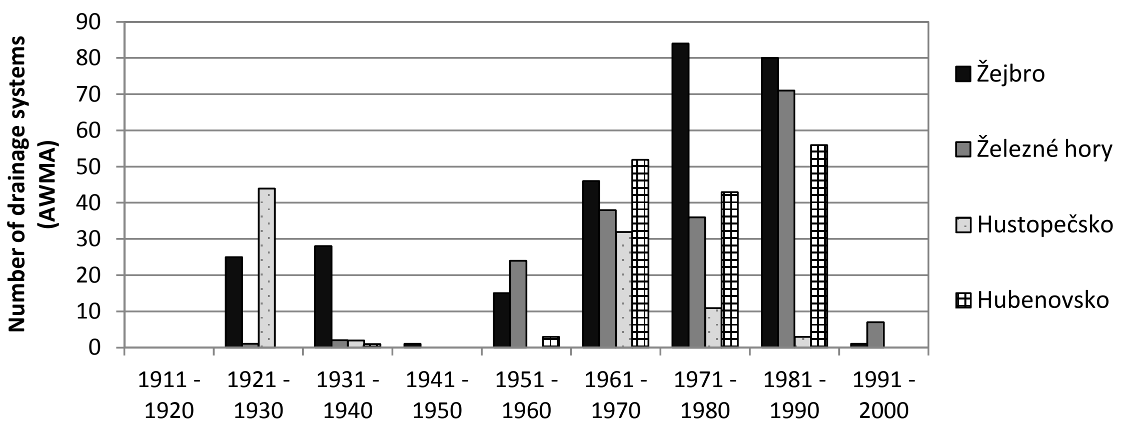

Fig. 5. Number of drainage systems constructed in the respective decades in the model localities; Source: AWMA.

With the exception of the district of Hustopeče, the maximum number of these drainage measures was implemented in the last decade, i.e. during 1980-90. Contrary to that, in the area of Hustopeče the drainage systems were constructed in two main waves. The maximum number was implemented in the period between the world wars and the second wave corresponds to the collectivization process and large-scale cultivation in the period 1960-70. The construction then continued on a smaller scale. The localities of the Železné hory Mts. PLA and Hubenov were almost exclusively drained only in the post-war period of agriculture socialization with a stable intensity in 1960-90. In the Železné hory Mts. PLA there was almost a double increase between 1980-90, which resulted from an extensive drainage of the whole of the Chrudimka River basin affecting both the Železné hory Mts. PLA and the Žejbrostream basin.

The data on the number of measures and the area covered over the individual years differ between the AWMA records and the design documentation. The processed vector layer of drainage measures (according to project documentation) does not contain all completed constructions. This is due to the fact that it was not possible to obtain the design documentation for each and every measure recorded by the AWMA (for reasons of incomplete archives) and also by the fact that with respect to the drainage measures located in the same area the project documentations do not agree as to the year of construction and in the attribute of vector layer of drainage structures according to AWMA. Overall, we succeeded in obtaining project documentations for ca 49% constructions in Žejbro, 72% in Železné hory, and 89% in the Hustopeče region. Even these incomplete data show that numerous draining systems for which we obtained the documentation are not comprised in the AWMA layer, or differ in their spatial extent. At present, the only applied drainage system supporting data is quite inaccurate and does not include all the hydromelioration measures. Figs. 6 and 7 show the development of the drained area and the numbers of executed constructions according to the completed design documentation.

In the Žejbrostream basin, Železné hory Mts. PLA, and Hustopeče our detailed analysis identified drained areas that are not included in the AWMA database, but are included in the design documentation (Fig. 8).

The greatest differences were determined in the locality of Hustopeče where, following analysis, we identified 23% more of the drained areas (396 ha of drained areas) not plotted in the AWMA layer. The situation is similar in the model locality of the Železné hory Mts. PLA, where the total drained area increased by almost 22% (259 ha have

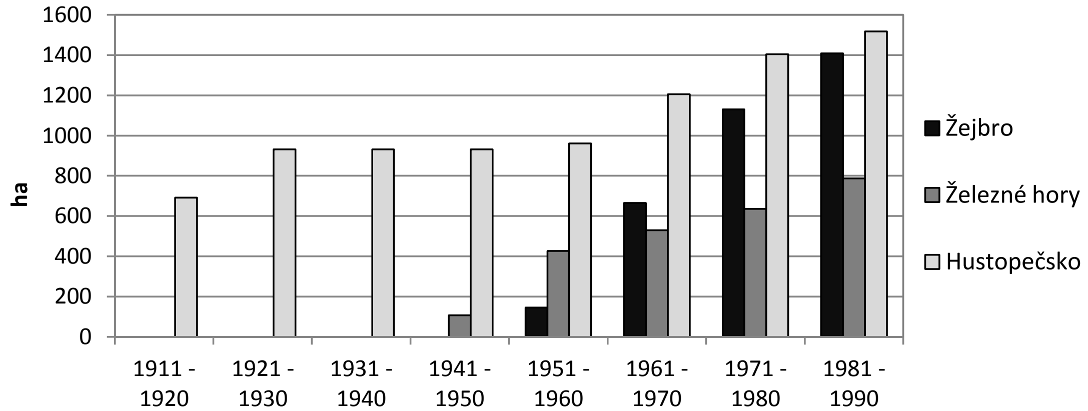

Fig. 6. Development of drained areas in the model localities over decades; source: authors (vector layer created according to the design documentation).

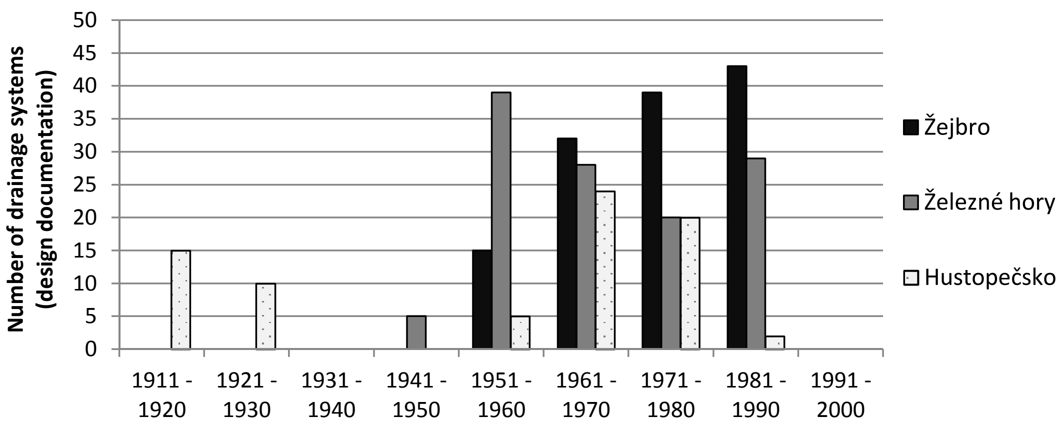

Fig. 7. Number of drainage measures implemented in the individual decades in the model localities; source: authors (vector layer created according to the design documentation).

Table 1. The size of drained areas according to the AWMA and after the update from design documentation; source: AWMA and authors (vector layer created according to the design documentation).

	Žejbro	Železné hory	Hustopečsko	Hubenovsko
Area of model territory [ha]	115,542	7,782	14,234	8,050
Drainage according to AWMA [ha]	3,319	1,196	1,703	1,017
Updated drainage area [ha]	432	259	396	*
Total drainage area after update [ha]	3,751	1,455	2,099	1,017
Total drainage area after update [% of model territory]	3.2	18.7	14.7	12.6

*no design documentation

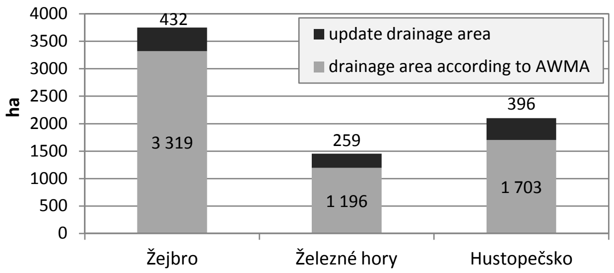

Fig. 8.The size of drained areas according to the AWMA and the addition of missing areas according to the vector layer from design documentation in the model locations.

not been included yet) after comparing the extent of the drainage systems. In the Žejbro stream basin the increase is by 13% of the drained areas (432 ha). The analysis shows that the generally used AWMA layer (database) is quite inaccurate and a major percentage of the hydromelioration measures are not included in the database at all (Table 1, Fig. 9).

In addition to the discrepancies found in the reported years of construction, there are also significant differences in the parameters of space, shape, and, in a number of cases, geography of the drained areas. The shape-related characteristics of both the analyzed layers demonstrate how the layer of the drained areas according to the AWMA can be affected by inaccuracies caused by the processing method. As expected, this layer cannot achieve a fine shape plotting comparable to the plotting according to the design documentation. This corresponds to the shape index value (Fig. 10) in the individual localities where the greatest shape variety is achieved by drainage systems according to the design documentation in the locality of Hustopeče. Drainage systems of comparable shape variability according to the project documentation are constructed in the Žejbrostream basin, where there is also the greatest difference between the shape index of these measures and measures according to the AWMA records. This fact holds true for all the analyzed localities with some smaller differences in the Železné hory Mts. PLA. This may be explained by the character of the locality, which is topographically more

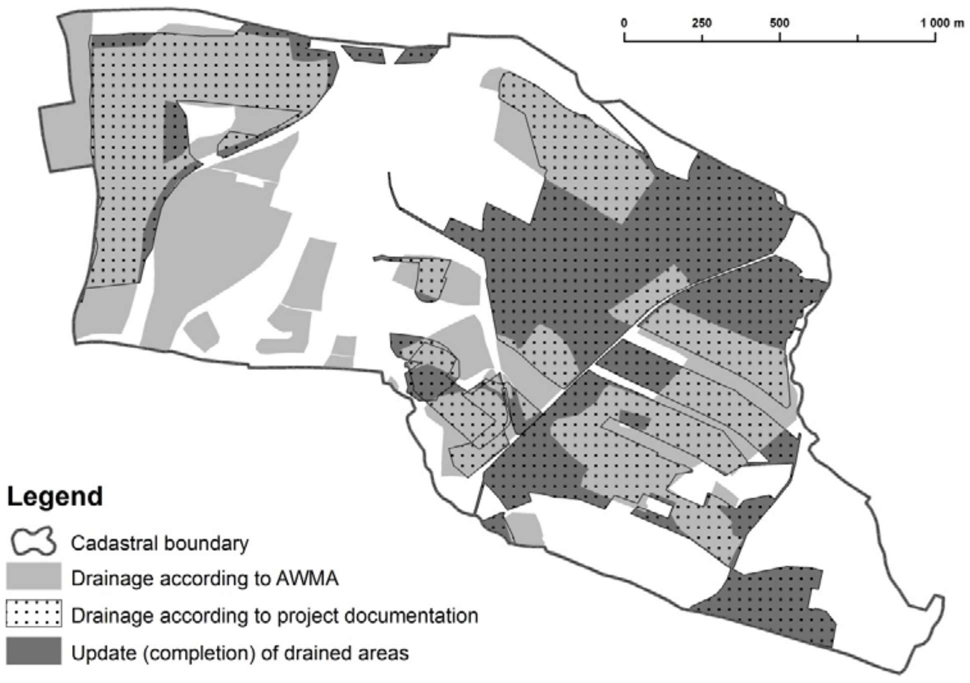

Fig. 9. Example of differences in area drainage according to the design documentation (created vector layer) and according to the AWMA data – the model locality of Žejbro, selected cadastral district of Radčice u Skutče.

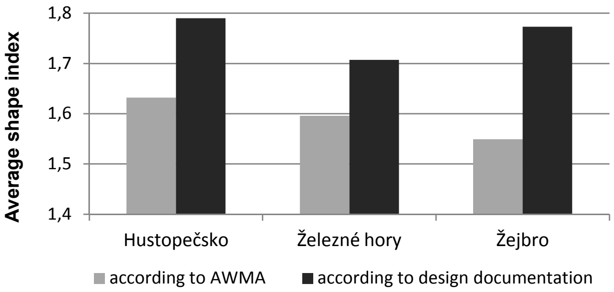

Fig. 10. Comparison of the average drained area shape index according to the AWMA records and the vector layer from design documentation in the model localities (shape irregularity increases with increasing value).

rugged and where agricultural land is not dominant. This is also reflected in the character of the drainage systems.

Discussion

Relatively significant changes in the record-keeping of hydromelioration measures occurred in the 1990s. The constructed drainage systems were transferred to landowners along with the relevant design documentation. These circumstances triggered the process of gradual degradation, leading to complete liquidation of the design documentation. A similar process can be observed in the case of archives formerly administered by the AWMA (canceled in 2012). Potential use of the archive materials and handling of these materials is demanding in terms of time, manpower and funds, and has an uncertain result – the incomplete archives do not guarantee the retrieval of the required project documentation. A 1:10,000 map represents the primary information layer with the plotted drainage systems. It is the basic information layer with a considerably outdated digitalized basis (situation in approx. 1992), entailing also other risks of credibility (method of processing, completeness). Digitalized plotting is made by means of a manual copying of the design documentation (usually on a scale of 1:1,000/2,000) into maps on a scale of 1:10,000, distortion in terms of shape and position. A lot of drainage systems are not include in the official AWMA vector layer (Hustopečsko – 396 ha, Železné hory Mts. PLA – 259 ha, Žejbro – 432 ha). These drainage systems were identified from original design documentation. There are not enough records concerning drainage systems of a higher age, constructed before the establishment of the AWMA (before 1970). Loss or damage of a part of the AWMA archives (during floods after 1997) and the departure of responsible staff, the knowledge of drainage systems in the region of the territorial workplace was not transferred to the new staff after 1992. There are a lot of incomplete supporting documents in the archives. All the above-mentioned facts have to be taken into consideration in the evaluation of any hydromelioration measures and their management, and it is necessary to consider the existing, not fully satisfactory, condition of the record-keeping and archiving of crucial documents related to drainage systems.

Conclusions

In spite of all the above-mentioned problems with finding information about implemented hydromelioration measures, the related record-keeping and the quality of supporting data, these measures must be dealt with in the future. The hydromelioration projects include a lot of important information about the real extent of drainage areas. Working with them is time-consuming, but the results are clear and useful. These projects are not important only as underlying documents for current measures taken in the landscape, but in a number of cases they are valuable for their historic worth and they should be treated as historic documents while efforts should be made to preserve them. The hydromelioration systems significantly influence water regime of the landscape. In many cases these constructions are almost at the limit of their viability and will require repairs, revision, or limitation or even abolishment of their function. The draining systems are often situated in areas covered with grass populations (see PLA Železné hory). At the time of their building, the proportion of arable land even in these localities with particular wildlife and landscape protection was much higher than at present. Today, these systems artificially dry up the permanent grass covers and pastures, and namely in the localities with specific nature protection this fact is not very positive. The unknown exact surface area and age of these constructions (according to the time of their building) will bring serious troubles in the future. Recently, major attention has focused on the issue of surface and underground water pollution with nitrates and phosphates. One of the sources of this pollution is agriculturally exploited land vulnerable to accelerated infiltration, in many cases drained by the draining systems. Therefore, most efforts should be concentrated on obtaining the best possible data on the extent of these constructions. The project documentation deposited in the archives may just be the solution to the above-mentioned problems and issues. The study presented in this paper shows clearly that the information layers used at present are not complete, and only processing of historic materials can lead to more precise localization of the extensive systemic drainage in the Czech Republic.

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