JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(2), 256–264
https://doi.org/10.12911/22998993/157020
ISSN 2299–8993, License CC-BY 4.0

Received: 2022.11.11
Accepted: 2022.12.16
Published: 2023.01.01

Identification and Database Creation of Selected Historic Irrigation Structures in the Czech Republic

Petr Karásek[1*], Igor Pelíšek[1], Michal Pochop[1]

[1] Research Institute for Soil and Water Conservation, v.v.i., Department of Land Consolidations and LandUse Planning, Lidická 25/27, 602 00 Brno, Czech Republic

* Corresponding author's e-mail: karasek.petr@vumop.cz

ABSTRACT

Since the 19th century, the irrigation industry on the territory of the Czech Republic has undergone considerable technological development and an increase in irrigated areas. Irrigation has become an important part of the Czech landscape. Large complex irrigation systems of tens to hundreds of km^2 have been built. Towards the end of the 20th century, there was a significant decline due to the change of political regime, abolition of agricultural companies, etc. Irrigation systems and buildings were often destroyed, devastated, left without maintenance. There have also been several changes in the administrative management of the irrigation sector. The consequence was that there was no single database of irrigation systems. At present, a database of these irrigation systems is being compiled by the Research Institute for Soil and Water Conservation using geographical information systems (GIS). In connection with climate change, the threat of drought, and irregular distribution of precipitation during the growing season, and the issue of irrigation are back on trend. In this study the current state of irrigation systems in the Czech Republic was presented. In the Czech Republic, a total of 175115 ha of irrigation area has been recorded so far (of this area, about 41% is currently in functional). Selected historic irrigation structures were documented by unmanned aerial vehicles (UAV).

Keywords: irrigation; irrigation system; melioration; UAV; aerial photography; database; GIS.

INTRODUCTION

Melioration, i.e. the regulation of watercourses and the construction of irrigation systems, is an important way of managing water in the landscape. Evidence of the construction of protective dams around watercourses as a means of protecting agricultural land against periodic flooding dates to the 18th century, but the mass establishment and construction of irrigation systems in the Czech Republic did not fully develop until the 19th century (Beranová et al., 2010). The maintenance of sufficient agricultural production gradually necessitated the need to modify and regulate the water regime in the soil. Thus, from the mid-19th century onwards, the development of so-called water melioration began to accelerate. Their visual manifestation is the regulation of watercourses, drainage of waterlogged areas or bringing water to areas where there is a lack of moisture (Poláček et al., 1927). The revolutionary changes in owned property and agricultural land (collectivization of agricultural in the second half of the 20th century – the emergence of unified agricultural cooperatives), as well as the gradual promotion of central planning, had a major impact on the significant development of irrigation structures. The historical context of the administration of hydromelioration structures is part of the publication (Kulhavý et al., 2017). Many historical irrigation structures (often no longer in function) can be considered a type of cultural heritage. This is a sector of industry and agriculture that has made a significant impact on the landscape of the Czech Republic (Hudcová et al., 2021). Identification of historical irrigation structures allows for their reconstruction and restoration if necessary (Karásek and Pelíšek, 2022).

The number of irrigation structures built in the Czech Republic is estimated at about 1,000, with an estimated total area exceeding 180,000 ha. These include mainly irrigation of field crops, vegetables, and fruit, as well as irrigation for forestry purposes and, only marginally, irrigation of urban parks and other irrigation applications in intravillages and greenhouse farms. The system operated in this way until the early 1990s, when the agricultural cooperatives and state farms broke up or were transformed. The new owners were often not interested in maintaining the irrigation facilities, which were destroyed by theft and vandals.

Historical irrigation systems, which originated in the Czech Republic mainly in the second half of the 19th and the beginning of the 20th century and then from the 1960s onwards (Dvořák et al., 2004), gradually came to the forefront of interest. This is in terms of assessing the potential for their renewal, reconstruction, or, conversely, the removal and replacement of a modem functional system. For newly constructed and reconstructed irrigation systems, the use of modern technologies is currently recommended, including irrigation management based on the moisture requirements (moisture balance) of the crops grown (Cahn and Johnson, 2017) and the use of satellite data to monitor soil moisture status and crop development during the growing season (Pereira et al., 2015; Pôças et al., 2015; Drerup et al., 2017; Bois et al., 2008).

The predicted climate change resulting from global warming is also affecting the climate of Europe and the Czech Republic by increasing the incidence of drought. In general, the importance of irrigation has been growing, especially in the last decade, in connection with climate change and the increased need to use irrigation (Seidel et al., 2016). Results (as early as around 2000) have signaled that global warming is a serious problem requiring increased attention in the country as well. One of the most important results of the analyses is the recommendation to regularly increase the area of irrigation and the capacity of the required water resources, to promote the reconstruction or construction of efficient irrigation systems (Spitz et al., 2001), which is also documented for Central European (or German) conditions by Riediger et al. (2014). Irrigation systems should be highly efficient in the future, optimized for specific conditions and crops. They should also put as little strain as possible on existing water resources. Therefore, it is advisable to capture the maximum amount of rainwater in dams and reservoirs. This water can then be used for efficient irrigation. Alternatively, pre-treated wastewater can be used in irrigation. Their potential use has been addressed in a study addressing the potential use of pre-treated wastewater for irrigation of agricultural crops in the EU. It is concluded that the use of pre-treated wastewater can mean average irrigation coverage of around 10%, in the regions with intensive irrigation (Pistocchi et al., 2018).

METHODOLOGY AND DATA

Identification of irrigation structures

Considering the time of implementation of most irrigation structures, the identification of irrigation structures and individual objects was carried out from available map sources in raster and vector form. Furthermore, the data from publicly accessible databases (Ministry of Agriculture of the Czech Republic, State Land Office, etc.), original project documentation, archival records, images taken by unmanned aerial vehicles (UAVs), and field survey, were used.

Identification of historic irrigation structures was made using historical maps, archival records, old topographic maps from various periods of the 20th century, plans and site drawings from available sources from various time periods of the 20th century, historical and contemporary aerial photographs, and UAV imagery. For selected sites, it was possible to use original design and technical documentation (Fig. 1) made available for inspection from the archives of selected government departments. Geographical information systems (GIS) were used to identify the objects. The location of the irrigation structures was plotted in the geodatabase in the S-JTSK coordinate system. The current vector layer ZABAGED® ČÚZK, ZM10 was primarily selected for locating the objects.

UAV mapping of current state of the selected irrigation structures

Selected localities with historical and present irrigation structures were photographed by UAV. The purpose was to survey the current state of these systems. A drone operated at the Research Institute for Soil and Water Conservation,

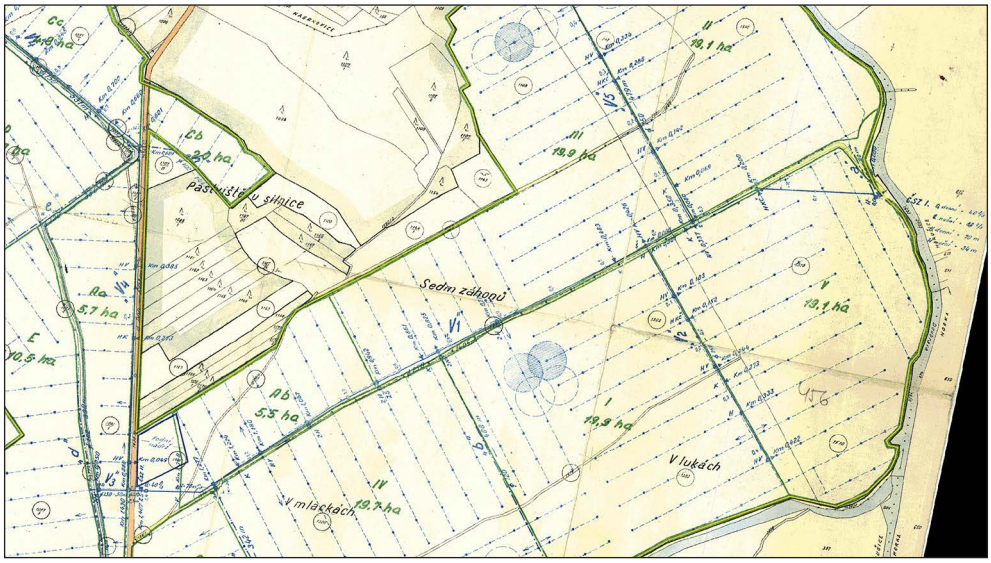

Figure 1. Example of historical project documentation of irrigation constructions

specifically the DJI Mavic 2 Pro type with a 4k camera and a maximum photo resolution of 5472×3078 pixels.

Figure 2 shows an example of a possible interpretation of the data obtained. This is the irrigation system Uherčice (South Moravia). From the original project documentation, vector layers in GIS are processed, showing the course of individual elements of the drainage system. Photographs of individual objects are also added, including overview photographs from a drone.

RESULTS

Current state of irrigation systems in the Czech Republic

Currently, the database of historical and current irrigation structures in the Czech Republic (including the area of irrigated areas) contains approximately 175115 ha (2.2% of the total area of the Czech Republic; 4.2% of the area of agricultural land) (see Fig. 3). Included are mainly

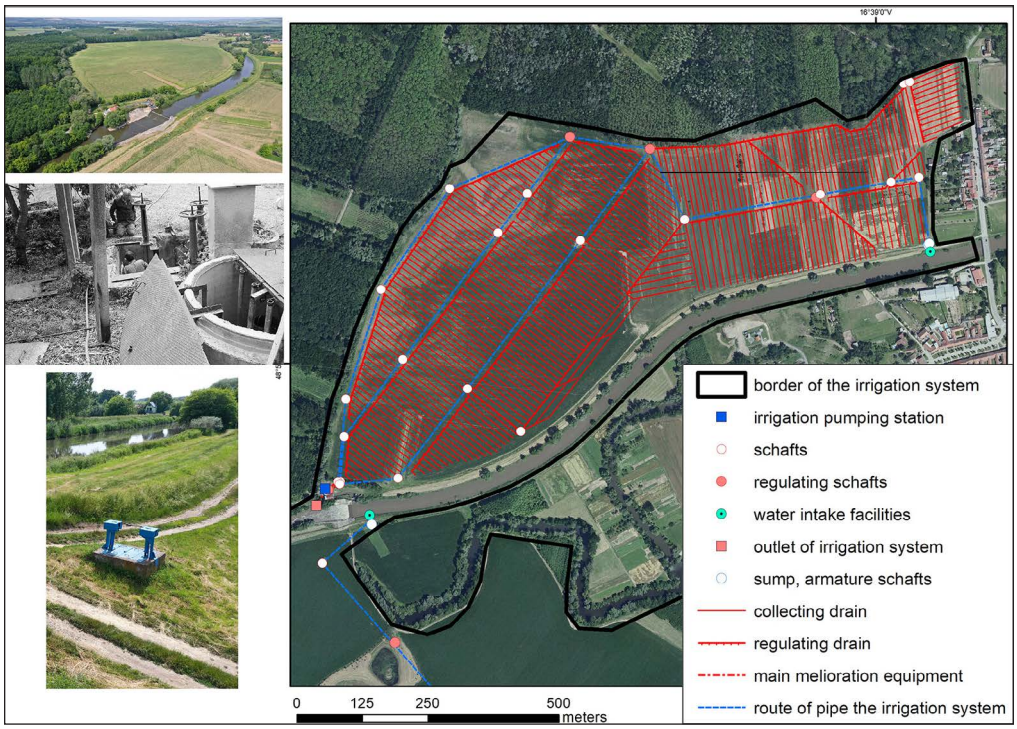

Figure 2. Example of map output of the irrigation system Uherčice (South Moravia)

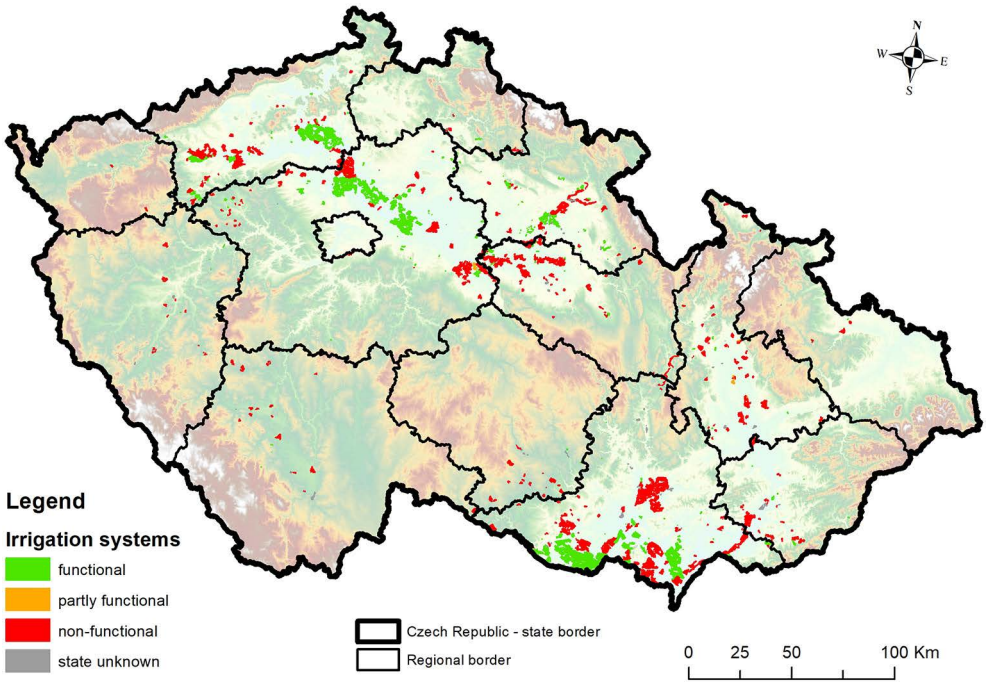

Figure 3. Current state of irrigation systems in the Czech Republic

irrigation of field crops, vegetables, and fruit, as well as irrigation for forestry purposes and only marginally irrigation of urban parks and other irrigation applications in intravillages and greenhouse farms. This figure is based on a detailed analysis of the available data and the ongoing consolidation and processing of data in the context of research activities and studies (for the Ministry of Agriculture, the State Land Office, etc.) for the period 1750 to 2021. However, the total estimated area will be higher and may reach up to 180 000 ha.

On the basis of analyses, communication with irrigation operators, and a field survey, it was found that approximately 41% of these irrigation systems are currently at least partially in operation.

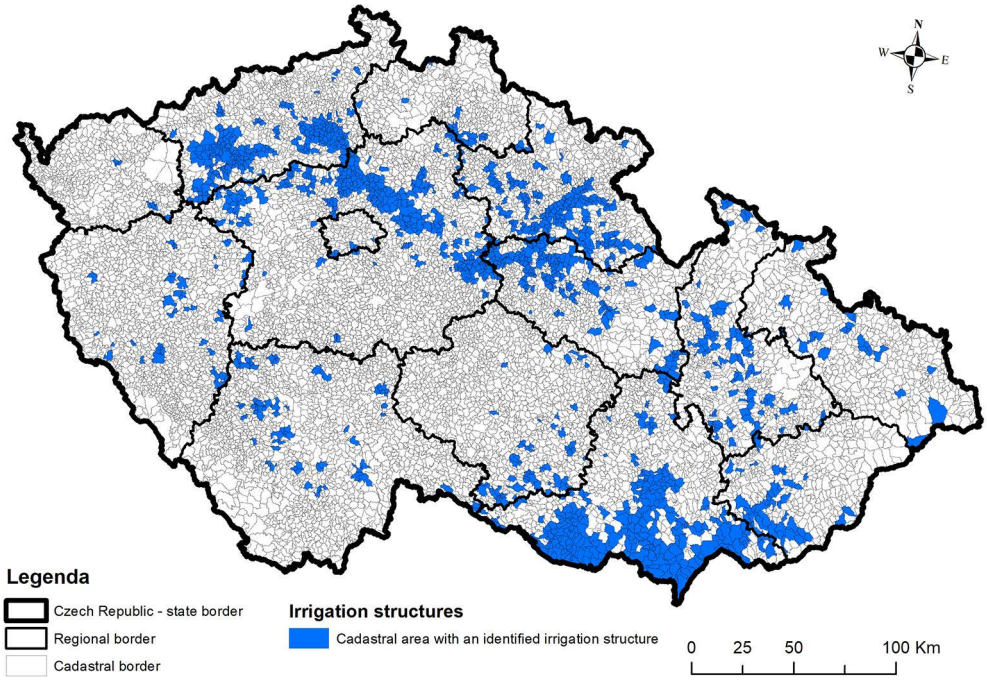

Figure 4. Cadastral areas in the Czech Republic with an identified irrigation structure (functional or non-functional)

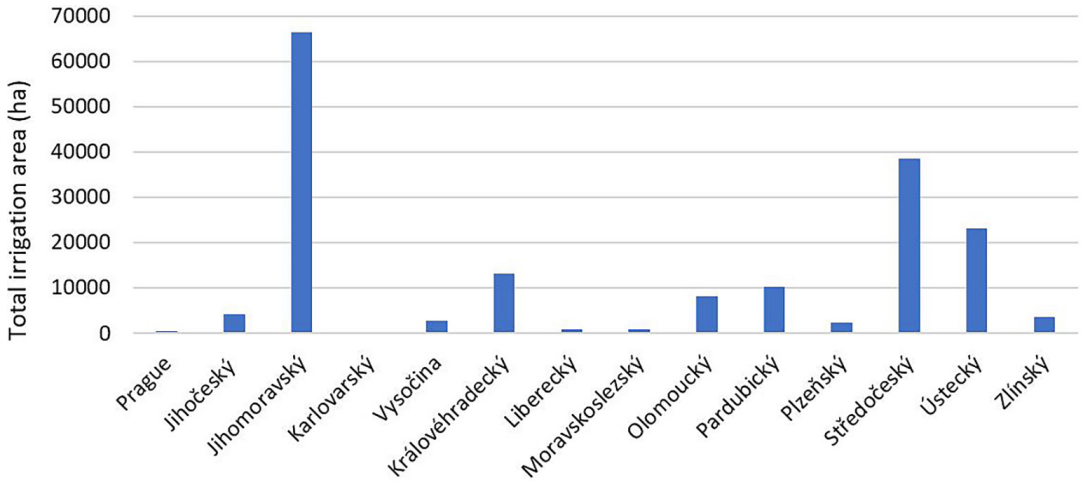

Figure 5. Irrigated area in the regions of the Czech Republic

Depending on the conditions of specific areas, irrigation systems vary in size and technical complexity, from the simplest methods of design and operation to very sophisticated and extensive irrigation systems.

Currently, there are a total of 13076 cadastral territories registered in the Czech Republic. Irrigation structures are (or were in the past) present on 1500 cadastral territories. This is a total of 11.5% of all cadastral areas (Fig. 4).

The maps show the targeted construction and presence of irrigation structures in warm and dry regions that need irrigation of field crops the most. These are mainly the regions of South Moravia (Jihomoravský), Central Bohemia (Středočeský) and Ústecký region (Fig. 5). These are the regions most affected by drought. This was most evident in the dry years of 2014–2015, when yield losses of up to 40% of field crops were common.

The results of the analyses and field surveys carried out in the period 2016–2022 revealed the following findings on the condition of irrigation systems in the Czech Republic. The irrigation systems in the Czech Republic, built in earlier years before 1993, are at the limit of their service life, especially in terms of the condition of pipe systems. Most of the large irrigation systems in the Middle Elbe region and in southern Moravia remain in operation.

Age of irrigation systems and their functionality

Within the financial and technical possibilities, irrigation operators are renewing pipe networks using new materials. Investment is also being made in other major equipment (pumping stations, irrigation water reservoirs). More than 50% of the irrigation structures that have been constructed so far and a small number that have disappeared are in various stages of modernization and operation. However, the situation is worse for the older irrigation structures that are not in operation; in most cases, all the technical facilities of these structures are missing, and their destruction has been caused mainly by the theft of technical elements and, in the case of buildings, by neglected maintenance or, again, by vandalism or the use of building materials (Fig. 6). Non-functioning pumping stations are often destroyed, and irrigation water reservoirs are overgrown with vegetation. Non-functioning pipes in the ground and manholes with intake objects are often destroyed or damaged.

The age of irrigation structures in the Czech Republic can be indicatively stated as follows: 18% of the structures were built before 1969, i.e. their age is about 50 years or more, 20% of the structures date from the period 1970–1974, i.e. their age is about 50 years, 13% from the period 1975–1979, i.e. their age is about 45 years, 16% from the period 1980–1984, 18% from the period 1985–1990, i.e. their age is about 35 years, 13% after 1990, i.e. their age is up to about 30 years. These numbers are indicative and partly include the renovation of facilities, not including derelict buildings and buildings not yet inspected. The normal situation in many locations includes 2 to 3 generations of irrigation facilities, in some locations 5 generations have been recorded during development.

Figure 6. Non-functional and abandoned irrigation water filling stations and water reservoirs (Brandýs nad Labem)

The investments in the construction of irrigation facilities in the whole country amount to hundreds of billions of CZK. However, these investments are often left to their own fate. The monitoring campaign has documented many non-functional irrigation structures.

Creating a database of irrigation structures

For the purposes of evidence of irrigation structures in the Czech Republic, the Research Institute for Soil and Water Conservation in cooperation with the Ministry of Agriculture of the Czech Republic has developed a web application called – Information System of Melioration Structures (https://meliorace.vumop.cz). The web application is available on the Geoportal of the Research Institute for Soil and Water Conservation. This web application has been continuously updated and supplemented with the latest knowledge and materials related to irrigation systems in the Czech Republic since 2016. The system software of the servers consists of a standard Microsoft Windows Server operating system, the functions of the Internet server are provided by IIS 10.0. The project web pages, into which the database is integrated, use HTML (Hypertext Markup Language), ASP (Active Server Pages), CSS (Cascading Style Sheets) and JavaScript technologies. The data is published from source files in SHP (shapefile) geodatabase format, and the user interface is used to display and interact with the user via a web browser. The web application is currently localized only in Czech language.

Irrigation system Krhovice - Hevlín

The Krhovice - Hevlín irrigation system was documented in detail to demonstrate a complex and functional irrigation system (Fig. 7). It is a large-scale functional irrigation system in South Moravia.

This irrigation system consists of the main irrigation canal, which receives water from the river "Dyje" at the weir near Krhovice and transports it to individual irrigation pumping stations, or the water is pumped to other sections of the irrigation system with accumulation water stations (Fig. 8).

The irrigation canal is fed from the Dyje River and the Vranov water dam is an important water reservoir. The irrigation canal Krhovice - Hevlín was built between 1949 and 1954. It is 15 kilometers long and is partly cut into the terrain, partly created by a hopper. The bottom and walls were fortified with concrete slabs. Underpasses were built along the canal route at the crossings with the road network. Reinforced concrete aqueducts were built in several places. The entire main system is equipped with sluice gates at the points necessary to regulate the flow or to shut down selected sections. The system is also provided with lateral spillways to relieve excess flow. The main irrigation canal Krhovice - Hevlín is connected to two feeder canals built in 1966, which strengthen the water distribution. The irrigation area in 1966 was 6 000 ha, and further large sections were built until the 1980s. From a technical and historical point of view,

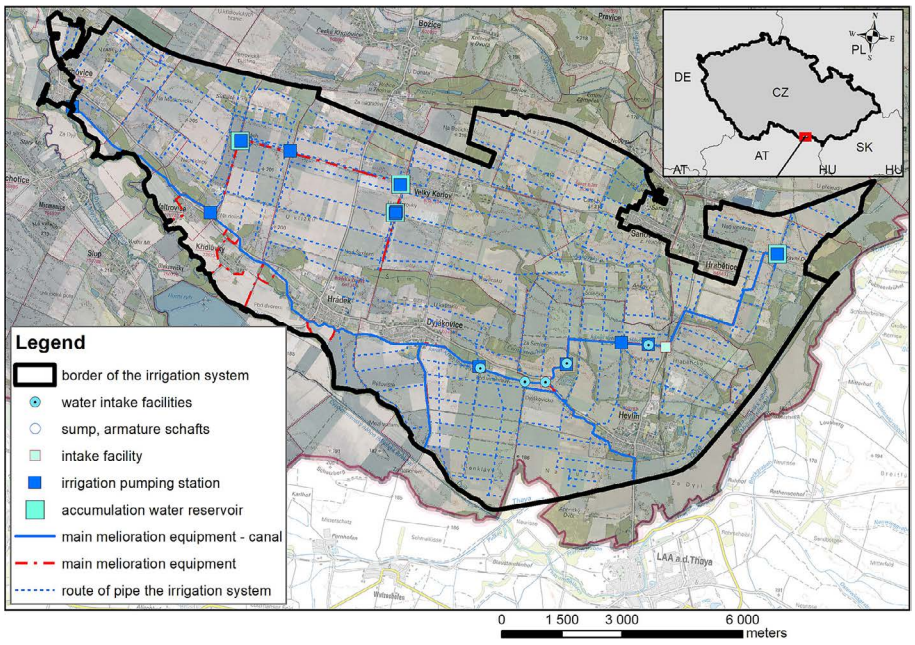

Figure 7. Overview map of the irrigation system Krhovice - Hevlín (current state)

Figure 8. Water reservoir and water filling station (up), regulation device on the irrigation canal Krhovice-Hevlín (middle), historic aqueduct on the Krhovice-Hevlín irrigation canal (down)

Figure 9. Wide irrigation "pivot" machine (up) and belt sprinkler in the irrigation system Krhovice - Hevlín

the use of a wide range of irrigation technologies (irrigation with belt sprinklers, wide pivot machines, drip irrigation) is important (Fig. 9).

The irrigation system Krhovice - Hevlín represents a unique set of irrigation structures, which has been operated under the conditions of the arid region of Znojmo city in its entirety up to the present day. The operation of this large-scale irrigation system clearly demonstrates the necessity of irrigation in similar conditions; it is, among other things, a necessary condition for the quality and regional production of vegetables, fruit, wine, etc.

The future of irrigation systems in the Czech Republic

Currently, fruit and vegetable growers are particularly interested in irrigation. Irrigation of cereals, maize and hops is carried out in dry areas. The present and future of irrigation is also determined by the need for irrigation and territorial development (settlements, infrastructure). At the same time, however, it is in the interest of the State to ensure food self-sufficiency and manage agricultural land in accordance with sustainable development.

From a review of the age of the original structures and some of their equipment, the irrigation systems will face obsolescence and necessary renewal in the future. The re-commissioning of older types of structures is also realistic, of course with appropriate structural and technical modifications. The possible use of older buildings and irrigation methods requires bringing them into line with modern land management practices. The use of new, more modern technologies (modern and more energy- efficient pumping station equipment, newer wide irrigation "pivot" machine, new generation of belt irrigators, drip irrigation) is essential. However, these technologies already exist and there is a lot of active research going on within the sector.

CONCLUSIONS

Irrigation is necessary to ensure agricultural production in dry areas, for water supply during longer periods of drought during the year, but also for water supply during shorter periods of drought, interfering with critical stages of plant growth. Irrigation serves in balancing environmental conditions, so that it has a positive effect not only on intensification of production but also on its stabilization. Irrigation can also help

to target optimal or even inexpensive delivery of nutrients and protectants directly to the plants. According to more recent terminology, irrigation is an effective adaptation measure. For the future, these are measures that respond to the effects of climate dynamics, but also to the effects of other factors, in particular the need to use land more efficiently and to ensure food self-sufficiency. The irrigation sector has a long tradition in the Czech Republic. The Research Institute for Soil and Water Conservation has been dealing with irrigation issues for a long time. One of its activities is the creation of a database of the areas with currently functional or historically non-functional irrigation (including related infrastructure). This database is available as an interactive web application on the website https://meliorace.vumop.cz. The results of the analysis show a significant degradation of the entire irrigation sector from the end of the 20th century to the present. Today, only about 41% of the areas where irrigation systems were built in the past are at least partially functional. The creation of a database is important in terms of understanding our history, the cultural value of the sector and for future restoration. Due to climate change, an increased need for irrigation of field crops, fruits, vegetables, and other agricultural commodities can be expected in the future.

Acknowledgements

The research was financially supported by the research project DG20P02OVV015 NAKI II Ministry of Culture of the Czech Republic „lrrigations - rediscovered heritage, their documentation and popularization", and institutional support No. MZE RO0218.

REFERENCES

1. Beranová, M., Kubačák, A. 2010. History of agriculture in Bohemia and Moravia. Libri, Prague.
2. Bois B., Pieri P., Van Leeuwen C., et al. 2008. Using remotely sensed solar radiation data for reference evapotranspiration estimation at a daily time step. Agricultural and Forest Meteorology, 148 (4), 619–630.
3. Cahn, M.D., Johnson, L.F. 2017. New Approaches to Irrigation Scheduling of Vegetables. Horticulturae, 3, 28.
4. Hudcová, et al. 2021. Irrigations as a part of the rediscovered industrial heritage of the Czech Republic: Identification, documentation, and popularization. In Fialová J. (ed.) Public recreation and landscape protection - with sense hand in hand! Křtiny: Mendelu..
5. Drerup, P., Brueck, H., Scherer, W.H. 2017. Evapotranspiration of winter wheat estimated with the FAO 56approach and NDVI measurements in a temperate humid climate of NW Europe. Agricultural Water Management, 192, 180–188.
6. Dvořák, P., Šálek, J., Janský, L. 2004. History of irrigation, drainage, and flood control in Czechoslovakia in the Danube Sasin. ln: Danube Valley: history of irrigation, drainage, and flood control. ICID-CIID, New Dehli, 311–322.
7. Karásek, P., Pelíšek, I. 2022. Identification and drone aerial photography of selected historic irrigation structures in the Czech Republic. In Fialová J. (ed.) Public recreation and landscape protection - with environment hand in hand. Křtiny: Mendelu, 9, 177–181.
8. Kulhavý, Z., Pelíšek, I. et al. 2017. Procedures for achieving the sustainability of hydromlioration measures in the conditions of the Czech Republic. Methodology.
9. Pereira, L.S., Allen, R.G., Smith, M., et. al. al. 2015. Crop evapotranspiration estimation with FAO56: Past and future. Agricultural Water Management, 147, 4–20.
10. Pistocchi, A., Aloe, A., Dorati, C., Alcalde Sanz, L., et al. 2018. The potential of water reuse for agricultural irrigation in the EU. A Hydro-Economic Analysis, EUR 28980 EN, Publications Office of the European Union, Luxembourg.
11. Pôças, I., Paço, T.A., Paredes, P. et al. 2015. Estimation of Actual Crop Coefficients Using Remotely Sensed Vegetation Indices and Soil Water Balance Modelled Data. Remote Sens., 7, 2373–2400.
12. Poláček, J., et al. 1927. Forty years of activities of the Provincial Agricultural and Technical Office in Moravia 1887–1927. Brno 1927.
13. Riediger, J., Breckling, B., Nuske, R.S., Schröder, W. 2014. Will climate change increase irrigation requirements in agriculture of Central Europe? A simulation study for Northern Germany. Environmental Sciences Europe, 26, 18.
14. Seidel, S., Werisch, S., Barfus, K., et. al. 2016. Field evaluation of irrigation scheduling strategies using a mechanistic crop growth model. Irrig. and Drain., 65, 214–223.
15. Spitz, P., Filip, J. 2001. Irrigation needs under predicted climate change in the Czech Republic. In: Rožnovský, J., Janouš, D. (ed). Workshop, Brno 2001.