The Potential of Greenable Area in the Urban Building Stock

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Abstract. In the context of establishing green infrastructure in cities, urban retrofit has presumably larger area potential than ground-based green. To support the large-scale advancement of urban green, the assessment of greenable potential plots in the building stock, both on horizontal and on vertical scale, provides first indispensable indications for decision-making. However, reliable and solid data to the state of the buildings is currently not available. The research study Urbane GmbA explored a new methodological approach, based on publicly available geo-data, and applied it at two study sites in high-density urban quarters in Vienna. The combination of a GIS-based analysis with digital and on-site photos allowed for the creation of a Level of Detail 2 (LOD2) 3D-model and subsequently the estimation of the green retrofit potential of roofs and facades. Comprehensive maps with the data of the 2D building footprints provide valuable information for planners, including building characteristics and greenable area potential. The approach proved to provide more comprehensive information including building characteristics fundamental to the planning and decision-making process. The achieved results are merged with an evaluation matrix generated for attributing available facade and roof greening systems. This allows for more focused decision support for the retrofit of the building stock towards more sustainable and resilient district development.

1. Introduction

The quantitative increase in urban green areas is no longer the sole vision of environmentally conscious minorities. In 2015, the Paris Climate Agreement put the necessity for actions to confine the effects of climate change on the political agenda of national authorities. Many countries reacted with national climate protection and adaptation strategies.

Natural solutions have to become an integral alternatives or additions to grey infrastructure for the regional development [1]. With its research and innovation policies on Green Infrastructure and Nature-Based Solutions the EU strives for innovations based on natural and nature-inspired solutions to bring sustainability and resilience into the cities [2]. In Vienna, the city’s Urban Heat Island Strategy (UHI-STRAT) aims to expand Green Infrastructure as an effective measurement against the effects of urban heat islands and proposes a variety of technical and strategic measures for planners, architects and administrators [3]. City planning and development will have to increasingly deal with the renovation of long-lasting architectural heritage and the results of an excessive building culture where so much undeveloped and natural land was lost to building projects. The restructuring of urban areas to incorporate more vegetation in horizontal and vertical orientation has a higher potential for success if the existing building stock is considered in addition to the construction of new (green) buildings. The potential of vertical areas is believed to be especially high. MA 22 estimates a potential net area of 12,000 ha facades, which can be used for the installation of green walls. This is well over a third of the total net area. In comparison, the potential net area for green roofs is only 1,800 ha [4].
The assessment of the potential of greenable area is the basis for the conception and planning of vertical and horizontal green on small and large scale. Reliable basic data is of the utmost importance to increase urban green infrastructure in the building stock (in streets, urban quarters and on district level). At the moment, the necessary data is only available in a very restricted way as the currently available instruments and various fragmented approaches, in part isolated solutions, reach their limit with their practical application. For example, the Viennese Gründachpotenzialkataster (cadastre of potential green roof area), based on the survey of roof inclination via airborne laser-can images, shows only a very small potential for green roofs. Important technical (e.g. statics) and legal parameters (e.g. preservation order, protection areas) were not included in the assessment or analysed. An adequate adaptation of the current cadastre would be necessary, but will be not released due to the economic expenditure for the individual users.

To fill this void, a new methodological approach was developed and applied at two study sites in the frame of the research project Urbane GmbH. The created maps provide comprehensive information for the planner regarding building characteristics and potentially greenable area.

2. Methodology

2.1. Description of the study sites

The study was conducted in two districts of distinct characteristics. The study site Neulerchenfelderstraße is situated in the 16th district of Vienna. It includes the street and its adjoining building stock. The site is characterised by a versatile building structure. Historical buildings alternate with modern ones along the street. The ground floor zone is strongly influenced by the retail trade, while the upper floor zone is mainly used as living space. In the public open space, there are barely public green areas. The adjacent sidewalks are often very narrow, which can represent an obstacle for the implementation of ground based green facade retrofits. The study site Innerfavoriten – Kretaviertel is situated in the 10th district of Vienna. Most of the buildings are from the years after 1945. The site is characterised by large blocks of flats and individual smaller historical buildings. Many of the large residential buildings are community buildings. Both, the ground floor zone and the upper zone are mainly used as living space.
2.2. GIS-based system analysis

GIS-based analysis was performed and combined with analyses of photos, taken of each building in the study areas. On the basis of a Level of Detail 2 (LOD2) 3D-model the slope and exposure of the roof surfaces were calculated and the green roof retrofit potential was estimated. In combination with the photo analyses, the net-area facade retrofit potential was assessed. In order to describe the ground connection of the facades, the surrounding land cover was attributed by means of vicinity analysis. Subsequently, all data was transformed to 2D building footprints in order to make them easy to integrate in existing geo-date bases of the city of Vienna.

2.2.1. GIS-based survey of the green facade retrofit potentials.

The surrounding land use can provide first indications of the feasibility of green facade retrofit potentials. The relation of the facade areas to the adjacent land use was calculated by means of neighbourhood analyses in ArcGIS. For this purpose, the facades of the 3D-model (LOD2) were first separated from the other wall elements. The next step was to reclassify the land use map and assign the respective attribute to the facades. In total, seven categories were formed (see Table 1). The categories were selected to allow an initial assessment of the external effect as well as the feasibility of the potential greening methods. The pavement width is a very important parameter for the feasibility of pot and soil based vertical greening systems. To form the first two categories, “pavement width < 2.2 m” and “pavement width ≥ 2.2 m”, areas that were disclosed as “pavement” in the FMZK (Flächen-Mehrzweck-Karte; map of the multi-purposes of areas) were analysed on basis of their width. The category “pedestrian zone” includes potentially greenable facades with a very high external effect. Facades in the category “green area” have a high potential for soil based systems as a direct contact to the soil can be established without any measures to re-open sealed surfaces. On the contrary, areas in the category “private parking and traffic areas” are connected to sealed surfaces and measurements and soil based
measurements are not possible without de-scaling measurements. Additionally, the implementation of greening projects can be complicated by the current use as a parking space or traffic area. Facades in the category “consolidated area” will also lack of initial soil contact, which means the areas need pre-treatments in terms of allowing permeability. An additional attribute, namely “no soil contact – flat roof”, classifies all facades which adjoin to a flat roof. This means the potential lies with pot based systems. After the classification, the gross area of the various types of facades was calculated for each building within the project area.

| Categories for the survey of facades | Description |
|--------------------------------------|-------------|
| Pavement width ≥ 2.2 m               | Facades connected to pavements with a minimal width above 2.2 m |
| Pavement width < 2.2 m               | Facades connected to pavements with a minimal width below 2.2 m |
| Pedestrian zone                      | Facades connected to traffic areas classified as pedestrian |
| Consolidated area                    | Facades connected to consolidated and sealed surfaces |
| Private parking and traffic areas     | Facades connected to traffic areas on private property (e.g. entry ways, parking areas) |
| Green area                           | Facades connected to green areas (all green areas and additional unsealed surfaces) |
| No soil contact – flat roof          | Facades with no soil contact, which direct contact to a flat roof |

Figure 2: Facades in the study area Innerfavoriten – Kretaviertel classified by the surrounding soil use

2.2.2. GIS-based survey of the green roof retrofit potentials.

The Guideline on Green Roofs in Vienna (2009) notes that the roof slope is a significant factor of the usefulness and profitability for the installation of a green roof. The category limits are based on the recommendations of the Guideline for Green Roofs [5] and the Gründachpotenzialkataster [4] and modified within the project. The direction of the roof is an important parameter to describe plant habitats. Therefore, the direction of the roofs was calculated and integrated in the classification (see Fig. 3). A
new category for very steep roof areas (15.1°-45°) in exposed sites (135°-225°) was created to gather these areas as they will have a very low potential for the installation of green roofs. As an additional information, the roof cladding was assessed based on visual interpretation of aerial images.

Table 2: Classification of the roof areas to assess the potentially greenable plots and a description of the categories.

| Classification of the roof areas | Description |
|----------------------------------|-------------|
| **Slope**                       | **Exposition** | **Description** |
| 0° - 5°                          | 0° – 360°    | In this category, roofs can be equipped with extensive and intensive green roofs with relatively low effort [4]. |
| 5.1° - 15°                       | 0° – 360°    | Possibility for extensive green roofs [5]. |
| 15°.1° - 45°                     | 0° – 134.9° and 225.1° – 360° | Slopes above 15° require a special shear barrier to prevent slippage of the structure. Extensive green roofs can be installed at roofs up to an inclination of 45° [5]. |
| 15°.1° - 45°                     | 135° – 225°  | Roof areas with a southeast to southwest exposition (135 - 225 degrees), which are strongly to very strongly inclined. These roof areas are classified as “exposed”. The installment of green roofs is very difficult. |
| > 45°                            | 0° – 360°    | Green roofs are usually not possible anymore [5]. |

Figure 3: Slope and exposition as a basis for the assessment of the potentially greenable plots

2.2.3. Image based analysis of the buildings in the project area and intersection with the GIS analysis
The geo-data and the results of the GIS-based analysis were verified by an on-site inspection. Images of the external facades were the basis for further collection of the relevant data. The facades were subclassified in ground floor and upper floor zone. All structural elements, that could possibly influence the decision for or against a green façade installation, were recorded. This includes balconies, stucco, logos, frescos, billboards, display cases and garage entrances. Subsequently, the total area of the structural elements was estimated in 25% intervals. Additionally, Google-Maps 3D complemented the survey, especially for inner courtyards, where in most cases access is difficult. Highly structured facades with a high cover ratio of structural elements have a lower potential for greenable area. Facades with a cover ratio ≥ 75% get the attribute “structured, covered facade”.

Facades with a historically representative character will most likely have special requirements for the implementation of green walls. The assessment was subjective and did not include legal boundaries.
The number of windows was assessed to calculate the window area in comparison to the total facade area. The windows were categorized in regard to their building period and multiplied with a factor to obtain the total window area. The estimated window area was then subtracted from the gross facade area of the 3D model. Subsequently, the results were intersected with the building outlines and presented cartographically. Buildings under preservation order were excluded from the potential analysis.

3. Results
The greenable area potential was calculated for both project areas. Table 3 and 4 give an overview of the total potential area in the project areas broken down to the defined categories. Categories with a generally higher potential are colored in green. Differences are obvious when comparing the two study areas. The study area Neulerchenfelderstraße is smaller, with less buildings (89 against 134), and the building development structure varies from Innerfavoriten - Kretaviertel. There, a few freestanding buildings are in contrast with the closed perimeter block development in Neulerchenfelderstraße.

The ground floor zone in the study area Neulerchenfelderstraße has a lower potential than the upper floor zone. This can be a result of the intensive use of the ground floor zone. These facades often end in a very narrow pavement, which is a barrier for the installation of soil based systems. The sum of the potentially greenable area for inner courtyards is notably higher. Facades within the category “no soil contact – flat roof” have a high potential for pot-based systems. Both project areas present frequent green oriented facades. This means the potential for the application of soil based systems is high. Both study areas have big, flat and only slightly inclined roof areas. Gravel roofs are very interesting for the installation of green roofs as after the relatively easy exchange of the gravel, most often no alternations to the building statics and roof waterproofing are necessary to adjust for the green roof structure. Flat or slightly inclined roofs with gravel are the preferred roof areas for retrofitting green roofs. It was not applicable to include other structural building requirements to the analysis such as roof seal, insulation, brim height or accessibility in this survey.

Table 3: Potential of the greenable area in the study area Neulerchenfelderstraße

| Project area Neulerchenfelderstraße | Category                          | Greenable potential area [ha] |
|-------------------------------------|-----------------------------------|-------------------------------|
| Facade area                         | Total area – facades              | 6.44                          |
|                                     | Pavement width ≥ 2.2 m            | 0.92                          |
|                                     | Pavement width < 2.2 m            | 0.70                          |
|                                     | Pedestrian zone                   | 0.12                          |
|                                     | Consolidated area                 | 2.69                          |
|                                     | Private parking and traffic areas | 0.61                          |
|                                     | Green area                        | 0.87                          |
|                                     | No soil contact – flat roof       | 0.53                          |
| Roof area                           | Total area – roof                 | 3.75                          |
|                                     | 0° to 5°                          | 1.50                          |
|                                     | 5° to 15°                         | 0.42                          |
|                                     | 15° to 45°, no south exposition   | 1.74                          |
|                                     | 0° to 15°, gravel roof            | 0.09                          |

Table 4: Potential of the greenable area in the study area Innerfavoriten – Kretaviertel

| Project area Innerfavoriten - Kretaviertel | Category                          | Greenable potential area [ha] |
|-------------------------------------------|-----------------------------------|-------------------------------|
| Facade area                               | Total area – facades              | 17.74                         |
|                                          | Pavement width ≥ 2.2 m            | 4.85                          |
|                                          | Pavement width < 2.2 m            | 0.07                          |
|                                          | Pedestrian zone                   | 5.58                          |
### Project area Innerfavoriten - Kretaviertel

| Category                              | Greenable potential area [ha] |
|---------------------------------------|------------------------------|
| Consolidated area                     | 1.37                         |
| Private parking and traffic areas     | 4.65                         |
| Green area                            | 1.22                         |
| **Roof area**                         |                              |
| No soil contact – flat roof           | 10.19                        |
| Total area – roof                     | 4.2                          |
| 0° to 5°                              | 1.16                         |
| 5° to 15°                             | 3.91                         |
| 15° to 45°, no south exposition       | 0.92                         |

### 4. Conclusion

There is a need for supporting instruments to facilitate a more detailed survey of the potentially greenable area in the urban building stock on the neighborhood level. The study explored open source data for greening potential assessment and synthesised available applications. The presented approach is based on publicly available geo-data and was designed to enable the assessment of area potential for greening buildings on a larger scale. The results signify an advanced estimation of roof and façade based greening area potential and do not represent absolute values. They allow for more solid information on area potentials than provided in hitherto available instruments.

The numerous publicly available geo-data was a sound basis for the development of a GIS-based method. General information on the buildings (e.g. building outlines, location) is extensively available for the entire urban area of Vienna. The LOD2 3D model was used to calculate the gross façade area. In high resolution, the FMZK offers a lot of information on the surrounding land use of the buildings.

The presented approach allows for the creation of first indication maps, offering valuable information for planners and decision makers. However, it does not cover all necessary information on building requirements. The building characteristics were not or not extensively available as, e.g. referring to the building period of individual objects and their use, or are not provided in the required resolution.

The vertical greenable area potential is not yet recorded for the city of Vienna. Specific information on geo-data basis is lacking. In overall terms, a considerable need for geo-data is apparent to carry out an exact survey of the façade greening potential. The tested scheme needs further advancement since information on the structure, static condition and façade features is currently missing. The future integration of energy performance data and costs would be an additional asset for evaluation application on district level. An enhanced cadastre could further serve local authorities as decision support for green infrastructure development prioritisation and for financial support programs.

### References

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