05.09 Green Volume (Edition 2017)

Overview

Green volume is a **parameter used in landscape planning** denoted by the green volume number (GVZ). The GVZ was developed in Hamburg in the 1980s with the purpose of quantifying the required vegetation to be planted in binding numbers for landscape, green space and development planning (Schulze et al. 1984).

The GVZ measures the existence of three-dimensional vegetation bodies (trees, shrubs, grasses) present in one unit of area and is denoted in unit m^3 per m^2. In Berlin, this refers to both blocks and block segments shown in block map 1 : 5,000 (ISU5, Spatial Reference Environmental Atlas 2015) as well as to road segments.

The **functions of vegetation** are manifold. The following applies to many of them: the larger the green volume, the more pronounced its impact. The following functions are particularly important in relation to urban and landscape planning:

- dust binding,
- increase of evaporation,
- decrease of temperature,
- increase of small-scale air circulation,
- shading,
- habitat and biotope function,
- noise reduction.

Furthermore, green volume plays an important role in recreation, cityscape and landscape.

Comprehensive green volume data has been collected in multiple cities to date, e.g. by means of laser scanner data (Meinel et al. 2006a, Meinel et al. 2006b). In the Brandenburg state capital of Potsdam, the green volume number, along with biotope type mapping and the degree of imperviousness, is an integral part of its environmental monitoring carried out in a six-year cycle (Brandenburg state capital of Potsdam 2014). With the help of the impervious soil coverage and green volume parameters, the environmental status may serve as an indicator of quality of life and housing and the climatic burden on urban quarters (Arlt et al. 2005, State capital of Potsdam 2010).

Due to the climate change and **climate adaptation in the cities**, the green volume has become more and more important in recent years (cf. “Concept for Adaptation to the Impacts of Climate Change in Berlin” (AFOK) (Reusswig et al. 2016, SenStadtUm 2016a)). The diverse beneficial effects vegetation has, e.g. on the local climate, have been proven in a range of studies. The shading effect of trees, among other things, was hence investigated. Using the example of three sites, an Oxford research project demonstrated that the surface temperature of lawns and paved areas in the shade of trees was greatly reduced (by up to 13 K), as compared to that of unshaded areas. Furthermore, the project found that green volume has a direct impact on surface temperature. By increasing the green volume by 10 %, it is possible to reduce the temperature by 2.2 K (1961-1990) and 2.5 K (scenario 2080) (Gill et al. 2007). By increasing the green volume, the effects of climate change and urban climate (urban heat islands) can thus be counteracted and the maximum surface temperature decreased.

For Potsdam, green volume and imperviousness were confirmed to be relevant in influencing the temperature development within the context of climate adaptation. Based on a hot summer day with temperatures ranging from approx. 25 to 35 °C, it was demonstrated that each additional m^3/m^2 of green volume reduces the temperatures by about 0.3 K, while 1% (1 m^2/100 m^2) of additional imperviousness causes the temperature to rise by about 0.03 K (Tervooren 2015).

The distribution of green volume also plays a role in this (Mathey et al. 2011). Large, connected open spaces and parks have a more pronounced small-scale climatic effect and a slightly greater cooling effect on their surroundings than many smaller, scattered open spaces. At the same time, however, a dense network of smaller open spaces allows for easier accessibility, compensating for the above advantages. These effects can be explained applying the indicators “Cold air affect range within

settlement areas" and "Green spaces with high volume flow" (SenStadtUm 2016) of the summary Climate Analysis Map of Berlin.

Statistical Base

The Environmental Atlas Map "Building and Vegetation Heights" (06.10, 2014 Edition) (SenStadtUm 2014) data forms the basis for calculating the green volume number for all ISU5 blocks and road areas (Spatial Reference, Environmental Atlas 2015).

The Partial Map "Vegetation Heights" contains all vegetation areas in the State of Berlin indicating their mean vegetation height (Figure 1).

Basic data was collected in two aerial photography flight phases; one in early autumn 2010 covering the city centre and parts of the southern city area and the other in late summer 2009 covering the outskirts of the city. Thus, the green volume data was collected already 6 or 7 years prior to its analysis.

Due to changes in land use (e.g. by covering agricultural and fallow areas) or vegetation type (e.g. by succession of vegetation-free fallows that developed into meadows, shrubbery and trees) and the creation of new parks (such as the facilities at Gleisdreieck), the values stated here may have considerably changed in the meantime. In order to study individual cases, current aerial imagery is available for reference in the Geoportal Berlin. Furthermore, some errors due to methodology occurred in the vegetation data of the outskirts (e.g. of Grunewald and Spandauer Forst).

Both content-related and topological errors had to be rectified in the vegetation data before transferring the same to the ISU5 areas.

- Topological errors, such as multiple vertices, areas overlapping with themselves as well as overlaps within and between data sets.
- Vegetation areas with a height of 0 were generally assigned a height of 10 cm (corresponding to lawns, low-growing roof greening).

Rather than creating a 3D canopy model, a simple cylinder graph was used (Figure 1). As a result, the green volume has mostly been somewhat overestimated.

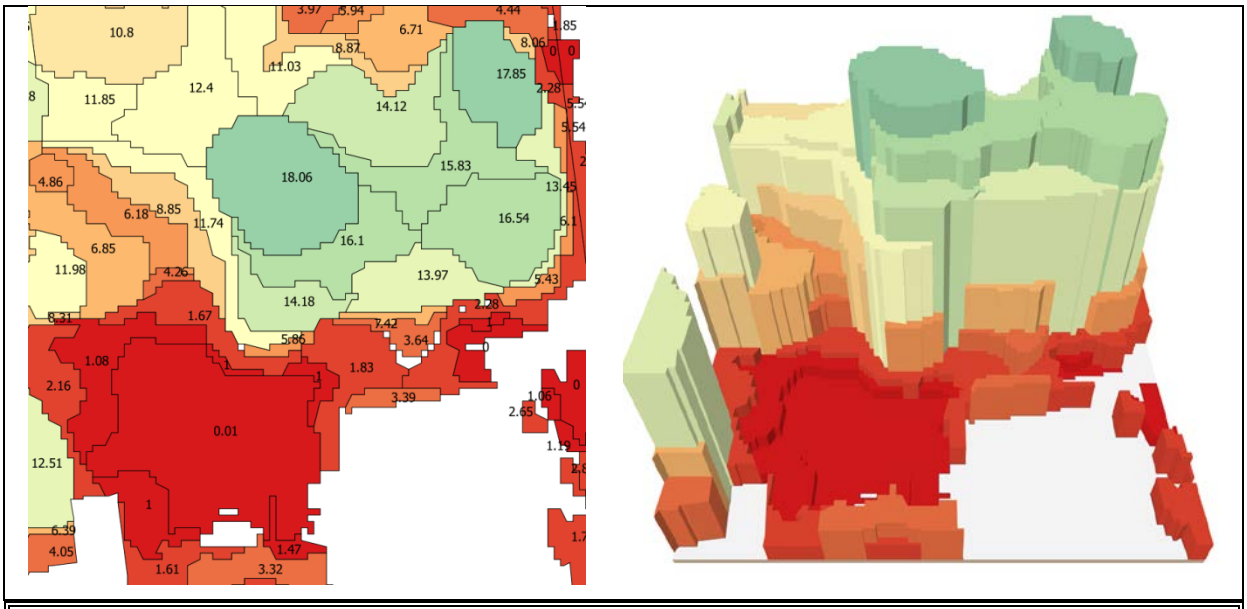

Fig. 1: Vegetation areas incl. height indicator (left) and 3D cylinder graph of vegetation (right)

The green volume of the non-built-up block area was determined using buildings above ground (main and auxiliary buildings) from the Automatic Register of Properties (ALK, as of January 2015) in addition.

Methodology

To calculate the green volume, the adjusted data sets of vegetation heights were intersected with the ISU5 areas (block, block segments and road areas) (intersections formed, Figure 2) and the vegetation data was transferred to the ISU5 areas by area.

Green volume of blocks, block segments and road areas

Each ISU5 area was used to trim each corresponding vegetation area. The area size of the trimmed vegetation area was then multiplied by its mean height (Figure 2) (= green volume of a trimmed vegetation area).

The sum of these for each ISU5 area yields the green volume of all individual blocks, block segments and road areas (m^3). Dividing the green volume by the respective area sizes (m^2) then results in the respective green volume number for each area (m^3/m^2).

The green volume number also serves as the mean vegetation height relative to the entire block / block segment or the non-built-up parts of the block / block segment or road area (m).

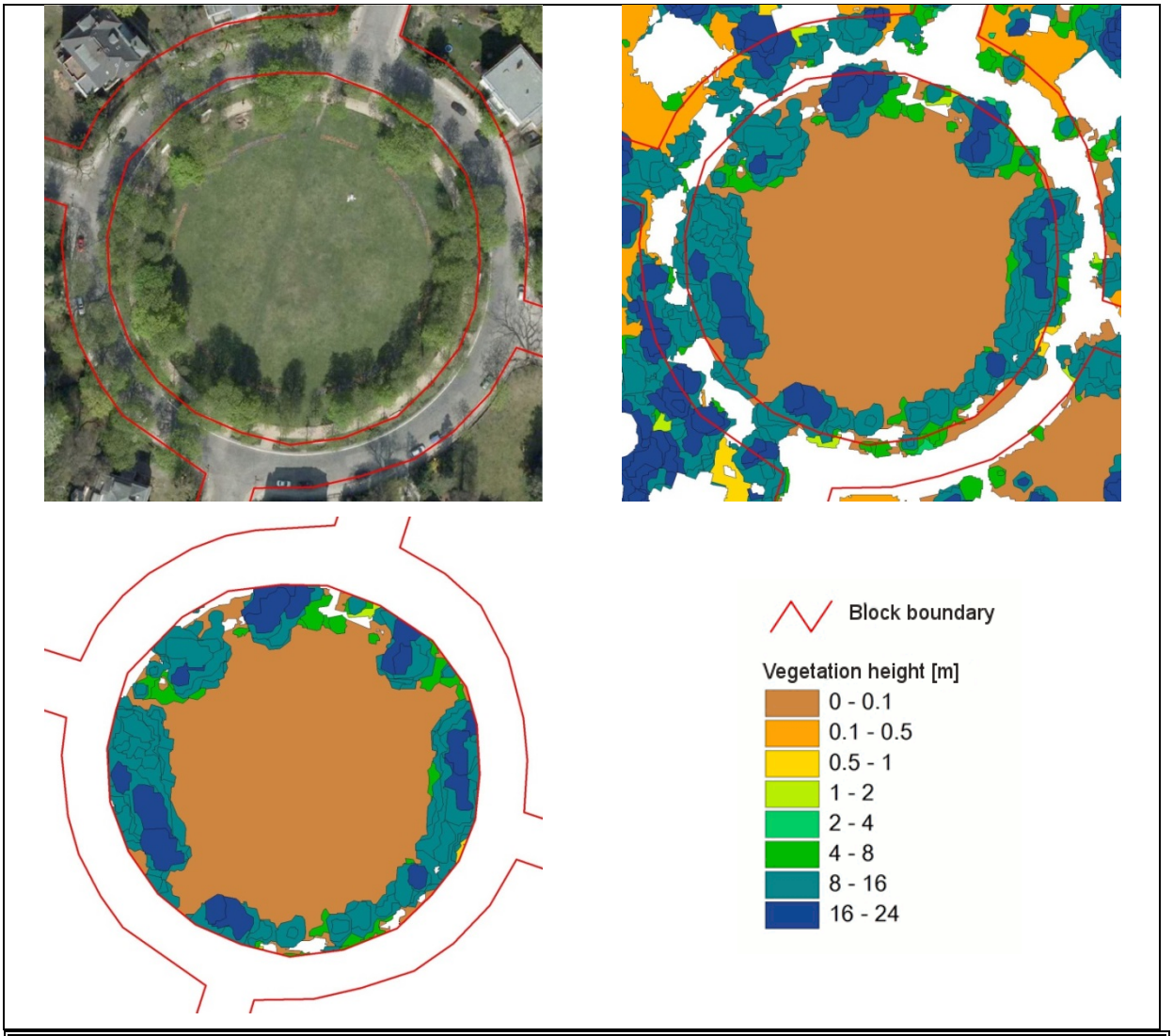

Fig. 2: Method for calculating the green volume (top left: ortho-photo with block boundaries; top right: vegetation areas with block boundaries; bottom: trimmed vegetation areas and legend)

Green volume of non-built-up parts of block and block segment areas

To determine the green volume of non-built-up block areas, the ALK buildings above ground (main and auxiliary buildings) were first assigned to their respective areas. These buildings were then used to trim the individual areas.

The vegetational stock assigned to the areas extend beyond the non-built-up parts (vegetation in road areas, canopies above building level and green roofs).

Trimming the vegetation share based on the non-built-up areas yields the desired vegetation of the non-built-up block and road areas (Figure 3).

The green volume was calculated further according to the process described above.

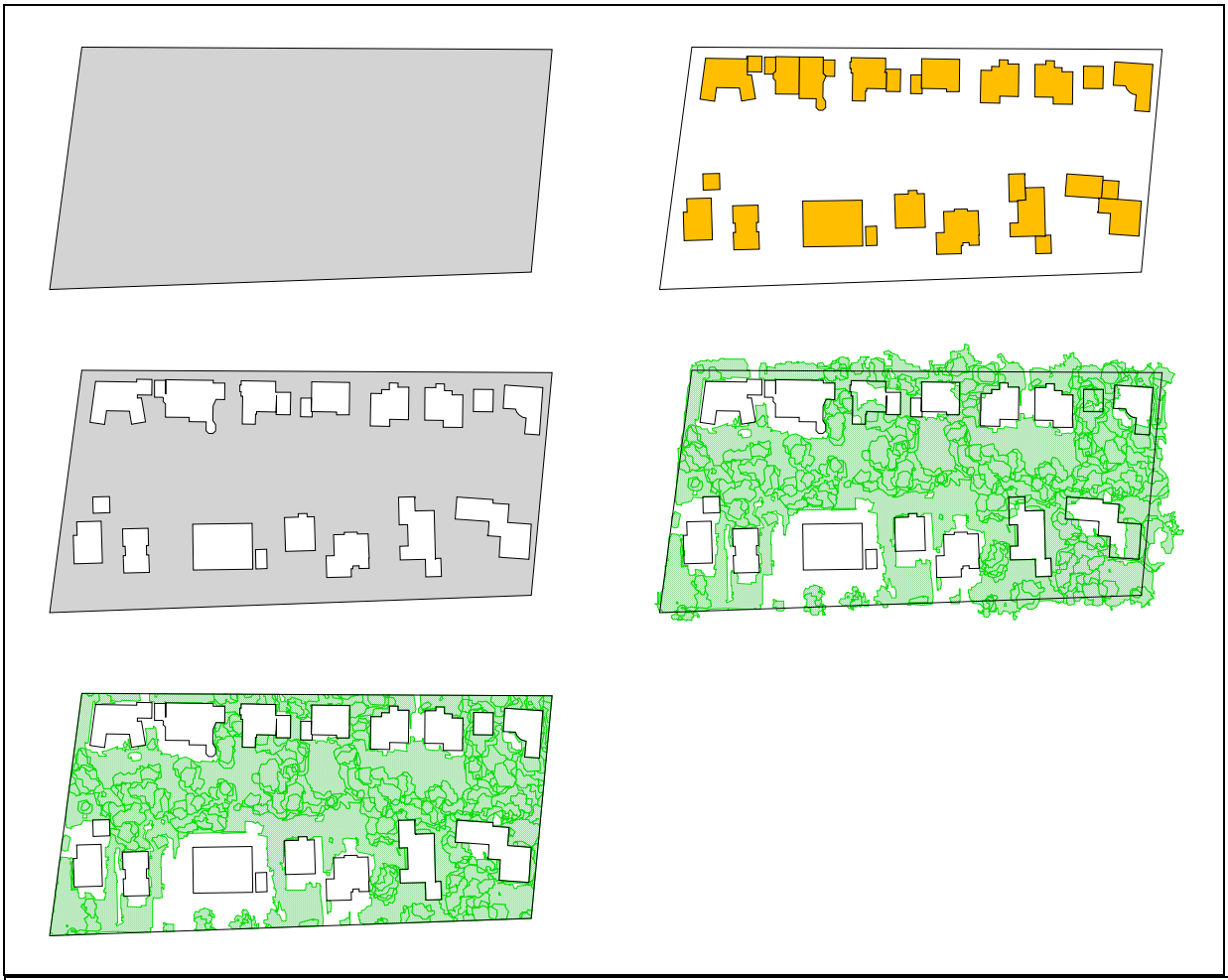

Fig. 3: Method to calculate the green volume of non-built-up block areas (top left: block area; top right: buildings above ground; centre left: non-built-up block area (grey share); centre right: vegetation cover; bottom: vegetation of the non-built-up block area)

Map Description

The map illustrates the green volume for blocks, block segments and road areas. As expected, the highest green volume numbers were recorded for Berlin's forest areas. Varying green volume numbers were also recorded within residential areas, however, which are described in more detail below.

In total, Berlin has a green volume of 4.877 km³, excluding bodies of water. This corresponds to an average green volume number of 5.8 m³/m². As expected, more than half of the green volume stems from forest areas (2.783 km³, 17.3 m³/m²). The built-up blocks and block segments house the least vegetation per area (2.6 m³/m²) as do the roads (3.1 m³/m²) (Table 1, cf. Environmental Atlas Maps 06.01 and 06.02).

Regarding the green volume of road areas, it should be noted that it is mainly roadside trees and vegetation, e.g. tree crowns, protruding from blocks and block segments that influence green volume calculations. Due to the cylinder graph used (cf. Figure 1), the green volume is often overestimated here, compared to other areas.

Tab. 1: Green volume of various use groups and road areas			
Use	**Green volume number [m³/m²]**	**Green volume [km³]**	**Share of green volume [%]**
Built-up area	2,6	976	20,0
Forest	17,3	2.783	57,1
Other green or open space	4,0	820	16,8
Roads	3,1	298	6,1
Berlin without bodies of water and roads	**6,2**	**4.579**	**93,9**
Berlin without bodies of water	**5,8**	**4.877**	**100,0**
Based on their use, 1,964 areas fall into both the built-up area and the non-built-up area category. For this analysis, it was the open space use that was considered for areas with dual use (green priority).			

Tab. 1: Green volume of various use groups and road areas

On closer inspection of the area type level, and especially the residential development, striking differences within the built-up area become evident. The green volume numbers of the total areas corresponding to residential blocks and block segments vary between 0.8 m³/m² for the area type "Core area" and up to 4.7 m³/m² for "Villas and town villas with park-like gardens" (cf. Table 2 and Figure 5).

Comparing the green volume numbers for non-built-up parts of residential blocks and block segments, however, the numbers for densely built-up area types also increase in some cases, which applies particularly to the following area types:

- "Dense block-edge development, closed rear courtyard, 5 - 6 storey",
- "Closed block development, rear courtyard (1870s-1918), 5-storey",
- "Closed and semi-open block development, decorative and garden courtyard (1870s-1918), 4-storey" and
- "Block-edge development with large quadrangles (1920s-1940s), 2 - 5 storey".

In relation to the entire block and block segment, these area types display a low green volume number. However, considering the non-built-up parts only, the green volume number rises sharply. This is mainly due to the existing old tree stocks, which occupy a large volume on a relatively small area (Figure 4).

Fig. 4: "Closed block development, rear courtyard (1870s-1918), 5-storey" incl. old tree stocks (left: example from Gipsstraße to Sophienstraße; right: example north and south of Zehdenicker Straße, Background: digital and coloured ortho-photos 2010 (DOP20CIR, pseudocolouring)

For area types with a more balanced ratio between built-up and non-built-up parts, there is little difference between the green volume numbers of the total block area and the non-built-up part. Furthermore, the green volume numbers are generally lower here than in densely built-up areas (Table 2, Figure 5). This is also related to greenery, which is often characterized by a high proportion

of low-growing vegetation or lawns (“green fringes”). The following residential area types of private and rental housing construction illustrate these conditions:

- “Rental-flat buildings of the 1990s and later”,
- “Row houses and duplex with yards”,
- “Detached single-family homes with yards”.

Forest tree estates constitute a special case within the overall green volume picture. These are estates that were built on Berlin’s forest edges. Their gardens and open spaces are characterized by stocks of old pine, oak and birch trees. The Berlin Landscape Programme identifies areas of forest tree estates along the Grunewald Forest, the Spandau Forest, in Gatow, in the Köpenick Forest, in Hermsdorf, Frohnau and Waidmannslust (cf. SenStadtUm 2016b). In contrast to residential areas built on former farmland areas (e.g. the ground moraines of the Teltow and Barnim plateaus consisting of bolder clay and marl), the green volumes differ significantly.

Tab. 2: Green volume number of area types and roads			
Area type		Green volume number [m³/m²]	Green volume number non-built-up [m³/m²]
1	Dense block development, closed rear courtyard, 5 - 6 storey	1,8	4,6
2	Closed block development, rear courtyard, 5-storey	2,2	4,3
3	Closed and semi-open block development, decorative and garden courtyard, 4-storey	2,9	4,5
6	Mixed development, semi-open and open shed courtyard, 2 - 4 storey	2,2	3,0
10	Block-edge development with large quadrangles, 2 - 5 storey	3,1	4,6
72	Parallel row buildings with architectural green strips, 2 - 5 storey	3,9	5,2
8	Heterogeneous inner-city mixed development, post-war gap closure	2,4	3,6
7	De-cored block-edge development, post-war gap closure	2,8	4,5
73	Rental-flat buildings of the 1990s and later	1,9	2,4
9	Large estate with tower high-rise buildings, 4 - 11 storey and more	2,9	3,6
11	Free row development, landscaped residential greenery, 2 - 6 storey	3,9	4,9
25	Densification in single-family home area, mixed dev. with yard and semi-private greening	3,9	4,8
21	Village-like mixed development	2,2	2,6
24	Villas and town villas with park-like gardens	4,7	5,6
22	Row houses and duplex with yards	2,1	2,6
23	Detached single-family homes with yards	2,6	3,0
59	Weekend cottage and allotment-garden-type area	2,7	2,9
29	Core area	0,8	1,5
31	Commercial and industrial area, large-scale retail, dense development	0,6	1,1
38	Non-residential mixed use area, dense development	1,5	2,4
30	Commercial and industrial area, large-scale retail, sparse development	1,3	1,7
33	Non-residential mixed use area, sparse development	2,2	2,9
32	Utility area	3,3	3,6
92	Railway station and railway ground, without track area	2,0	2,1
99	Track area	2,8	2,8
91	Parking area	2,6	2,7
94	Other traffic area	3,2	3,3
93	Airport	0,6	0,6
43	Administrative	3,4	4,0
45	Culture	3,7	4,3
41	Security and order	5,3	5,9
12	Old school (built before 1945)	3,6	4,7
13	New school (built after 1945)	3,2	4,0
44	University and research	3,4	4,1
47	Children's day care centre	5,0	5,8
51	Other youth facility	8,4	8,9
58	Camping ground	8,6	8,8
60	Other and miscellaneous public facility / special use area	5,3	5,8
49	Church	5,3	6,1
46	Hospital	5,8	6,9
98	Construction site	1,4	1,5
54	City square / promenade	3,9	4,0
17	Sport facility, covered	2,8	3,7
16	Sport facility, uncovered	3,1	3,3
36	Tree nursery / horticulture	1,9	2,0
37	Allotment garden	1,5	1,5
53	Park / green space	5,6	5,6
27	Cemetery	9,7	9,8
57	Fallow area	3,6	3,6
56	Agriculture	0,6	0,6
55	Forest	17,2	17,2
	Roads	3,1	3,1

Tab. 2: Green volume number of area types

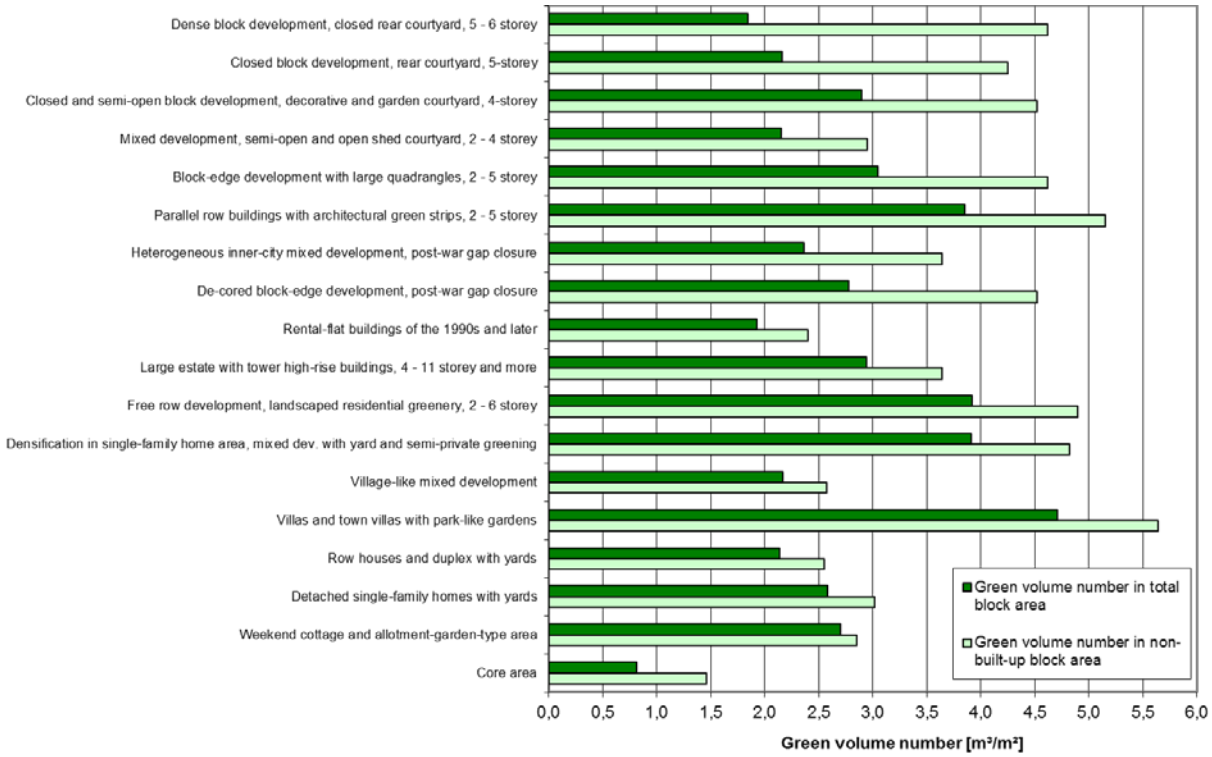

Fig. 5: Green volume number of residential area types

Figure 6 illustrates the distribution of uses at an aggregate level. The range of values for heterogeneous residential area types is discussed above. In this representation, the high values for non-built-up parts under “Cemetery” and “Public and special use” stand out in particular. Structurally, the cemeteries differ mainly in their tree population. Especially the forest and old park cemeteries influence the green volume number positively.

The “Public and special use” category displays the highest green volume number for built-up use excluding cemeteries. This is due to a large number of areas with a high proportion of greenery and trees, e.g. the Olympiapark and hospital locations with old tree stocks, which fall into this use type.

The relatively low green volume number of 1.5 m³/m² for allotments may be explained with the planting and management regulations, which prohibit the planting of large deciduous trees as well as decorative trees and shrubs. Parks and green spaces are at least partially characterized by trees and shrubs, resulting in the second highest green volume numbers, following those of forest areas.

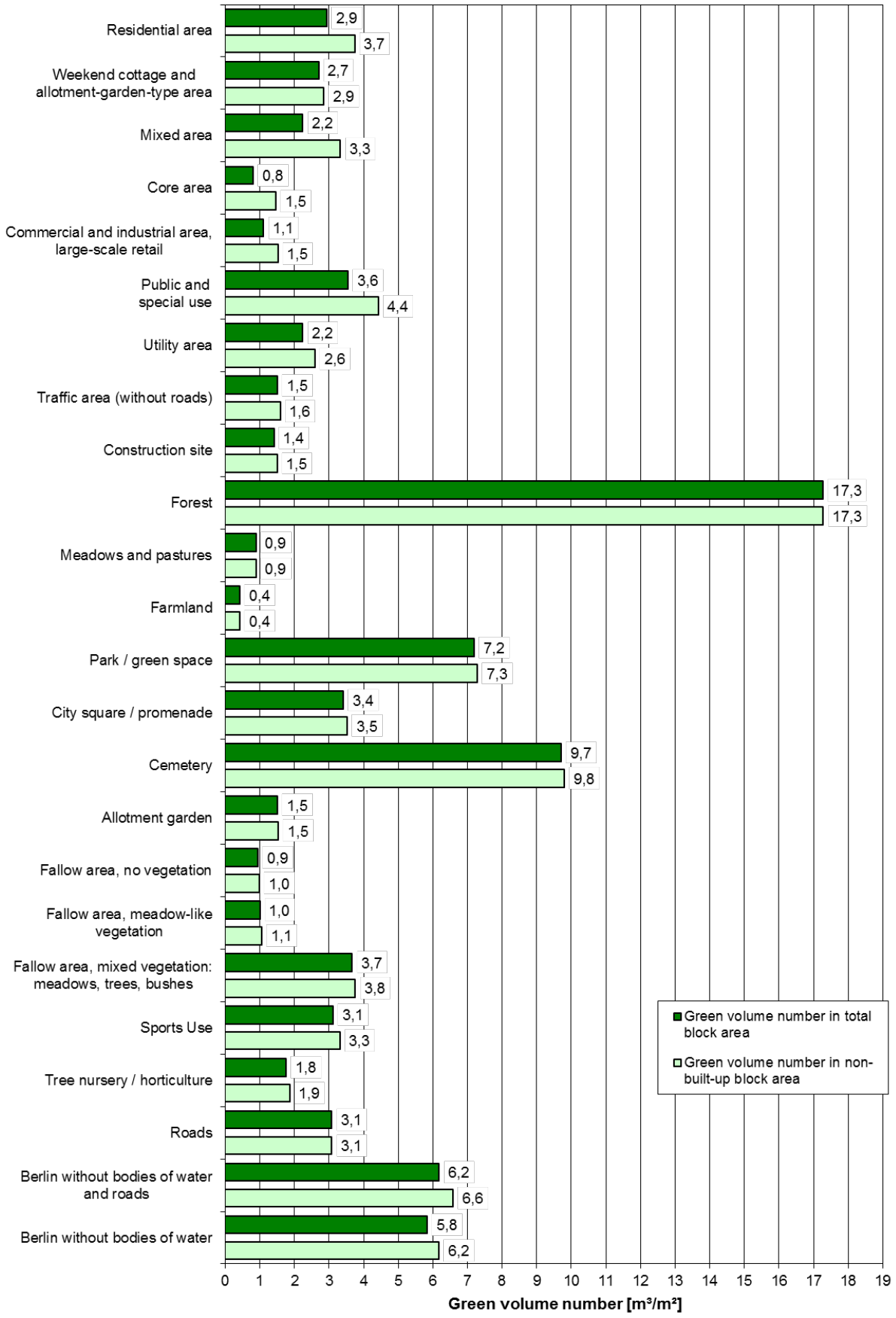

Fig. 6: Green volume number of various uses and roads

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