ASSESING ADAPTATION MEASURES IN A SELECTED 4TH ORDER WATERSHED

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Abstract

The aim of this study is to propose and evaluate adaptation measures within the selected 4th order watershed (4-15-03-104). The primary goal of these proposed measures is to stabilize the water regime in the landscape and manage extreme hydrological phenomena, as well as to mitigate erosion risks in the territory. This approach aims to create a harmonious landscape aligning with the fundamental principles of sustainable development. Prior to the proposal, the territory underwent a detailed analysis based on available data and field reconnaissance. The research compares two variants with the current state of the landscape. Variant 1 utilizes historical maps as a foundation, while variant 2 incorporates measures designed to optimize the landscape in response to ongoing climate change.

Keywords

Adaptation measures, critical points, erosion, historical changes in land use

1 INTRODUCTION

Hydrological extremes are becoming increasingly frequent and a significantly modified landscape cannot sufficiently withstand these extreme phenomena. Within the Czech Republic, there is not even a small piece of landscape that has not been touched by man. We are not only talking about direct impacts, but also secondary impacts, for example light smog or atmospheric pollution. People altered the landscape for practical reasons, such as improving mills (sawmills and hammer mills), facilitating timber shipping, drainage of swamps but also for creation of ponds. Nowadays, knowledge of changes in the landscape can help us to design adaptation measures. On historical maps, we can read whether there was a former pond at the site of the future construction, or whether in the past people tried to forest or grass the prominent path of concentrated runoff. Locating old water mills can tell us about the water level of a given stream, while old maps can reveal the places of the original channel of a straightened stream.

2 METHODOLOGY

This scientific paper is part of a larger work, when an area of interest was selected based on local conditions. The area of interest was the 4th order basin (4-15-03-104) which is located in the territory of nine municipalities (especially in four of them – Sokolnice, Telnice, Kobylnice and Měnín). The exact areas are shown in Tab. 1. The main water stream is Říčka (Zlatý potok, IDVT 10100107) [1]. In terms of water quality, the stream is heavily polluted. The name Zlatý potok is used for this stream from the confluence with the Roketnica near Ponětovice. The subcatchment was defined as a smaller area for the calculation of runoff conditions for two variants, but also within the framework of the erosion risk comparison (Fig.1). The main reason for the delineation was the identification of a critical point (criteria for identification see below [2]) in connection with the prominent path of the concentrated runoff, visible on aerial maps.

Tab. 1 Municipalities with the largest area in the studied region.

Name	Municipality code	LAU 1	Area (km^2)
Sokolnice	583898	Brno	5.4
Telnice	583979	Brno	4.4
Kobylnice	583219	Brno	4.3
Měnín	583383	Brno	2.6
Prace	583685	Brno	0.7

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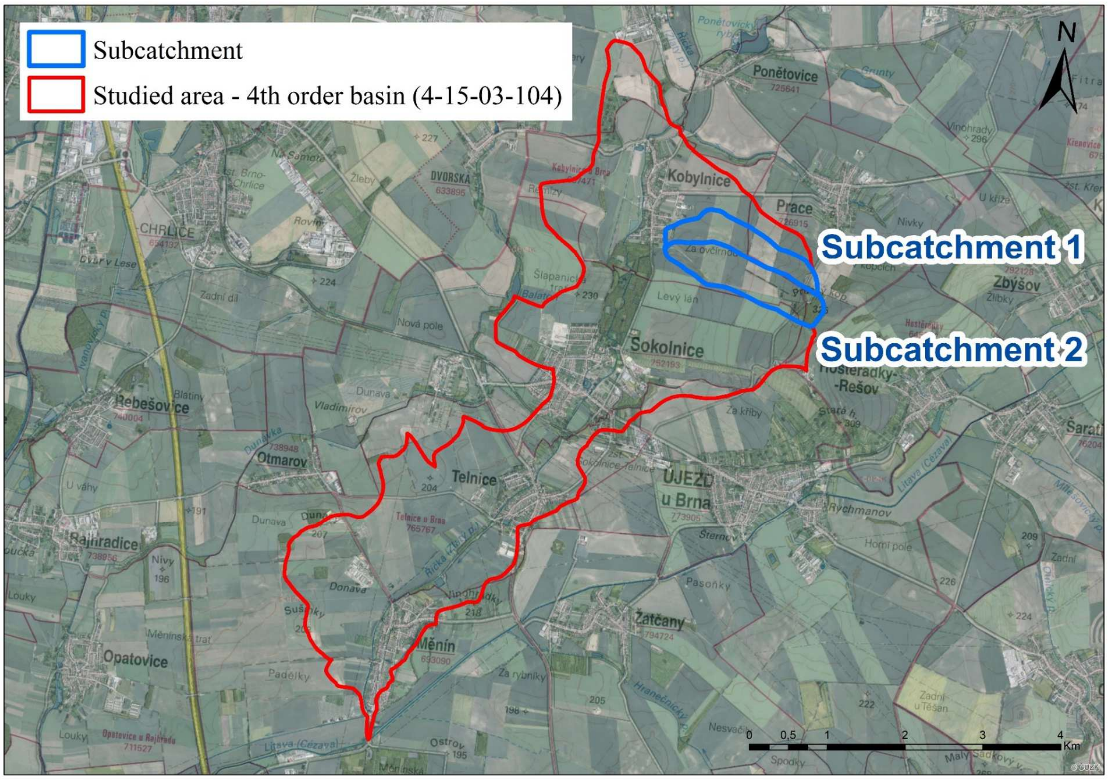

Fig. 1 Map of studied area.

The main goal of the presented study was to compare historical land use with the impact on erosion and runoff conditions in the defined subcatchment. The main source was aerial photographs from the 1950s. This was the last period before large-scale changes in the landscape. Older historical documents (stable cadastre map, 2nd, and 3rd military mapping) were used to find out additional information that could be relevant for the design of measures.

To determine the possible threat to real estate, the issue is solved in the long term by processing flood maps and determining flood areas [1]. Designated flood areas according to the Water law (254/2001 Sb.) are "administratively determined areas that may be inundated with water in the event of a natural flood", i.e. territory declared by the water authority. On the other hand, flood maps determine the degree of risk occurrence from an economic point of view. These are processed, for example, for the insurance sector. Floodplains are further updated as part of water management planning, by creating maps of flood danger and flood risks in areas with a significant flood risk. The Říčka river has a defined flood zone and is also included within areas with a significant flood risk (DYJ_03-03). This flooded area was compared to the historical development. As a first step, real estate from current state (ZABAGED information) was compared to an aerial map from the year 1953. Subsequently, properties in the floodplain of the hundred-year water, which were built after 1953, were determined. These given data were processed using analyses in the environment of geographic information systems.

The landscape was not only changed by different land use, but also by modifying rivers and streams, and by draining agricultural and forest areas [3]. Agricultural land drainage was categorized into primary and secondary systems. Primary drainage structures, often consisting of open channels or piped sections, were primarily designed to manage excess surface and underground water. Secondary drainage systems comprised immediate soil water management measures, including collection and drainage drains, outlets, and drainage shafts. Data on drainage areas, digitized from analogue maps by the Agricultural Water Management Administration, were examined for analysis. However, the territory of South Moravia was not only drained; extensive fields were also irrigated in later times by building an extensive system of pipes. Geographic information systems were employed for all analyses and mapping processes.

In 2009, a methodology [2] was also created for identifying places that are potentially at risk of flash floods. These critical points were subsequently revised based on current documents in 2015. According to the aforementioned methodology, the intersection of the concentrated runoff path line and the built-up area boundary is the critical point. It follows from the methodology that combined criteria are recommended for the selection of critical points (the size of the contributing area is 0.3–10 km^2 (K1), the average slope of the contributing area is ≥ 3.5% (K2), and the share of arable land in the basin ≥ 40% (K3)). The fourth condition of the criterion (K4) is the limit value of the indicator ≥ 1.85, which includes a combination of physical-geographical conditions, land

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use, regional differences in land cover, and the potential occurrence of extreme precipitation values supplemented by weights of relevant quantities. According to the model areas, the selection was also extended to include critical points with the size of the contributing area from 1 km^2 to 10 km^2 (K1A) and with the average slope of the contributing area being ≥ 5% (K1B). As critical points are a potential site of real estate threat from flash floods, attention for designing measures was drawn to the contributing area to the point.

The universal RUSLE equation was used for calculating soil erosion rates. It estimates the average annual soil loss caused by sheet and rill erosion, factoring in various parameters such as rainfall, soil erodibility, slope length and steepness, land cover, and erosion control practices. The calculation was conducted according to the Soil Protection against Erosion method [4] using LS converter, USLE 2D, and hydrological analysis within a geographic information system (ArcMap). Average annual soil loss is calculated by multiplying the following factors: C factor is the cover and management factor, which was determined based on the climatic region; the K-factor (soil erodibility), which was determined based on the main soil unit; the R-factor (represents the rainfall factor) with a value of 40, and the LS-factor, which comprises two sub-factors, namely slope (S) and slope length (L), which was determined with the help of the USLE 2D program. The P factor was used with a value of 1, with no protective measures. As part of the erosion risk, two variants were considered, namely the variant according to the current state of the territory and the second variant with the restoration of historical roads.

The DesQ-maxQ model was used for N-year maximum flow and wave volume. The solution to the process of maximum runoff from the basin is based on the principle of a kinematic flood wave. The method enables the calculation of the volume of direct runoff for a specified height of rain (runoff height H0), run-up time and concentration time. Additionally, it calculates the culminating flow for a specified height of rain, considering the effect of changes in the characteristics of the basin on the values of the above-mentioned characteristics of the maximum runoff hydrogram [5]. The basic input information is mainly the basic characteristics of slopes and thalweg, but also the CN number of the curve. The number of the CN curve was also determined using the same methodology [4] for soil protection against erosion using analysis in the environment of geoinformation systems. Within the framework of the maximum outflows from the basin, three variants were compared: variant 0 as current state; variant 1, when historical roads were considered into the territory; and variant 2, when three grassy strips and stabilization of the path of the concentrated runoff by grassing were inserted into the existing use of the landscape.

3 RESULTS

Historical land use

As part of the study of historical background data [6], the former pond and historical mills become the most interesting from the point of view of the water regime of the area. The historic pond used to exist in the village of Kobylnice in the local part characteristically called "The Pond", as shown in the Fig. 2. The last recorded mention of this pond is on (several) maps from 1825. On more recent maps, we already find drainage ditches running all over this area. Until now, one of them has remained here and was registered as the main drainage facility.

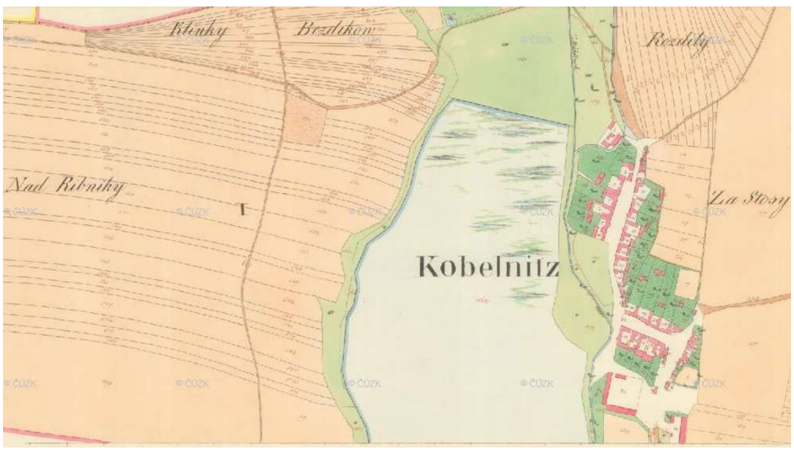

Fig. 2 Historical map from the year 1825.

On the other bank of the stream there was a historic mill, as shown in the Fig. 3. The large building of the renovated mill stands on the northern edge of the village on the left bank of the Říčka river. The mill has recently

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undergone repairs, and construction works around the mill are still ongoing. The mill is privately owned. The second mill is in the village of Sokolnice. The mill stands on the outskirts of the village under the castle, next to the castle park.

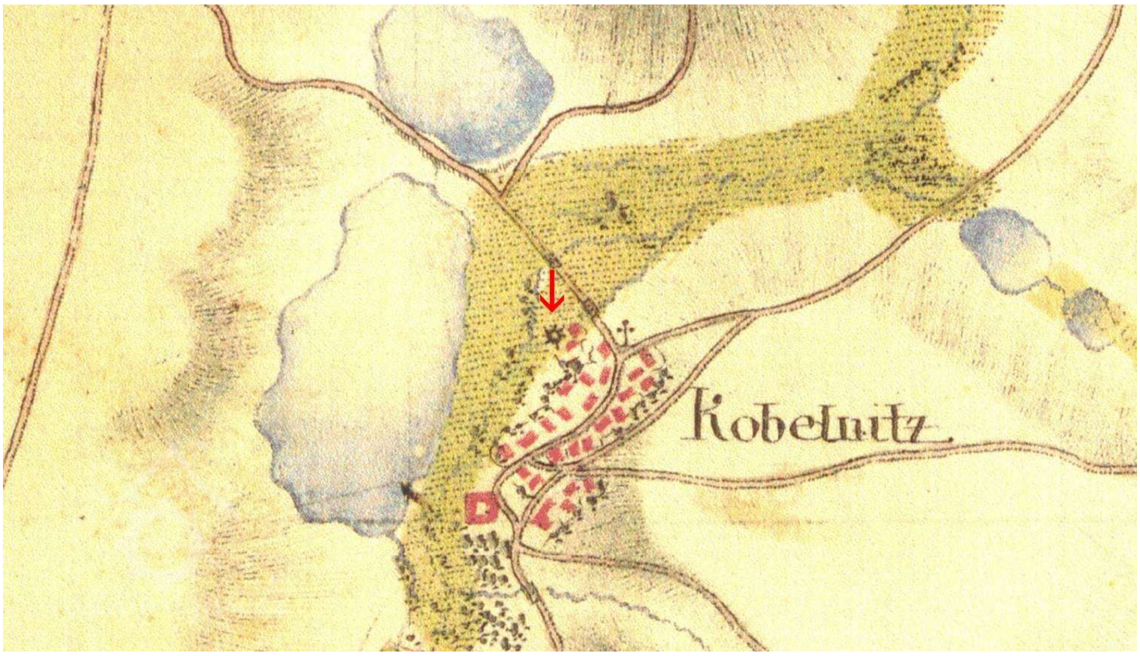

Fig. 3 Historical map from years 1764–1768 (1st military map). The red arrow shows the mill.

However, the main historical basis was an aerial map from 1953 [7]. The landscape here was intensively used for agriculture, characterized by long, narrow plots. Small historical roads lined with alleys could be seen between them. On the other hand, there were significantly fewer forested areas in the monitored subcatchment. The individual fields were located perpendicular to the path of the concentrated runoff, where, subsequently, the interaction of stony and grass borders reduced the erosion risk of the area. We can see the different use of the landscape in Fig 4.

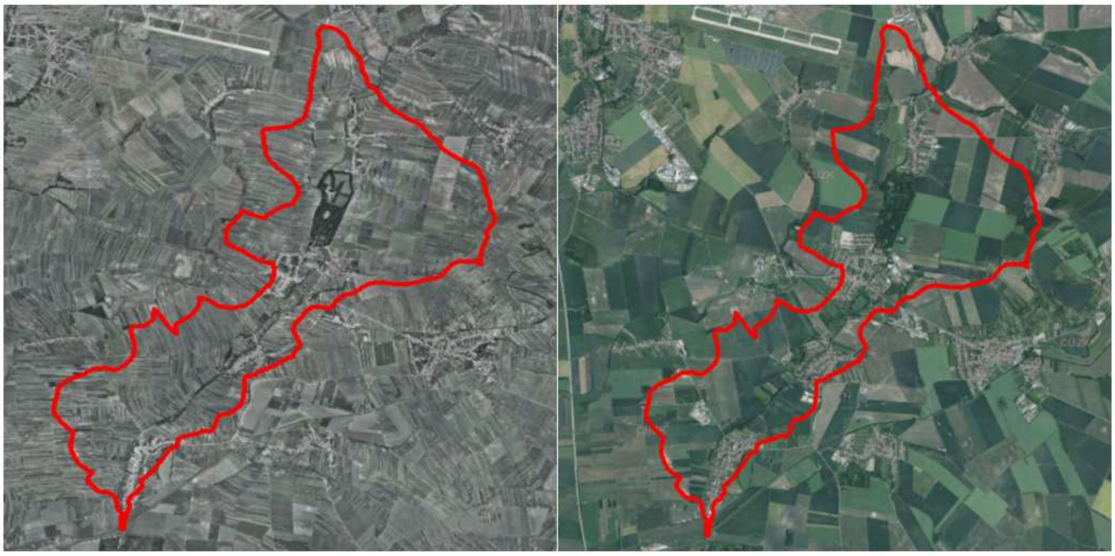

Fig. 4 Aerial map from 1953 (left) and aerial map of the current state.

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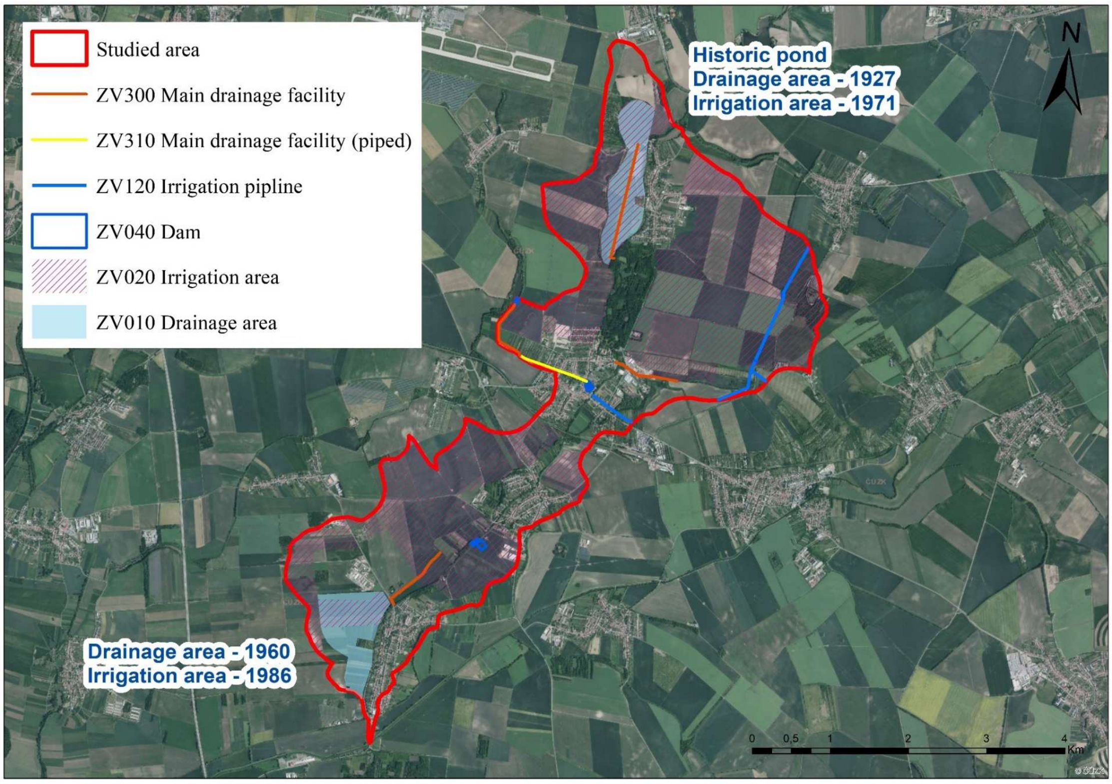

Fig. 5 The main amelioration facility in the studied area.

Even the fertile areas of southern Moravia did not escape collectivization tendencies. As we can see in Fig. 5, part of the territory was drained, the streams in the territory were straightened and modified. An interesting feature of this area is that drainage tendencies first took place in two locations; namely at the site of the former pond (in 1927), and in the southern part at the confluence (in 1960). Subsequently, this area was widely irrigated. Based on the field survey, however, the above-ground parts of the irrigation systems are significantly damaged, and surface drainage at the site of the pond is not visible except for the main drainage device.

The erosion risk [8] was calculated in two variants for the addressed sub-catchment. The first variant included the current state, while the second incorporated only historical roads in the territory. Erosion was calculated according to the methodology mentioned above. The calculation included the C-factor, which was determined based on the climatic region; the K-factor, which was determined based on the main soil unit; the R-factor with a value of 40 and the LS-factor, which was determined with the help of the USLE 2D program. The P factor was used with a value of 1, with no protective measures. The reason for this, was the effort to evaluate the change in the erosion risk of the territory only by restoring historical roads.

If we look at Fig. 6, we can see that the restoration of historical roads had an effect especially in terms of the LS factor. The average long-term soil loss for the defined sub-basin decreased from 8.71 t/ha/year to 7.8 t/ha/year. The effort was also to set aside individual small parcels in the territory, but this was not completed. The reason was the poor quality of the aerial photograph from 1953, when cloud cover was visible in some parts, which made the borders of individual parcels disappear. Also, the resolution of some cultures was problematic, affecting the overall quality of the photography. It is possible that this is specific only for a given sub-catchment, and the possibility of comparison would be achievable in another area. Another problem can also be the use of a 5×5 grid, when sometimes the width of the plot did not even reach a width of 3 m. For this reason, there was an effort to compare at least the change in land use along the path of the concentrated runoff. Currently, there is an intersection with a paved road and 3 changes in land use on the defined length of the path of the concentrated runoff. In the past, according to the aerial photograph, land use changed 69 times (Fig. 7). Even with these small limits, the runoff speed was significantly slowed down and did not cause an erosion threat to properties in the urban area.

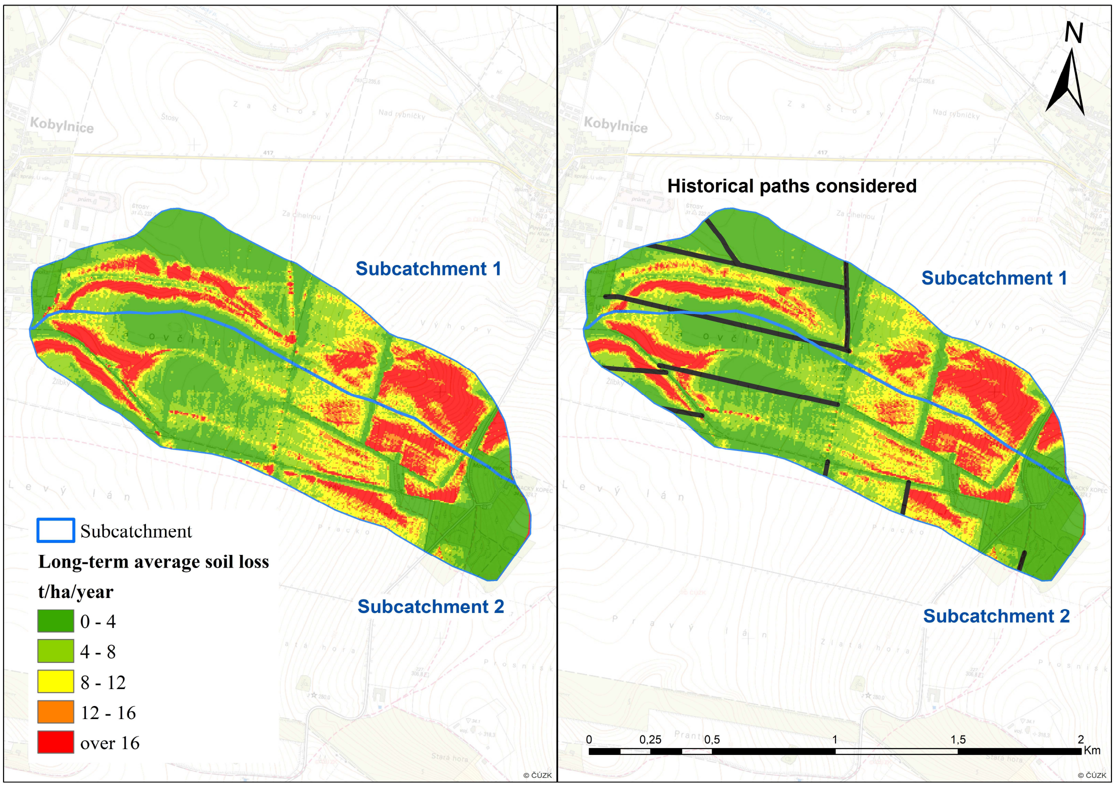

Fig. 6 Long-term average soil loss; the current state on the left, historical paths considered (right).

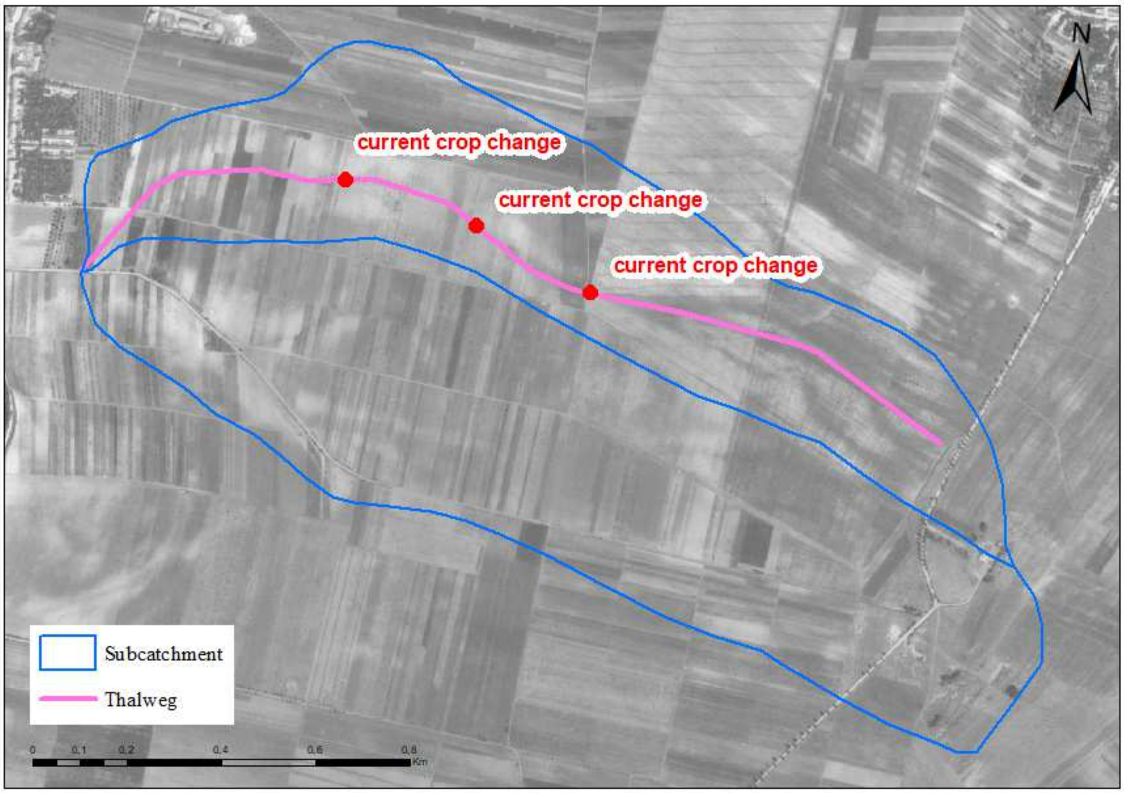

Fig. 7 Visualization of the disruption of thalweg in aerial map from 1953 and the current state.

Real estate in the area of interest is at risk both from surface runoff from areas intensively used for agriculture, but also due to being in the floodplain of the Říčka stream. According to a comparison of an aerial photograph

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from 1953 and the current state, we can tell that due to inappropriate construction practices, 95 properties were built in the flood zone in the last 70 years. The most prominent addition can be seen in the village of Telnice (Fig. 8).

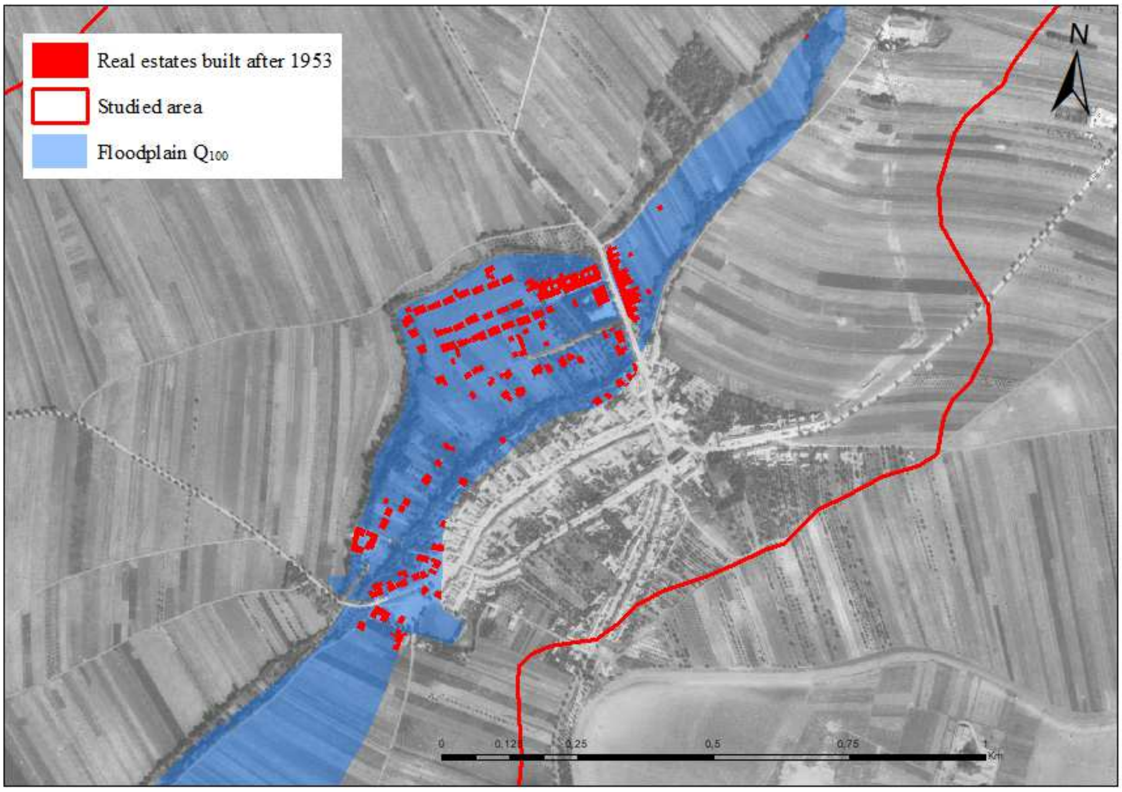

Fig. 8 Real estates built after 1953 in Q_{100} floodplain (Telnice).

From the point of view of the proposed measures, the N-year maximum flow and wave volume were also compared within the sub-basins. Three variants were compared. Variant 0 as current state, variant 1, when historical roads were considered into the territory, and variant 2, where three grassy strips and stabilization of the path of the concentrated runoff by grassing were inserted into the existing use of the landscape (Fig. 9). We assume that no significant changes have occurred in the terrain, as there are no visible embankments of railways, roads, or highways. Because of this, we see changes in the roughness of the monolith slopes and a change in the CN number (Tab. 2).

In terms of flows, we can see an improvement of up to 23% (flows of 50- and 100-year water) in variant 1, where only the protective grassing of the path of the concentrated runoff and the creation of three protective belts were chosen. In variant 1, the highest improvement was at Q_{50} flows, with a 10.5% reduction in flows. In terms of flood wave volumes, we also see the greatest improvement in option 2 (approx. 18% at Q_{100}), when option 1 reduced the flood wave volume at Q_{100} by 5.5%. See Tab. 3 for exact data.

Tab. 2 Characteristics of subcatchment 1 entering the calculations.

Length of thalweg	Slope of thalweg		Area (km^2)	Slope (%)	Roughness			CN		
2.47 km	4.56%				Var. 0	Var. 1	Var. 2	Var. 0	Var. 1	Var. 2
		Right	0.415	5.24	6.81	6.78	6.62	84.9	83.43	82.45
		Left	0.257	7.89	7.07	6.77	6.51	84.21	83.42	77.02

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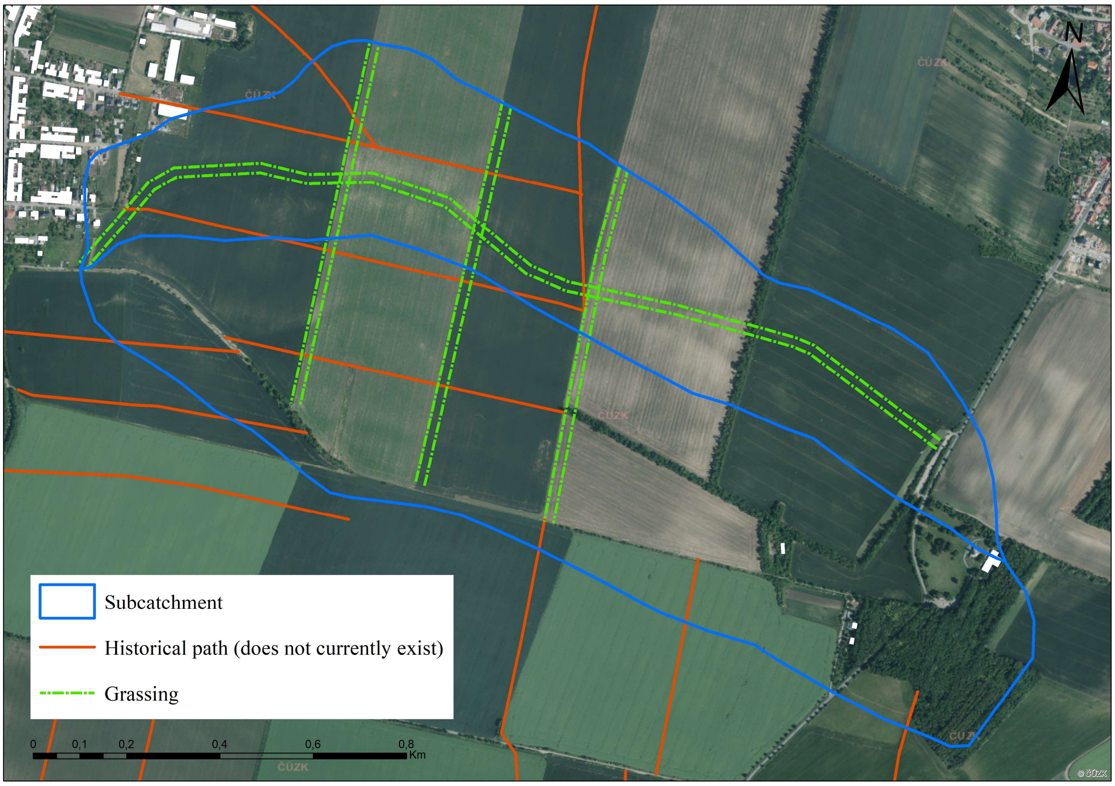

Fig. 9 Variants of measures (var. 0: current state, var. 1: just considered historical paths, var. 2: grassing of thalweg and three grassing strips.

Tab. 3 Changes of N-year maximum flow and flood wave volume in 3 variants (subcatchment 1).

N-year maximum flow and flood wave volume						**Units**
N	5	10	20	50	100	$[m^3 \cdot s^{-1}]$
Q_N var.0	1.4	2.13	3.12	4.66	5.95	$[m^3 \cdot s^{-1}]$
Q_N var. 1	1.28	1.94	2.84	4.17	5.35	$[m^3 \cdot s^{-1}]$
Q_N var. 2	1.11	1.68	2.44	3.59	4.58	$[m^3 \cdot s^{-1}]$
$W_{PVT,1d}$ var. 0	15.6	18.7	21.5	24.7	27.4	$[10^3 \cdot m^3 \cdot s^{-1}]$
$W_{PVT,1d}$ var. 1	14.9	17.8	20.5	23.4	25.9	$[10^3 \cdot m^3 \cdot s^{-1}]$
$W_{PVT,1d}$ var. 2	13.3	15.9	18.2	20.5	22.5	$[10^3 \cdot m^3 \cdot s^{-1}]$

4 DISCUSSION

The available data and analyses provided valuable insights into the selected watershed. By integrating historical maps and aerial photographs, it identified problematic areas that need to be addressed. Proposed minor measures, such as the restoration of historic roads and grassing, have proven effective in reducing the risk of erosion. The findings highlight the importance of historical landscape analysis in the design of measures. By understanding past adaptations, it is possible to design sustainable measures that are in harmony with the natural dynamics of the landscape. However, limitations of the available historical data, such as cloud cover and resolution issues, presented challenges in detailed analysis. Despite these limitations, the study successfully demonstrated the practical application of historical information in designing effective adaptation strategies.

Overall, the study underlines the importance of interdisciplinary approaches that combine historical knowledge with modern techniques, with the aim of restoring and developing sustainable watershed management solutions in the face of evolving environmental challenges.

5 CONCLUSION

In recent years, attention has been directed to the protection of real estate at the expense of the environment, often resulting in large-scale technical solutions, such as dry reservoirs, in areas where the same effect could be achieved with the help of measures close to nature. On the other hand, the evaluation of measures from the point of view of drought is left behind, i.e. the measures are included in the ecological and landscape-forming categories without subsequent quantification. It is also a widespread practice to oversize measures with a view to safety in the wake of climate change, resulting in huge interventions not only in the countryside, but also in inner cities. For this reason, there has been an effort to point out small adjustments in the landscape, which can also act as a complex protective measure. Drawing information from historical data can help us to find problematic areas, while also serving as an imaginary model for the implementation of soft measures.

The proposal of restoring historical routes is the best graspable and enforceable measure during normal negotiations with business entities. Of course, supplementing the roads with suitable plantings in combination with grassy strips would mean a more significant benefit for the intensively agriculturally used landscape.

As only one sub-catchment was addressed due to the chosen area, it is expedient to propose small measures within the entire IV catchment order. As we are in a basin with significantly polluted water, it is expedient to pay attention to the entire basin from the source, when unfortunately, near a large agglomeration such as Brno, it is not possible to rely only on self-cleaning processes in the landscape.

Acknowledgement

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