GIS ANALYSIS OF POTENTIAL LOCATIONS FOR RAIN GARDENS IN VILLAGE ALEKŠINCE

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Abstract: Climate change leads to the creation of landscape measures for its stabilization. One of the steps of sustainable land-use is the measures aimed at processing rainwater in settlements. Rain gardens represent a way of storm water treatment at settlement level. It is necessary to follow several rules – for proper functioning which include natural conditions and site parameters. The aim of study was the establishment of methodology for determining the suitable locations for rain gardens, in application to settlement – village Alekšince. Selection of potential sites is based on the attributes of soil properties, slope, land use, ownership and ground water level in the given area, that are processed in GIS software QGIS. The methodology used is based on implemented methodologies of last years. The result is raster map which shows the suitability of village location for rain garden based on the spatial analysis with the use of overlaying of the value raster of the mentioned attributes.

Key Words: rain garden, GIS analysis, water management, stormwater management

INTRODUCTION

Water management in landscape requires various approaches in accordance to land use (Halaj et al. 2012, Muchová et al. 2016). Evaporation rates may be affected in various ways in the real conditions (Zarzycki et al. 2015, Žarnowiec et al. 2016). The planting helps to eliminate and treat the storm water (Stiffler 2013) as the water quality may be threatened nowadays (Bedla and Misztal 2014, Policht-Latawiec et al. 2015). Tóth et al. (2014) states water as an important part of green infrastructure.

Rain gardens (RG), as an important storm water management practice, are common tool in landscape creation of public spaces. Their ecological characteristics include collection, processing, infiltration, transpiration and filtration of storm water, which are increased by strong economic aspects because of its relatively low-cost demand and final money savings. These low terrain depressions planted with perennials, shrubs and small trees are notable aesthetic and landscape element used by landscape architects worldwide. Soils in urban areas have significantly altered the natural structure and impaired functionality that greatly extends the time of infiltration of storm water. Increasing input of water to the sewerage system may result in flood conditions.

The study is aimed at determining the methodology for selection of suitable site for RG based on natural conditions and conditions of the current state of locations, in application to settlement – village Alekšince.

MATERIAL AND METHODS

Materials for spatial analysis

Data processing and spatial analysis was performed in software QGIS v. 2.12.0. and used materials below.

• WMS servers: Map of parcels and municipality borders, Map of soil units, Base map of Slovakia (contours),
• WFS servers: map of administrative units (boundaries of cadastres),
- Web GIS pages: Soil maps of Slovakia, Map of dominant soil units, Map of underground water level, Map of village parcels in the village with the orthophotomap layer,
- Parcel ownership identification: Ownership of the village parcels (community/private land),
- Spatial planning documentation,
- Map of underground water levels.

Spatial analysis methodology

Analysis of the spatial and ecological parameters of the land in the studied area was based on work of authors - McCormack (2015), Rokus (2005) and Marney (2012). They focused on various input parameters affecting the suitability of the location for RG (Table 1–3). Each author assigned values (on the scale 1–5 or 1–3) to selected parameters, multiplied them by a weighting coefficient. Studied areas were divided into cells – depending on used methodology were recalculated and resulted in raster map of suitable localities for RG.

Marney’s (2012) methodology used values on scale 1–3 for selected parameters of partial and land elements (Table 3) – soil, slope of area, depth of the ground water, proximity to structures (buildings, roads), ownership and land use. For final calculation of suitable RG locality, he used formula: 
\[ YDZ = \sum_{i=1}^{n} (W \times C_i) \]

Table 1 The input parameters for analysis to determine a suitable location for RG by McCormack (2015)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Parameter value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrological soils group</td>
<td>25%</td>
<td>D - very high absorption</td>
</tr>
<tr>
<td>Minimal soil depth</td>
<td>35%</td>
<td>0-14 inch</td>
</tr>
<tr>
<td>Slope</td>
<td>25%</td>
<td>12-700%</td>
</tr>
<tr>
<td>Exposure to the cardinal points</td>
<td>10%</td>
<td>0-90°, 90-112.5°, 112.5-135°, 135-157.5°, 157.5-225.5°</td>
</tr>
<tr>
<td>Use of area</td>
<td>5%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 2 The input parameters for analysis to determine a suitable location for RG by Rokus (2005)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Parameter value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of impervious surface</td>
<td>1/3</td>
<td>designed using complex calculations from the number of parameters</td>
</tr>
<tr>
<td>Soil permeability</td>
<td>1/3</td>
<td>designed using complex calculations from the number of parameters</td>
</tr>
<tr>
<td>Slope</td>
<td>1/3</td>
<td>0-18%</td>
</tr>
</tbody>
</table>

Table 3 The input parameters for analysis to determine a suitable location for RG by Marney (2012)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Parameter value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0.25</td>
<td>loam, clay-loam</td>
</tr>
<tr>
<td>Slope</td>
<td>0.25</td>
<td>0-1.9%</td>
</tr>
<tr>
<td>Depth to ground water</td>
<td>0.10</td>
<td>0-1.9 ft</td>
</tr>
<tr>
<td>Proximity of structures</td>
<td>0.15</td>
<td>0-9.9 ft</td>
</tr>
<tr>
<td>Public/private</td>
<td>0.15</td>
<td>private</td>
</tr>
<tr>
<td>Use of area</td>
<td>0.10</td>
<td>housing</td>
</tr>
</tbody>
</table>

The parameters used in the analysis process

According to available data, we focused on the categories, which are directly involved in the process of proper functionality of RG in the surrounding village Alekšince. Categories were then assigned the values, which were adjusted with the coefficient by relevance of given parameters in the process of RG creation (Table 4).

Table 4 Input parameters for creating GIS analysis to determine a location for RG

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient</th>
<th>Parameter value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0.25</td>
<td>light soils</td>
</tr>
<tr>
<td>Slope</td>
<td>0.25</td>
<td>2-4.9%</td>
</tr>
<tr>
<td>Ownership of parcels</td>
<td>0.20</td>
<td>owned by the municipality</td>
</tr>
<tr>
<td>Use of area</td>
<td>0.20</td>
<td>public greenery</td>
</tr>
<tr>
<td>Depth to ground water</td>
<td>0.10</td>
<td>more than 2.00 m</td>
</tr>
</tbody>
</table>

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Process of analysis

Workflow analysis to the development and subsequent assessment in the form of map output included following steps:

• vectorization of village boundaries and parcels with the use of cadastral map and Land Register portal map, assigning the parameter values,

• vectorization of soil types boundaries in cadaster using maps and Guide for Valuated Soil – Ecological Units (Linkeš et al. 1996), assigning the parameter values for categories of soils in accordance to the main unit of soil and soil granularity classifier,

• vectorization of contour lines, assigning the parameter values for slope categories, creation of a digital terrain model (DTM) created from the nodes extracted from the contours of the area,

• vectorization of ground water levels using Map of underground water levels, assigning the parameter values for categories of water depths levels,

• vectorization of buildings and paved surfaces using cadastral maps, orthophoto maps and Land Registry portal maps,

• vectorization of land use zones using a land use plan and a field survey, assigning the parameter values of the land use.

RESULTS AND DISCUSSION

Result maps that show the values of particular parameters within the boundaries of Alekšince were developed by processing the input data according to the methodological model. There were created 9 maps that were combined to create the result map of suitability of sites for RG placement.

Soil type and its characteristics were considered as one of the most important parameters in RG construction process. Using Valuated Soil - Ecological Units maps and Soil map of Slovakia, different soil types in area were plotted (Figure 1). According to the analysis, it can be concluded that the territory is covered with two types of soils – brown modals and black earth soils which predominate. Using Map of soil types (Figure 1) and converting it into three soil categories based on process model – light soils, medium and heavy soils with their associated values, we obtained the Map of soil categories (Figure 2). The map shows there were located just medium heavy and moderate soils. We can state that soils in studied area are suitable for RG.

Digital elevation model was created after vectorization of contours and extraction of their nodes (Figure 3) using TIN interpolation. The model shows that the urban area is sloping downward to the central part (around water streams area). Total elevation difference is approximately 56 m. The highest parts are located in most south village area called Lahne. Digital elevation model was used to create the map of slope, which was afterwards categorized and reclassified to model values (Table 4). Sites, where the slope was exceeding 8%, were considered as unsuitable for RG placement.

Map of ownership within the boundaries of the village Alekšince (Figure 5) was created with the use of ownership parameter. Map of land use (Figure 6) displays the area divided into 3 categories - public greenery - the most suitable areas for RG, private green areas (housing gardens, vineyards, meadows and permanent grassland) and industrial sites. Industrial zones were considered as inappropriate for RG because of high proportion of the paved surface and special business. There were also areas totally excluded from analysis process – forest area, water streams zones, area of cemetery and areas in Lahne, which are zones of building process and it is not possible define the final state.

Map of ground water levels (Figure 7) describes division of area into two underground water zones. Both of them are suitable for RG placement. Main area is situated in water depth of 2 m and more. For more detailed elaboration it would be suitable to perform local measurements.

Zones excluded from the possible locations for RG (Figure 8) are paved areas - asphalt roads and buildings, these layers were subsequently merged into a single layer - areas excluded from the analysis (Figure 9). The roof area of the buildings was extended with a buffer distance of 3 m; roads were extended with 1 m buffer. It is generally considered inappropriate to install RG
beyond this limit, as they could lead to waterlogging of subsoil and construction disturbances of structures of buildings.

Raster map of suitability was reclassificated to contain value 0 - 1 = 1; 1 - 2 = 2; 2 - 3 = 3, after that it was vectorized to create a set of polygons with correspondent category of suitability. Value of area size was calculated for each category in MS Excel environment (Table 5).

The result of this study consists of raster map (Figure 10) which shows division of area to three categories in respect to their suitability to RG placement. There were not areas with perfect suitability, the best areas for RG are represented with value 1.25, red areas with value 2.55 the less suitable.

Table 5 Size of areas suitable for RG placement in village Alekšince

<table>
<thead>
<tr>
<th>Value of area</th>
<th>Area size [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25</td>
<td>10028</td>
</tr>
<tr>
<td>1.575</td>
<td>32364</td>
</tr>
<tr>
<td>1.9</td>
<td>204292</td>
</tr>
<tr>
<td>2.255</td>
<td>203456</td>
</tr>
<tr>
<td>2.55</td>
<td>82096</td>
</tr>
<tr>
<td>Sum of area size</td>
<td>532236</td>
</tr>
</tbody>
</table>

Based on the present methodology and implemented process of analysis can be summarized than the application of procedure in conditions of municipalities can help to identify suitable locations for RG placement.

In territory of Alekšince, there were localities suitable for RG placement depending on local conditions. Specific value of the parameter and its suitability must be supported with further research in order to create more detailed categorization suitability. The given fact is related to verification of individual methodologies McCormack (2015) and Marney (2012) in the field. Also, it is appropriate to apply a specific field measurements in selected localities focused mainly on soil conditions. Linking the issue with practice it is based on the verification of results - creation of demonstrative RG.

Figure 1 Soil types in Alekšince cadastral area
Figure 2 Map of soil categories

Figure 3 Digital elevation model
Figure 4 Map of slope categories
Figure 5 Map of ownership of parcels

Figure 6 Map of land use

Figure 7 Depth to ground water level

Figure 8 Map of paved area

Figure 9 Areas excluded from the analysis

Figure 10 Map of the site suitability for RG design within the boundaries of the village Alekšince
CONCLUSION

This paper focused to propose a solution of storm water management in public spaces of smaller settlement of the Nitra region - the village Alekszince through rain gardens. Solution aims to establish a methodology for identification of the suitable locations for RG creation after analysing the conditions of each locality. The methodology sets the values of necessary parameters for evaluation of suitability of the areas, the weight value, and impact on the overall suitability of the sites.

ACKNOWLEDGEMENT

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REFERENCES


