Evaluating superblock design to enhance urban greening

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Abstract. Superblocks are an urban transformation strategy to create pedestrian-centric neighbourhoods. This study presents a methodological framework to assess the potential for urban green space (UGS) arising from superblock design. A quantitative assessment of the current state of UGS in superblocks is performed with geospatial analysis and earth observation techniques for a Swiss city. We find that UGS varies considerably across identified locations and decreases with smaller block sizes. Based on two scenarios, we illustrate how information on current UGS at the street or block level can be used to benchmark and assess urban greening potentials at superblock sites.

Keywords: urban greening, earth observation, alternative street use, NDVI, urbanism, density

1. Introduction
Superblocks were prominently proposed in Barcelona as an innovative approach to improve urban sustainability [1]. A superblock typically consists of 9 (3x3) urban blocks, interior as well as exterior streets (cf. schematics in Figure 2). Superblock design shifts the focus from car-based transportation to pedestrian or cycle-friendly street space and allows to transform interior streets, i.e. streets which are within the superblock [2]. This urban transformation strategy however not only provides opportunities to calm traffic or reduce noise but also to foster urban greening within cities. Urban green space (UGS) is rapidly shrinking in many cities around the globe [3] which is precarious as UGS provides multiple functionalities and plays a crucial part in urban wellbeing for people and animals alike. UGS has however gained increased attention with the ongoing urbanization of cities [4]. Also, the recent coronavirus pandemic triggered in many cities policies for transforming urban space. The quantification of the potential for urban greening at a high-resolution in urban spaces is ongoing [5–7] nevertheless, considering superblock design to enhance urban greening is lacking. This study assesses the potential of superblock design to foster urban greening for a Swiss case study. The current state of UGS is analyzed for potential superblock sites in Zürich with help of different data sources. The potential for additional UGS is quantified for different street transformation scenarios.

2. Materials and methods

2.1. Superblock identification
Superblocks sites are located based on network morphology, geometric properties and urban density as outlined in full detail elsewhere [8]. The individual square urban blocks in Barcelona forming a superblock (3x3) have an individual side length of ~115 m. Superblocks thus are ~400 m wide and
contain 4 intersecting street network nodes with four edges each. Street network geometry and typological characteristics are compared to the Barcelonan superblock, which are only allowed to deviate within a certain range to be considered as a potential superblock site. All major streets critical for local and regional traffic flow, as well as locations with low population density (100 inhabitants/ha) or low building footprint coverage (<30 %), are not considered as suitable for superblocks. To apply the superblock concept to Switzerland, also ‘miniblocks’ are considered, which are urban configurations consisting only of 2x2 urban blocks [8]. Including miniblocks enables to increase the potential number of sites for urban transformation. Urban blocks are generated by polygonising the street network and to derive super- or miniblocks from the identified street segments, adjacent urban blocks are merged.

2.2. Quantifying current UGS within blocks

Different data sources (a-d) were obtained to derive UGS for a case study city (Zürich, Switzerland) (Table 1): (a) shows the normalized difference vegetation index (NDVI) from the red and near-infrared band (NIR) of Sentinel 2 imagery with less than 30 % cloud coverage, using a median from 2016 – 2019 for April – October [12]. (b-c) are orthorectified multispectral SWISSIMAGE RS imagery (RGB+NIR) with different resolution and fly-over dates used to calculate NDVI values [10]. As suggested [9], NDVI values above 0.2 were selected to classify UGS and a classification scheme following Back et al. [10] was used. (d) a vegetation height model (VHM) combines a laser borne digital terrain model with stereo imagery whilst masking buildings [11]. (e) The SWISSIMAGE RS (b) dataset is combined with the VHM using its height information (h) for reclassification to obtain a combined dataset that allows differentiating between different types of UGS. Four vegetation classes are defined as follows: grass (0.2 < NDVI, h < 5 m), tree (0.2 < NDVI, h>5m), tree (VHM only) (0.2  > NDVI, h > 5 m), no green (0.2 > NDVI, h  < 5 m). The python packages rasterio and shapely are used for data analysis and processing. UGS are quantified within entire blocks and separately for street space only, which was defined using street geometries from the cadastre data.

| Resolution [m] | Description | Data source |
|----------------|-------------|-------------|
| a 10           | Sentinel orthophoto (2016 – 2019, April - October) | [11]         |
| b 1            | SWISSIMAGE RS, multispectral image (2013, June 13th) | [12]         |
| c 0.1          | SWISSIMAGE RS, multispectral image (2019, March 23rd) | [12]         |
| d 1            | Vegetation height model (VHM) 2019 | [13]         |
| e 1            | Composite dataset (combination of datasets b and d) | n.a.         |

Figure 1: Assessed UGS for an example superblock in Zürich, using the datasets a–e (Table 1).

2.3. UGS scenarios based on urban street transformation

We provide an explorative quantification of urban street transformation potentials towards greener neighborhoods using the superblock concept. Many cities have urban green coverage targets [14], which
can be used to derive UGS potential resulting from urban street transformation [4]. In a first scenario, we assume a minimum UGS target value of 40% for all street areas of super- and miniblocks. In a second scenario, we target a value of 80% UGS for all street areas of super- or miniblocks. This higher value was also suggested in other case studies to reduce urban summer heat and improve livability [15].

2.4. Sensitivity analysis for different scales of analysis
The effect of the spatial resolution is a common challenge in many types of analysis and has been widely studied [16]. This is of particular relevance for this analysis, as we perform high-resolution analysis within urban areas and available areal imagery have very different resolutions. To determine the effect of the raster resolution of our datasets, we systematically changed the raster resolution for an exemplary dataset (dataset c) and assessed the change in UGS for different raster resolution. For resampling, the python package rasterio was used. As smoothing algorithms (e.g. mean-based) would lead to a systematic bias and lower the NDVI values, a nearest neighbor resampling algorithm was chosen.

3. Results and discussion

3.1. Superblock identification
Overall 129 potential sites (42 superblocks, 87 miniblocks) were identified for the city of Zürich (Figure 2). The sites cover ~1000 ha (of which ~92 ha are street areas) and are spatially distributed across the entire city. While our preliminary assessment reveals that Zurich has considerable opportunities to enhance greening through superblock design, a detailed assessment regarding suitability or practicability for actual implementation in the context e.g. of urban mobility has not yet been carried out.

Figure 2: Overview of simulated super- and miniblock sites for Zürich, Switzerland. Even though the internal street length of miniblocks is generally smaller than for superblocks, the overall size of a miniblock may be larger in the case of large adjacent urban blocks used to form the miniblock.

3.2. Quantifying UGS at the block and street scale
Figure 3 depicts the distribution of classified UGS for the datasets in Table 1 for the entire block as well as for the street space. We note considerable variation in UGS across the different super- and miniblocks. Some outliers with very high UGS values are explained because parts of public parks were included in the automatically generated super- or miniblocks. UGS based on Sentinel data (a) are high, as the resolution of 10 m seems unable to capture buildings well and thus overestimates urban greening. Values for the SWISSIMAGE RS (c) are lower due to a fly-over time early in the year prior to leaf emergence. As expected, UGS values are typically lower when only considering the street space as typically street have less UGS than private land plots (Figure 3). The identified distinct differences in USG estimations
depend on the underlying data and methods, which highlights the importance of reflecting the chosen approach for UGS detection. We can draw several conclusion: First, the respective date of the imagery is critical to detect urban greening based on NDVI calculation, as vegetation has strong seasonal effects. The resolution also matters: To detect UGS within the superblock and even more at the level of street space within superblocks, a high spatial resolution is required (see Section 3.4 for more details). We argue that the advantage of using a dataset with repeated measurements across different seasons is to be preferred to a very high-resolution dataset (e.g. 0.1m) which may not be available for multiple time steps or has strong shading or perspective distortion due to low flight altitudes. Finally, we find that the rule-based quantification of different types of UGS based on NDVI values has several limitations. Classification errors were observed, i.e. roofs or other man-made structure were classified as vegetation due to e.g. shading and reflection effects. To improve classification results, machine learning approaches going beyond rule-based classification are suggested in the literature [17].

The quantified UGS is analysed more systematically for the super- and miniblocks in Figure 4. The large value ranges represent well the heterogeneous distribution of existing UGS in the city and within the corresponding street area. Our results indicate a higher percentage of UGS for larger blocks. This trend is however less pronounced if only street areas are considered. Outliers can be explained with the super- or minblock generating algorithm that sometimes includes rivers or railroad areas (resulting in low UGS values) or public parks (resulting in high UGS values).

**Figure 3:** Urban green space (UGS) as a percentage of the entire super- or minblock (left) and for the street space (right) for different data sources a – e (see Table 1). Whiskers depict the full value range.

**Figure 4:** The percentage of urban green space (UGS) for the super- and minblock (left) and its street area only (right). UGS calculations are based on the composite dataset (Table 1, e).
3.3. Urban greening estimations of greening scenarios
The current UGS in all super- or miniblocks is ~382.5 ha (of which 31.2 ha within the street area) (31.6 m² per inhabitant). The calculated UGS potential for the 40 % coverage scenario is an additional 14.8 ha (112 sites are greened) and 50.8 ha (all sites are greened) for the 80 % coverage scenario (cf. Section 2.1). The implementation of these scenarios would result in an average per capita UGS increase of 1.4 m² or 4.2 m² (40 % or 80 % coverage scenario) for the residents in all super- or miniblocks. It however needs to be noted that the quantity of UGS alone does provide a complete analysis. Also, the quality (e.g. structural diversity) of UGS needs to be considered as well as the location. For example, UGS in highly dense areas currently lacking urban green may be ecologically more valuable [18].

These two scenarios showcase how the current state of UGS and assumptions on UGS target values can be used to estimate the potential to enhance greening in cities. As in our case, we have assumed the implementation of all identified super- and miniblocks, the identified potentials represent the upper limit of urban greening enhancement through super- or miniblock design. In case of actual implementation, the potential may differ or be lower if not all super- or miniblock sites are considered.

3.4. Sensitivity analysis for different scales of analysis
Figure 5 shows the change in UGS for a systematically resampled areal image. The resampling reveals that a resolution of 10m (e.g. Sentinel) is clearly not providing good results. In contrast, a 1 m resolution from orthophotos is considered as fit-for-purpose at the super- or miniblock level. However, at the level of the street space, a higher raster resolution than 10 m is required to prevent large uncertainties resulting from the spatial intersection of the street geometry with the raster information. Therefore, not only the choice of data source affects calculated UGS, but also edge effects play a role, particularly for the analysis at the street level.

![Figure 5](image)

**Figure 5:** The spatial resolution of an exemplary raster dataset (dataset c in Table 1) is systematically decreased (resampled) from 0.1 to 20 m. The change in percentage of UGS is provided for all super- or miniblocks at the entire block-level (left) as well as for the street area only (right).

4. Conclusion
We have provided a quantitative assessment of urban green space in potential super- or miniblock locations based on geospatial analysis and earth observation techniques for a Swiss city. Our high-resolution analysis reveals the current state of UGS at identified locations for urban transformation by superblock design. Knowledge of the current state of UGS allows deriving the remaining potential for alternative street use to enhance urban greening. Detecting UGS enables to benchmark and estimate remaining UGS potentials for the superblock locations whilst considering further parameters such as urban density. We note a considerable spread and variation within existing urban blocks of the current
UGS in terms of percentage covered in green area or per capita UGS. The share of UGS within streets is generally lower than for the block. We also find higher UGS values with increasing block size. Our analyses reveal that estimating UGS for the street areas only is challenging due to the high required spatial resolution. The applied classification approach and introduced data combination enable to further distinguish between different types of UGS which could be used to refine this analysis. The presented assessment of UGS potentials is essential to inform most sustainable strategies for neighborhood transformation strategies for policymakers.

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