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Green infrastructure implementation and its influence on the hydrologic parameters of the urban catchment: Case study of the city of Trebišov, Slovakia.

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Abstract. This study presents changes in hydrologic characteristics of the urban catchment that are result of the implementation of the green infrastructure. Such data are used as a base for modeling of the urban drainage water flows. The research and its results are presented on the case study performed in the city of Trebišov, Slovakia. For the evaluation of hydrological parameters and their changes, available maps and a digital model of the terrain were used. Percentage of impervious, semi- and pervious surfaces, expected average curve number, travel time were determined, all in the particular sewer network subcatchments. Consequently, the areas of the city that have the highest development potential in the context of the implementation of green infrastructure were determined, were elaborated three different alternatives. The preliminary results of the current status research show, that the area of impervious areas is around 23% of the Trebišov inner city. Parks and squares account for about 10% of the city, and besides that, about a third of the area is occupied with concentrated private development. According to preliminary assessment, in the "maximal" GI implementation alternative the application of LID practices is appropriate for 12-15% of Trebišov area.

1. Introduction

Nowadays, the modelling of water flow in urban conditions is becoming an increasingly important task. The determination of the change in flow depending on the type of surface is especially relevant. This is important for the development of stormwater management plans, assessment of the risks of negative hydrological phenomena, assessment of the effectiveness of green infrastructure.

The purpose of this work is precisely a preliminary assessment of the prospects of various scenarios for the development of green infrastructure. The object of the study is the city of Trebišov, Slovakia. The city has a sufficiently extensive sewage network, different types of urban spaces, and there is a sufficiently large volume of data for it. The question of such assessment is relevant both in the context of the development of individual cities and as a check of individual steps of algorithms for modelling the efficiency of green infrastructure. The surface of the city, percentage of impermeable surface, curve number for individual sub-basins in the city, and changes of these parameters depending on several proposed scenarios of green infrastructure development were evaluated.

2. Materials, methods and methodology

Trebišov is a small industrial town in the easternmost part of Slovakia. The town is located on a plain, in the northern zone of the temperate climate. The lowland part is covered, in particular, by alluvial soils, civilized and muddy. Around Trebišov, most of the area is covered by chernozems and brown soils [1]. The water permeability of the soil is average or little, and in the flysch zone the soils are almost constantly wet, and the water-retaining function of mainly forest soils is performed even in the period without significant precipitation. The water regime of the soil is classified as wet; on slopes it is moderately wet [2]. For the purposes of this study, these soils were conditionally assigned to hydrological soil group C.

Open sources of information were used for data collection, namely ZBGIS, satellite images, data from Google Maps and OpenStreetMaps etc. The assessment was carried out using QGIS.

The territory of the inner city is approximately 7.6 km^2. The division of the city into partial watersheds was based on the available information about the sewage network and measurement points on it, the territory of the city was divided into 714 small watersheds. Due to the lack of data on measurements in the stormwater network in certain parts of the city, the analyzed watersheds cover only 4.8 km^2.

Curve number was used as an integral, digital indicator that allows evaluating the surface from a hydrological point of view. The curve number (CN) is a function of hydrologic soil group (HSG), cover type, treatment, hydrologic condition, antecedent runoff condition and impervious area in the catchment. Conceptually, CN can vary from 0 to 100, where a CN equal to 100 means that all the precipitation turned to surface runoff and no infiltration occurred, CN of 0 means that all precipitation infiltrated, so there was no runoff. Impervious surfaces were assigned a CN of 98 [3]. In order to identify this parameter, it is necessary to use special tables [4, 5]. and further refine these data using assessment of soil, land cover, etc.. Similar studies were also conducted for small natural catchments in Slovakia [6].

In the course of this study, curve numbers were determined using a combination of official tables, taking into account data from other similar cities, maps of land use categories and with clarification using satellite images and photos from the city. Averaging across catchments is done using QGIS. The classes according to which the territory was classified and the approximate determined values of cn are shown in Table 1.

Table 1. Cover types and their CN value for Trebišov.

Cover type	Curve Number value
Roads	98
Buildings	98
Paved area	98
Ground	90
Green zones	74
Water surface	100
Cemetary	86
Crops	80
Housholds	81
Other	83

In addition, the percentage of impermiable areas was estimated, where 100% impermeability was assigned to buildings, roads and paved areas, and a conditional 1% to other areas.

Current conditions and 3 proposed scenarios of green infrastructure development were evaluated. The assessment was carried out by changing cn and impermeability, the scenarios and their corresponding changes are shown in Table 2.

Table 2. Green infrastructure development scenarios.

N of scenario	Description	Curve number transformation
1	Large building with areas larger than 1000 m^2 are covered with green roofs	Building cn changed from 98 to 84 [7].
2	In addition to changes from scenario 1, identified paved areas transformed to permeable pavement. These areas became permeable	Paved areas cn changed from 98 to 82
3	In addition to changes from scenario 2, identified areas with bare ground are transformed into open spaces, lawns with good grass condition (75% or more)	Ground cn changed from 90 to 74

3. Results

The preliminary results of the current town conditions show, that impervious area occupies around 23% of the Trebišov inner city. These areas include buildings, 12% of the total area of the city, road surface, about 6%, and identified separately large paved areas. Green zones, such as parks, squares, lawns with good grass conditions all account for about 10% of the city. However, it is worth noting that a significant share is concentrated in one large park. Besides that, about a third of the town area is occupied with concentrated private development, often occupied by gardens.

Figure 1 shows the detailed distribution of CN across catchments within Trebišov. The city center and industrial areas on the outskirts have the highest values. The average CN value is more than 86.5.

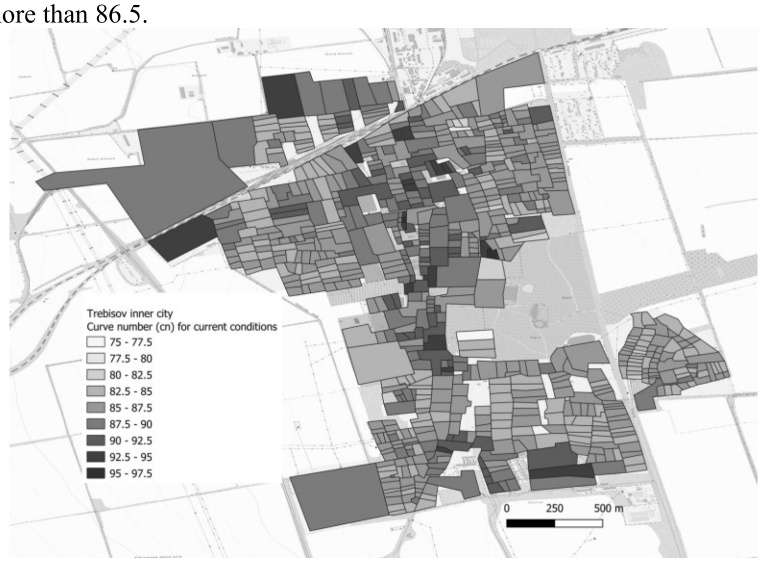

Fig. 1. Curve number (cn) for current condition, Trebišov inner city.

Figures 2.a and 2.b present the spatial distribution of cn according to scenarios 1 and 2, respectively. These changes cover, respectively, 6 and more than 13.3% of the total area of the received catchments. The main changes are taking place in the central parts of the city and on the outskirts. The total area proposed to be covered with green roofs is about 0.3 square kilometers. It is worth considering the significant cost of replacement, because the construction of green roofs of such an area would require at least 75 million dollars, with a price of 250 per square meter [8]- and projects of this scale cannot be completed quickly. However, the other benefits of green roofs are not discussed either. The values of CN consistently decrease to 86.2 and 85.8.

As part of this study, the technical conditions of specific buildings have not yet been evaluated, so there is a possibility that the installation of green roofs on the entire proposed area will be complicated.

a) b)

Fig. 2. Curve number (cn) provided by: a) scenario 1; b) scenario 2.

Also, upon completion of these two scenarios, we can estimate the change in water permeability of the studied area. Figure 3.a shows it for current conditions, Figure 3.b shows it after the changes proposed in scenario 3 are completed. Changes in this parameter are much more visible, with only one catchment having just over 60% impervious surface compared to 22 under current conditions.

3.a 3.b

Fig. 3. Percentage of the impervious area a) for current condition of Trebišov b) for scenario 2.

The last scenario (Figure 4) involves changes in large areas with bare soil or poor vegetation cover. The area of such plots within the investigated watersheds is 5.44%, accordingly, the total area of transformed sites is going to be almost 19%, or 12% of the area of the entire inner city of Trebišov. The average value of CN did not change significantly, decreasing to 85.68, however, the decrease is uniform, especially in the central and northern parts of the city.

Fig. 4. Curve number (cn), provided by scenario 3, Trebišov inner city.

4. Conclusions

The study shows that Trebišov has significant areas for the possible implementation of green infrastructure. At the same time, with a combination of several proposed scenarios, it is possible to achieve a fairly even decrease in the curve number and a significant decrease in the share of the impervious area.

Preliminary calculations show that the potential retention capacity in the scenario of transformation of large buildings, paved areas and areas with bare soil increases by 8%.

Research of this type is promising, in the future it is planned to compare potential retention capacity under different scenarios and conduct flow modeling for each of them. In addition, it is necessary to take into account the possibility that small private houses are disconnected from the storm water network.

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