**Introduction**

**%Part1: Accessibility to UGS**

Urban population is growing worldwide. 55% of the global population were living in cities by 2018 and 68% are projected to do so in 2050 (UN 2019).

A growing urban population means increased pressure on urban ecosystems.

Ecosystems supply ecosystem services (ES) which are critical to human well-being (Fisher et al. 2019).

Living in proximity of urban green spaces (UGS) was found to have positive effects on mental health and physical activity as well as reduce mortality (Kabisch 2017?).

Thus, having access to UGS can enhance urban inhabitants’ quality of life (EU 2018, Poelman 2018).

Likewise, the United Nations have agreed to provide universal access to public green spaces by 2030 in the Sustainable Development Goal 11.7.

In Europe, 74% of the population are living in cities (UN 2019).

Here, the population pressure on UGS might be amplified by the compact city paradigm, which is popular among European city planners: A more compact city can result in shorter traveling distances but also in more overcrowding effects (Commission of European Communities, 1990; Burton, 2003).

Accordingly, more people living in proximity to and benefitting from an UGS also increase the pressure on its ecological functions (Wolff & Haase, 2019).

In order to detect such mismatches in green space supply and demand and to provide equal access to UGS, mapping UGS accessibility is key (Larondelle & Haase 2013).

The walkable environment – the space *in between* urban dwellers and UGS – affects the quality of ES and, thus, the accessibility of UGS (Syrbe & Walz 2012).

A proper modeling of UGS accessibility must, therefore, put emphasis on modeling the walkable environment of a city (Wolff 2021).

Yet, easy to use and open source tools for comparatively modeling the walkability of European cities are lacking (Kabisch et al. 2016, …).

**%Part 2: State of the art**

Availability and accessibility of UGS in Europe have been analyzed and compared in multiple studies.

In their 2016 paper, Kabisch et al. carried out an assessment of green space availability in 299 EU cities. They used a population grid of 1 km² and land use data (urban atlas) to calculate the population within a buffer distance of UGS (Kabisch et al. 2016).

In 2016, the Joint Research Center (JRC) of the European Union developed an indicator for areas that are served by UGS in European cities. In their analysis, the authors used a 10 m² resolution land use data grid and a 100 m² population mosaic and a network-based approach (European Commission, 2016).

In another analysis from 2018, the JRC used urban atlas data and a street network to assess the area that urban dwellers can reach in a walking distance of 10 minutes. Their analysis also resulted in an area per population measure on a city level (Poelmann, 2018).

In a 2021 paper, Wolff coupled the population pressure and proximity perspectives by applying network characteristics. In his analysis, he found two promising indicators, the Detour Index (DI) and the Local Significance (LS).

The DI is a measure of the efficiency of a route taken to reach a goal (Bathelmy 2018).

With the DI, barriers that people have to overcome on their way to UGS can be modeled (Wolff 2021).

The LS is a simple measure to describe the relevance of different edges of a network (Esch 2014).

To model use-intensity of those edges leading to UGS, the LS can be used as well. As a consequence, LS might serve as a spatial indicator for overuse of UGS (Wolff 2021).

Using fixed distances in assessing green spaces accessibility often lead to binary results of ‘having or not having access to UGS’ instead quantifying a mismatch between supply and demand (Wolff 2021, Dworczyk & Burkhard 2021).

We also saw mostly one perspective being used to assess green space accessibility (provision, pressure or proximity).

A high provision of UGS in a city, for example, does not necessarily indicate an equal or adequate distribution of UGS (Poelman 2018).

Accordingly, previous research did neither account for the mutual dependencies of supply and demand, nor did it put the focus on the walkable environment (Syrbe & Grunewald 2017).

In addition to the previous points, the mentioned studies, if on a larger scale, were carried out on a coarse resolution.

A fine resolution can reveal spatial patterns at a finer scale enabling targeted intervention.

A finer resolution will also reduce the uncertainty that is introduced if e.g. a grid or a city block aggregation is used as in urban atlas data (Bathelmy 2018, Esch et al. 2014).

All things considered, knowledge about green space accessibility is important for planning and decision making.

Modeling of the walkable environment with a combination of population pressure and proximity aspects of green space accessibility might prove promising to detect mismatches between UGS supply and demand.

No comparable studies using e.g. a building-based approach on a European scale

Improving the modeling of the walkable environment / service connecting area for urban green spaces (UGS) in European cities based on a proximity approach

Provide solutions for easy-to-handle / understandable indicators based on publicly available data and software

Develop an approach to combine high-resolution data with a comparative approach

**%Part 3: Objectives**

Modeling the *walkable environment* of European cities by including the three perspectives mentioned above and using a network characteristics approach.

We want to answer the questions:

What does a modeling approach look like that estimates the walkability between green space supply and demand in cities?

(How to incorporate publicly accessible data and open source software in order to allow i.) a reproduction over time (e.g. with more recent data), ii.) assessments in data-scare regions, and iii.) comparative approaches covering a larger sample of cities)

How can easily understandable and applicable indicators be used in order to support urban planning in detecting mismatches between demand and supply?

Our objectives are to develop modeling approach that applies walkability indices, to comparing the results on a European scale and to implement the indices by showing possible use cases for city planners.

**%Part 4: Conceptualization**

Availability and accessibility of UGS:

* + The availability of UGS can be defined by the “amount of green area in a defined distance to where urban residents live” (Kabisch et al. 2016).
  + Having actual access to UGS might be limited by additional factors, though.
  + The physical accessibility, for example, can be limited by fences, opening hours of an UGS, or the detours people have to take to reach them.
  + Additionally, accessibility may be limited by perceived overcrowding effects through population pressure (Kabisch et al 2016, Wollf et al. 2020).
  + As use intensity can influence ES, it can create a mismatch between supply and demand (Syrbe & Grunewald 2017).

SPA and SDA

* Since ES are rarely consumed by humans at the same place where they are produced by the ecosystem, we distinguish service providing areas (SPA) and service demanding areas (SDA) (Fisher et al. 2009, Syrbe and Walz, 2012).
* Service providing areas (SPA) represent the supplying side, the spatial unit where the ES are generated.
* Service demanding areas (SDA) embody the demand side, e.g. the place where people live (Dworczyk & Burkhard 2021).
* In the case of UGS in and urban environment, the UGS are the SPA and the residential areas or buildings are the SDA.

SCA = modeling space between SPA and SDA

* + In order to account for physical and perceived barriers to green space access, it is beneficial to take a look at the space between SPA and SDA (Syrbe & Walz 2012, Dworczyk & Burkhard 2021).
  + As stated above, also called the service connecting area (SCA),

Proximity = Modeling green space proximity in cities important (SCA for green space and population in cities)

* + Three perspectives have been used in past studies to tackle model the availability and accessibility of UGS:
  + The provision perspective looks at the flow from green area to buildings, thus, focusing on UGS provision (area / person).
  + Secondly, the pressure perspective describes the flow from residential buildings (i.e. the population) to the UGS.
  + The focus here lies on the pressure on UGS or the demand for green areas (person / area).
  + Lastly, the proximity perspective considers the space between supply and demand. (minimum or average distance). A proximity perspective is necessary to account for barriers and network characteristics like overcrowding effects. (Wolff, 2021).
* Furthermore, green space proximity measures have been found to be among the most important factors influencing perceived accessibility (, especially for minority groups) (Wang et al. 2015, Ibes, 2015).
* Mapping capacity, flow and demand of ES in urban areas has been found to facilitate urban planning (Baró et al, 2016).
* Using the Euclidean distance as threshold in spatial models has been found to underestimate spatial distances and to overestimate the provision of UGS in contrast to using network distance (Moseley et al. 2013, Sander et al. 2010).