The consideration of the different values of public green space in urban development of Berlin after 1989

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For the quality of life of

Berlin’s

current and future

inhabitants.

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Main results of the research:

This study has revealed the politically motivated undervaluation of public green space in urban development of Berlin after the break through of the wall in 1989. It turns out as a mainly descriptive and segregated top-down evaluation approach of certain ecosystem system services instead of a comprehensive integration of the different values of urban green space in urban development. In being mainly monetary and short-time use orientated, it supports the deterioration of the living and working quality for Berlin’s inhabitants and biodiversity on its own. This refers in particular to the already highly densified inner city compared to the entire city of Berlin and to other European metropolises. A further severe democratic deficit are the insufficient participation opportunities for the public in decision-making of urban development which is mainly restricted to public hearings and surveys.

As a result of the second part of this investigation, the City Biodiversity Index (CBI) of the Convention on Biological Diversity (CBD) cannot serve as an alternative due to its deficits of reliable and validate indicators for the assessment of urban biodiversity. Nevertheless, a proposed new first set of 10 indicators would allow very rough practical assessments of urban green areas and other biodiversity parts between different cities in Europe and beyond. How this initial set of urban biodiversity indicators can be applied to Berlin and other metropolises at global level shall be left due its complexity and extent to further studies in comparison to what has been achieved already in urban planning abroad.

The key evaluation tool, however, is scientifically and democratically to apply bottom-up an existing interdisciplinary framework of the different values of biodiversity to urban planning which is based on participatory decision-making methods of the public directly and indirectly concerned.

Key points of the results of this research can be summarized as following:

- the moderate net population increase of Berlin is not the determining factor for the continuous deficit of public green urban areas in the inner city
- in particular urban brownfields have been converted to building grounds since the break through of Berlin‘s wall in 1989 above all due to the abolishment of thresholds to increase rents (rent control) and the speculative increase of real estate prices particularly in the inner city of Berlin
- the long-term economic and other values of public green space have been undervalued in Berlin's planning policy and strategies, in particular of non-use and non-monetary values through a schematically applied ecosystem services approach in urban and landscape planning
- Berlin has developed a high deficit of available public green urban areas per capita in the inner city parts relative to the whole core city in comparison with other European metropolises of more than 1 million inhabitants

- further densification mainly for housing is the political will which is contradictory to the unsolved problem of a high deficit of public green space and low share of private or semi-public open space, as well as the corresponding high degree of soil sealing particularly in the inner city of Berlin
- especially the poor, less mobile inhabitants, and migrants are most affected by the deficit of public green space within 500 m walking distance of a minimum size of 0.5 ha as landscape planning target of Berlin
- immigrants and inhabitants of low income (unemployed, inhabitants depending on social benefit transfer, and poor children) in the inner city had to face also stronger net migration rate than in the whole city of Berlin within 500 m walking distance of public parks of a minimum size of 0.5 ha
- there is politically a severe democratic deficit of public control through participatory decision-making of project driven urban planning decisions of the Senate of Berlin
- the democratic bottom-up movements are weakened when the social interconnections are lost due to the high turnover of inhabitants which can hinder the participation and optimization in decision-making of planning and project decisions in urban development in Berlin to integrate the different values of green space by the public directly and indirectly concerned
- the availability and quality of public accessible green space needs to be adapted to the personal needs of their neighbouring inhabitants and users, their demographic structure, economic and social situation
- Berlin's major urban planning tools and strategies lack scientifically of an already available transparent coherent and comprehensive biodiversity evaluation framework of the different values mentioned in the preamble of the Convention on Biological Diversity
- there is also scientifically a lack of indicators and survey and analysis methods related to common criteria and their underlying different values of urban green space as part of biodiversity for integrating their values comprehensively into urban planning tools and strategies in Berlin
- the schematically quantitative calculation of available public green urban areas per inhabitant and the mainly general description of the ecosystem services related to them are not sufficient indicators for considering the different values of public green space in urban development for the citizens concerned and urban biodiversity on its own
- the City Biodiversity Index (CBI) of the Convention on Biological Diversity does not sufficiently distinguish between completely different values of urban biodiversity, i.e. partly contradictory indicators with deficiencies of their reliability and validity
- a proposed first new set of 10 indicators for interdisciplinary evaluations of biodiversity

allows very rough practical assessments of the current status and development of urban biodiversity and its governance between different cities

- a representative monitoring needs to be established which covers the different abiotic and biotic urban biodiversity aspects including keystone and umbrella species, structures, functional relations and material flows of urban ecosystem types, as well as the dynamically developing human relations and values related to them

1. Introduction

Berlin has been in a unique situation in comparison to other European metropolises like London, Paris, and Bucharest. When in 1989 the wall was broken down under pressure for freedom by Eastern Germans, suddenly huge open space became available which was formerly neglected as no man's land within the former wall or adjacent to it on either side of Eastern and Western Germany. Likewise, an investors' run on the often public estates began such as at the almost completely built-up open space of the Potsdamer Platz, which was a central traffic point of Berlin before World War II (Zisenis et al., 2013).

Other European metropolises have experienced a similar densification of inner city areas before like London, Paris, and Bucharest. However, there is a limit to densification on the one hand, and the loss of living and working quality of citizens on the other hand (Haaland and Bosch, 2015; Westerink et al., 2013). Open green space provides several benefits for the public and on its own. These range from filtering air, reducing wind speed, recharging ground water, producing oxygen, providing habitats for species or serving as social meeting or psychological relaxation points, just to mention some examples (Gómez-Baggethun et al., 2013; Handley et al., 2003).

With a population of 4.2 billion in urban areas in 2018 (55% of the global human population) which is estimated to grow to 6.7 billion (68%) by 2050 while the rural population is expected to decline from 3.4 to 3.1 billion at the same time (UN, 2018). There is an urgent need for action to be taken in order to provide healthy living and working conditions, which are based on a number of factors including sufficient quality and quantity of green space as part of urban biodiversity. Health is understood as "...a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." according to the Constitution of the World Health Organization (WHO, 1946), which refers also to the psychological and social health values of public green space (Zisenis, 2006, 2009).

In the 28 EU Member States (EU-28), already 71.7% of the whole population lived in densely-populated and intermediate urbanised areas in 2012; thereof about 200 million in densely-populated areas and approximately 160 million in intermediate urbanised areas (Eurostat, 2014). These were 41.6% of the EU-28 population living in cities, 31.0% in towns and suburbs, and 27.5% in rural areas in 2014 (Eurostat, 2016a). It is necessary to have indicators for managing and monitoring the quality and quantity of green space as part of biodiversity in urban areas which cover the different values of biodiversity as mentioned in the preamble of the CBD for the direct and indirect benefits of humans, but also for the intrinsic value of urban biodiversity (CBD, 1992). Syrbe et al. (2018) provide an overview of different quantitative approaches to calculate the necessary urban green space per inhabitant and in total for a city, namely the proportion of green space per city area, per capita, the green space accessibility by linear distance or path length, the volume and tree canopy, as well as the degree of soil sealing.

Kabisch et al. (2016a) related the availability of green space in European cities to the urban population density in m² of a size of at least 2 ha within 500 m distance per capita per region for Western, Eastern, Southern, and Northern Europe respectively. They also calculated the share of the urban population within 500 m distance to green and forest areas of at least 2 ha, classified in tertiles, for each European city based on data of the Urban Atlas of the European Environment Agency. In addition, the share of available green space in each European city was calculated on the more coarse smaller scale based on Corine Land Cover data (Fuller and Gaston, 2009) related to the urban population development from 1990 to 2006 (Kabisch and Haase, 2013).

Wüstemann et al. (2016) calculated a mean distance to urban green space of 250.97 m in Berlin (median: 208.34 m; standard deviation: 196.97 m; min: 0 m to max: 1617.20 m) and at median 8.1 m² provision per inhabitant of green space within major German cities. The calculation was based on data of the European Environment Atlas of the European Environment Agency in 2011.

As a study example, Kabisch and Haase (2014) related the available green space in Berlin, as defined by the land use classes forests, parks, cemeteries, allotments, and brownfields with vegetation to the number of inhabitants per km², proportion of immigrants, and percentage of elderly of an age of more than 65 years. In their study, they assumed an increase of Berlin's population by 7.25% from 3,502 million inhabitants in the year 2001 to 3,756 million in 2030 according to the prognosis of the Senate of Berlin in 2012. Kabisch (2015) provides a general overview of ecosystem services which are mentioned in Berlin's urban development and strategy documents and interviewed a selection of stakeholders. Kabisch (2015) concludes that pressure on green spaces is caused by growing population on the one hand. On the other hand, financial constraints in managing urban green space and staff cuttings of planning authorities would hinder effectively implementing planning goals of green spaces in Berlin as well as communication barriers between the Senate of Berlin and the district authorities.

However, there is no evidence that the demographic population development is the crucial factor that determines the availability of public green urban areas in European cities. It is not clear how inner city areas differ on European scale in available public green urban areas from more suburban districts and the entire city. The major driving urban planning factors need to be revealed for the loss of green space in a society which is mainly economically determined. Berlin is a perfect study example, because there is a recent starting point in 1989 after the break through of Berlin's wall by the people which opened huge publicly owned open space for urban development. Berlin has a sophisticated, well established planning system over years to integrate green space as factor for the living and working quality in further urban development of the unified city. This refers in particular to the naturally grown ruderal urban nature on former no man's land and unused railway tracks due to the unique cruel separation since the construction of the wall in 1961.

Therefore, this research focuses first on the practical case study example of the city of Berlin to investigate to the extent to which the different values of biodiversity have been considered of public green space in urban planning after the break through of the former wall in 1989, which formerly divided the city of Berlin in two geographical parts and political systems (Chapter 2. The case study Berlin on page 13). The results were compared with the availability of public green urban areas in downtown city parts of other European metropolises (Chapter 2.6. Available public green urban areas in the inner city parts of other European metropolises on page 149). In a further investigation, the role of Berlin's citizens was analysed in having the opportunity to influence planning procedures with an impact on green space which are based on evaluations of biodiversity in the city (Section 2.4.5. Participation tools with an influence on planning decisions on page 56).

Moreover, I analysed also the concrete available spatial biophysical data of public green space and socio-economic spatial data of inhabitants of Berlin's Environmental Atlas in walking distance within the inner city S-Bahn circle and the whole city of Berlin, namely of public parks, public accessible managed green areas/parks, allotments, and cemeteries (Chapter 2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin on page 57). This resulted in a discussion of the integration of the different values of public green space into major planning tools and strategies of urban development in Berlin (Chapter 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin on page 153).

Democratic urban planning deficits are highlighted for the city of Berlin of the participation of the people on the ground in decision-making for the long-term living and working quality in urban areas, which is currently rather limited to hearings. Urban development is understood as a dynamic and interactive process which should be led by participatory planning to include the demands, knowledge and support of the wider public. It turns out from this research that there are also severe scientific deficits of missing indicators and a comprehensive transparent, reliable and validate biodiversity evaluation framework for integrating the different values of green space as part of urban biodiversity into planning decisions for sustainable urban development in Berlin (Chapter 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin on page 153).

Therefore, this research introduces the international context of the City Biodiversity Index (CBI) as proposed key indicators' tool by the Convention on Biological Diversity (CBD) for the evaluation of biodiversity of urban areas (Chapter 3. The international context of measuring urban biodiversity through a City Biodiversity Index (CBI) on page 153). I analysed then critically whether the proposed indicators of the City Biodiversity Index are comprehensive, reliable and validate for assessing biodiversity in urban areas and whether they can function "…as a monitoring tool to assist local authorities to evaluate their progress in urban biodiversity conservation." (CBD, 2012a). Thereby, I discussed the conceptual approach to the proposed urban biodiversity indicators for the evaluation of biodiversity in urban areas within the main structure of the CBI indicators of "native biodiversity", "ecosystem services", and "governance and management".

As a result of this critical analysis, I proposed a first set of 10 alternative structural, functional, and material indicators for evaluations of urban biodiversity (Section 3.3. Proposal of a first set of 10 alternative indicators for evaluations of urban biodiversity on page 169. These were related via common evaluation criteria to the different supporting, provisioning, regulating, and cultural ecosystem services for which they are indicators (Table 16 on page 170). Furthermore, I suggested quantifiable cardinal or classified ordinal measurements for each indicator to allow spatially comparing urban biodiversity values of different cities for science-policy implementation and urban landscape planning (Table 16 on page 170). Finally, I discussed the practical application of these 10 structural, functional, and material indicators for evaluations of urban biodiversity for governance, project and planning processes (Section 3.4. Discussion of a new first set of indicators for evaluations of urban biodiversity on page 175).

Conclusions synthesise the outcomes of this research of the mainly monetary drivers of the deficits of urban green space in Berlin as a study example for other European metropolises (Chapter 4. Conclusions on page 177). They call for an integrative participatory ecosystem approach of evaluations of urban biodiversity and decision-making which is based on the different values of the Convention on Biological Diversity for sustainable urban development. This democratic bottom-up approach needs to be supported by a representative monitoring of abiotic and biotic components and the human relations to them of the different values of urban biodiversity. The first pragmatic set of newly recommended 10 "umbrella" urban ecosystems' related structural, functional, and material indicators can help comparing the performance of European metropolises in integrating the different values of green space as part of urban biodiversity into urban development.

2. The case study Berlin

Berlin was selected as case study example, because of its various opportunities to use the recovered open space after the break-through and abolishment of the wall around West-Berlin in 1989. In contrast, other European metropolises had already passed an inner densification and suburbanisation such as highly densely built-up London, Paris or Bucharest. The development of the area of green space, in particular in downtown Berlin, is commonly used as indicator of the different values of biodiversity to be integrated in urban planning systems for people's urban quality of life and working environment as well as for urban nature on its own. It can be assumed that green open space became particularly under pressure to be converted into building grounds for new constructions after the administrative unification of Berlin in 1990.

Therefore, the first part of the case study Berlin investigates the planning system, as well as the major planning tools and strategies which integrate the different values of green space (Section 2.1. Planning system on page 14). Second, the planning strategies and historical development of public green space were analysed for Berlin over time since 1989 (Section 2.3.1. Planning strategies after the breaking down of Berlin's wall by the public in 1989 on page 18). Results of a mainly text analysis of Berlin’s major green space planning tools and strategies provide an overview of the values and criteria which were used to assess green space in Berlin (Section 2.3.2. Overview of applied values and criteria of Berlin’s major green space planning tools and strategies to assess green space on page 21).

In addition, empirical data of prices of real estates and rents were analysed as main drivers for the pressure on the already existing deficits of public green space in Berlin since the fall of Berlin’s wall and reunification (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24). The development of the deficits of public green space was highlighted (Section 2.4.1. Deficits of public green space on page 32) and the proportion of different land use categories calculated in the inner S-Bahn circle of Berlin in comparison to the whole city since 1989 (Section 2.4.2. Development of green space over time after the breaking down of the wall in 1989 on page 41). In addition, the proportion of soil sealing as indicator was compared of the different districts of Berlin over time since the break-through of Berlin’s wall (Section 2.4.3. Degree of soil sealing on page 46). Other socio-economic and environmental factors were sorted out which influence the accessibility of public urban green space in practice (Section 2.4.4. Social and further environmental factors on page 53). Furthermore, the participation tools were analysed to the extent to which Berlin's citizens have the opportunity to influence directly urban planning decisions with an impact on urban biodiversity for their living and working quality (Section 2.4.5. Participation tools with an influence on planning decisions on page 56).

In the second part of the study, available spatial data indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin’s Environmental Atlas were analysed to investigate the difference between the inner city of Berlin and the whole city within walking distance of their inhabitants (Chapter 2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin on page 57). This concerned biophysical spatial data (microclimate, soil functions, vegetation volume, and hemeroby of biotope types), as well as social and economic spatial data of inhabitants. The results were discussed with regard to distinguish between public green space in the inner city versus the whole city of Berlin and the socio-economic demands of its population of inhabitants within walking distance (Section 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin on page 158).

In the third part of the case study Berlin, the current availability of public green urban areas in downtown Berlin was compared to downtown city parts of other European metropolises of more than one million inhabitants (Section 2.6. Available public green urban areas in the inner city parts of other European metropolises on page 149).

This research of the case study Berlin was based on available urban planning literature of the Senate of Berlin and an analysis of published official statistics, in particular of geometric data of Berlin's Environmental Atlas (Senate of Berlin, 2017a) and spatial data of the European Environment Agency (European Environment Agency, 2014).

2.1. Planning system

Berlin's planning system consists of urban planning and landscape planning levels respectively (Fig. 1).

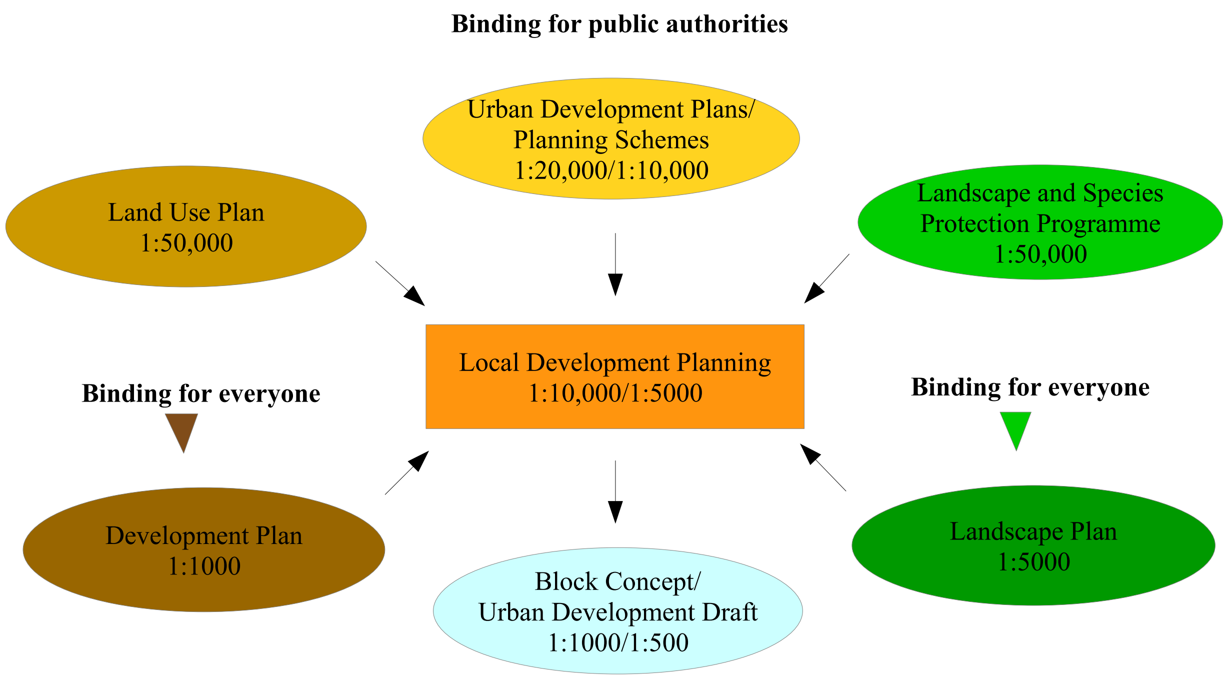


Fig. 1 - Berlin's urban planning and landscape planning levels (BA Marzahn-Hellersdorf, 2005).

At different scale, urban planning provides the basis for buildings and constructions while landscape planning contributes to the green part of the urban environment. In the Federal States' system of Germany, urban planning and landscape planning are theoretically equal on national level. However, there is no urban planning nor landscape planning scheme on national level in Germany, but the Federal states determine legally and practically the cooperation between the two planning tools. In Berlin, regulations in landscape plans are not allowed to be contradictory to those in development plans (NatSchGBln, 2013). Thus, the land use type and size of constructions are determined by development plans. Just the outer surfaces and surroundings of the buildings can be managed for biodiversity purposes according to the landscape plan. Both, however, are legally binding for the wider public whereas the preparatory Land Use Plan, particular Urban Development Plans or other planning schemes, and the Landscape and Species Protection Programme are only binding for public administration (Fig. 1). The Local Development Planning is an integrated planning tool of urban planning and landscape planning (Senate of Berlin, 2011a). The Block Concept/Urban Development Draft concretises the urban development on block scale. Both integrative planning levels are not legally binding for the public, just for public authorities (Fig. 1).

2.2. Major planning tools and strategies to integrate the different values of biodiversity

Berlin's major urban planning tools and strategies were analysed according to the interdisciplinary framework of the different values of biodiversity (Zisenis, 2006, 2009) as mentioned in the preamble of the Convention on Biodiversity (CBD, 1992), instead of the intransparent and anthropocentrically biased evaluation system of ecosystem services (Section 3.2.2. Ecosystem services on page 162).

2.2.1 Berlin's Landscape and Species Protection Programme

Berlin's Landscape and Species Protection Programme is structured in five parts (Table 1).

Table 1 - Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a).

Natural balance and environmental protection	**Habitat and species protection**	**Landscape scenery[1]**	**Recreation and use of open space**	**City-wide compensation concept**
- air	- biotope[2] types	- spatial structures, features, and design of open space and open areas	- generally accessible open space (open space and local recreational areas nearby housing and estates)	- compensation areas for impacts on nature and landscapes
- climate			- limited accessible open space (sports fields, allotments, cemeteries, protected areas, etc.)	
- soil			- private/semi-public open space (gardens, distance space between houses, and courtyards)	
- ground and surface water				

The underlying values of urban biodiversity are not particularly mentioned in Berlin's Landscape and Species Protection Programme, but they can be deducted from analysing its text and map parts (Senate of Berlin, 2016a, 1994a). It turns out that Berlin's Landscape and Species Protection Programme mainly focuses on use values, in particular as basis for urban life (natural balance and environmental protection), open green space and areas for sensory (landscape scenery) and recreational purposes (recreation and use of open space), as well as flora & vegetation, and to a limited extent fauna and biogeographical features (target species, biotope types) for ethical reasons (habitat and species protection). However, the ecosystem and related biodiversity values are unclear of these selected target species. Their function shall be the connection of habitat patches or corridors as umbrella species, but their biodiversity values for Berlin's citizens are not considered

[1] Landscape scenery is understood as the perception of the environment by all senses (Senate of Berlin, 2016a, 1994a).
[2] Biotopes as habitats for biocoenosis. Biotope mapping is based on mainly vegetation type and land use mapping, but less on animal species (Schulte et al., 1993, 2003).

(Senate of Berlin, 2016b). In addition, there are areas indicated for general compensation of negative impacts on nature and landscapes on mainly existing green space (city wide compensation areas) (Senate of Berlin, 2016a, 1994a).

The update of Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a) emphasizes that Berlin had to deal with a continuous growth of inhabitants for which housing needs to be enforced while taking into account the principles of a co-ordinated and sustainable urban development. Areas for compensation of impacts on nature and landscapes are neither sufficiently concretised nor quantified. They are mainly located in existing green corridors or green spaces, in particular in the inner city areas of Berlin (Senate of Berlin, 2016a, 1994a). Furthermore, it is possible to compensate the loss of the different values of biodiversity for Berlin's inhabitants, visitors and nature on its own in the inner city areas far away in the suburbs or even beyond (NatSchGBln, 2013).

The same analysis of the biodiversity values was carried out for Berlin's Land Use Plan, Urban Development Plans, and the integrative Local Development Planning in Berlin as following.

2.2.2 Berlin's Development Plans

Berlin's Land Use Plan indicates land use areas of a high content of greenery and open space for recreational purposes and other purposes, in particular the size and volume of construction parts for infrastructure and building types for housing, commerce, and public services as main purpose. There are even some relics of agricultural land use left in the suburbs (Senate of Berlin, 2015a, 2016c). The text and map analysis shows that use values are also predominant in Berlin's Land Use Plan. Natural balance and environmental protection of air, soil, and water, borders of nature reserves, green and open space, and recreational areas are determined or taken over from other legal designations, as well as the World Heritage Sites of housing areas as protected culture-historical values (Table 2).

Table 2 - Biodiversity values' relevant designations of Berlin's Land Use Plan (Senate of Berlin, 2015a).

Open space, water expanses	
Green space	Field, open land, and meadow
Park	Sport
Cemetery	Water sport
Allotment	Camping
Woodland	Agricultural field
Water expanse	
Use restrictions for the protection of the environment	
Landscape characterization of housing areas	World Heritage Site
Priority zone for air pollution control	Water protection area
Planning zone for settlement restrictions	EU Habitats Directive Natura 2000 site/landscape protection area/nature reserve

Borders of the open space protection act of the former airport Berlin-Tempelhof	Contaminated soils

Urban Development Plans exist for industry and commerce, climate, traffic, supply and disposal, housing, and centres (Senate of Berlin, 2015b, c). The Urban Development Plan Climate recognizes the value of green space for microclimate mitigation, water infiltration, and groundwater recharge (Senate of Berlin, 2011b). Contrary, the Urban Development Plan Housing foresees a densification potential for housing of 116.100 apartment units in the inner city areas, and 100.000 apartment units in the outskirts of Berlin on open space such as allotments of a size of 1 ha or more. Although it recognises the conflict of densification with sufficient open green space for climatic reasons (Senate of Berlin, 2014a, 2016d).

The most integrative planning level of Berlin is the Local Development Planning of urban and landscape planning. For instance, the more general land use focused Local Development Plan of the central district “Mitte” of Berlin (BA Mitte, 2004) is complemented by sectoral plans on green and open space, current social infrastructure, retail and centre concept, as well as housing and potential housing (BA Mitte, 2014). However, also the sectoral plan on green and open space of “Mitte” is limited to simply land use designations of green and open space with theoretical lines of green corridors between them without specifying their different biodiversity values (BA Mitte, 2008). Another example is quite similar of the Local Development Planning of a district towards the suburbs of Berlin, the District of Berlin Lichtenberg (BA Lichtenberg, 2007).

2.3. Historical development of the integration of the different values of green space into planning decisions

2.3.1. Planning strategies after the breaking down of Berlin's wall by the public in 1989

Similar to the concept of Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a, 1994a), the explaining text part of Berlin's Land Use Plan of 1994 was recently partly updated (Senate of Berlin, 2015a, 1994b) as well as the corresponding map (Senate of Berlin, 2016c). However, different new planning instruments were created after pressure and speculation on Berlin's green and open space began to rise since the fall of Berlin's wall in 1989 (Colomb, 2012). The Planning Concept Inner City was adopted by Berlin's Senate and taken note by Berlin's regional parliament in 1999 (Senate of Berlin, 1999a). Accordingly, the priority was set on densification of the inner city area of Berlin instead of building on the outskirts. Above all, private housing estates, offices, and shops were built to an extent and density of a “recreative use of existing green space” that residential green space and metropolitan parks as well as aeration for urban climate conditions are considered and optical axes shall be preserved (Senate of Berlin, 1999b). Berlin’s Building Lot Management has complemented the Planning Concept Inner City of small potential housing grounds (Senate of Berlin, 2016e). In practice, this meant that the former existing weighed up planning instruments (Fig. 1), developed over several years with different stakeholders, were overlaid with the new Inner City Planning Concept and Berlin's Building Lot Management for densification of an intended "compact city".

The Inner City Planning Concept foresaw several new building grounds in the inner city area on existing open green space (Senate of Berlin, 1999a, b) which were successively realized over time. For example, 47 town houses from 4.50 m to 9.75 m wide of five floors each were built for luxury prices of more than EUR 1 million of 300-400 m² floor space each along the Friedrichswerder on a former green belt that led to the square Spittelmarkt (Sauerbrei, 2010). The planning successor is the Inner City Planning Concept 2011, but comparable planning concepts were also developed for Berlin's West (2004), Northeast (2006), and Southeast (2009) (Senate of Berlin, 2011c).

The Senate of Berlin adopted Berlin's Biodiversity Strategy in 2012 which among others intends to develop parks and other public green urban areas within the context of their historical diversity. Natural succession shall be allowed as possible and more natural extensive management carried out of private green space. It points out many targets for involving the state's procurement, as well as private companies and business to enhance the possible experience of urban nature, among others, for the young and elder, education, and research (Senate of Berlin, 2012a). However, Berlin's Biodiversity Strategy still lacks concrete measurable quantified action targets with an allocated budget and responsibility.

Similar deficits in implementation can be concluded for Berlin's Local Agenda 21. It was adopted by Berlin's parliament in 2006 as guideline for Berlin's future policy with some concrete measures. For instance, ecological farming should be supported for the food supply of public institutions in Berlin, and soil sealing limited. However, it still lacks the political will for a concrete fundamental change towards sustainable urban development of Berlin. Apart from some realized model projects such as subsidies for greening of backyards in some districts, allotments for migrants, or designations of green space as nature experience areas (Senate of Berlin, 2009).

Berlin's Urban Landscape Strategy, adopted by the Senate of Berlin in 2011 (Senate of Berlin, 2012b), is structured in three generic urban development guidelines of "beautiful city", "productive landscape", and "urban nature". It repeats the concept of mainly use values of green space, including the cultural-historical values of garden monuments[3], but introduces also the general importance of green space for social hotspots as "psycho-social compensation areas". Garden monuments and urban green areas of city importance are descriptively valued for the culture-historical identity and for tourists. Streets, squares and parks are recognized as being valuable for social interactions. Social values of green space are mentioned such as of community and intercultural gardens, but also combined with educational values of children farms, adventure playgrounds for children, forest schools, school gardens, open air laboratories, and nature experience areas. The culture-historical values are generically mentioned of farming grounds, as well as the cultural values of open air cinemas and stages on green space. Sport grounds are recognized as psychological values for self-determined skating and dirt jumping. Public initiatives are welcomed to take over money saving maintenance tasks of public urban green areas from local district administrations, as well as public initiatives for temporary private use for economic, social,

[3] § 2 (4) DSchG Bln: "A garden monument is a green area, a garden or park, a cemetery, an avenue or any other witness of gardening and landscaping, ...", which is protected as cultural garden heritage by law.

and educational values as mentioned above.

However, brownfields are just considered in Berlin's Urban Landscape Strategy as potential areas waiting for new constructions on them. Their different biodiversity values are neglected, among others, as habitat for invertebrate and vertebrate species (Sukopp et al., 1984; Sukopp, 1990; Klausnitzer, 1993; Gardiner et al., 2013; Sukopp and Wittig, 1998), for the ruderal flora and vegetation (Sukopp and Werner, 1983; Sukopp et al., 1984; Wittig, 1991, 1998; Sukopp, 1990; Wittig et al., 1998), and for citizens (Andres and Grésillon, 2013; Mathey et al., 2015; Gebhard, 1998; Wittig and Zucchi, 1993; Wittig, 2011). Furthermore, green space is considered as potential for investors and young entrepreneurs to exploit their economic values for providing gastronomic, social, cultural, and health services such as beach bars. The productive use components of green space are emphasized. Apart from harvesting food and drinking water as economic value, green space is also considered for water regulation, biomass harvesting and solar panels with positive influence on the micro- and macroclimate. The biodiversity values of urban nature are generically mentioned for the use of recreation and experience as psychological (health) values, as well as habitat for species as ethical values.

Berlin's Urban Development Concept 2030 (Senate of Berlin, 2015d) proclaims to have considered opinions of about 2,500 citizens in a public consultation process of more than 1,000 individual contributions and further stakeholder workshops of more than 500 contributions of about 400 participants in a continuing process in 2015 (Senate of Berlin, 2015d). As a result: "...The city itself will be characterised by density tempered by a sense of proportion. Inward growth and the reclaiming of dead sites will have preserved space. Berlin will be green with large spaces dedicated to leisure and recreation, meetings and movement. ..." (Senate of Berlin, 2015d). Thus, open (green) space is considered as being dead to be used for urban development and densification of inner city areas: "...In comparison to other major European cities, Berlin possesses a wealth of potential development sites both inside the city and at its margins. Against the backdrop of current population forecasts for 2030, this space offers huge scope for development and can be employed, depending on location, for various uses: as land for new housing, sites for new companies and open spaces for a variety of temporary and permanent projects involving new and sometimes unconventional forms of activity. ..." (Senate of Berlin, 2015d).

Even cemeteries have been successively converted into building grounds and other commercial and infrastructural use according to Berlin's Cemetery Development Plan (Senate of Berlin, 2006a, 2016f). 290 ha (28.0%) of 1037 ha legally designated cemeteries in Berlin shall be closed due to a decrease of mortality and an increase of cremation instead of inhumation burials of Berlin's population. The planning purpose is to release approximately 81 ha (27.9%) for commercial building and construction purposes and to keep 209 ha (72.1%) as green space/woodland/cemetery park. 57% of the foreseen 290 ha conversion area was in public ownership of the State of Berlin and 43% was confessional property in 2014. For instance, 104,577 m² of legally designated cemeteries shall be converted in the central district "Mitte" of Berlin. 22,485 m² were already converted in "Mitte" by 31 May 2014. None shall be preserved as cemetery park (Senate of Berlin, 2016f).

Contrary to the foreseen conversion in practice for commercial constructions of about 81 ha (7.81%) of the total area of cemeteries in Berlin, Berlin's Cemetery Development Plan highlights the cultural-historical values of cemeteries, particularly of designated garden monuments and other historical monuments and arts and craft of graveyards. Apart from the practical main use as burial grounds, it points out the outstanding value of cemeteries for contemplation and recreational purposes of Berlin’s inhabitants, particularly in the inner city of Berlin. Berlin’s Cemetery Development Plan recognizes the importance of cemeteries for the urban climate and other biophysical purposes and as important habitat for fauna and flora. Cemeteries are seen as an important part of the network of green spaces and biotopes in Berlin (Senate of Berlin, 2006a).

The Allotment Development Plan points out the importance of allotments for the living quality in the residential neighbourhood, particularly for elderly people for recreational use and relaxation as well as for children to experience and to understand nature in the city. The social values of allotments are emphasised for the cooperation and human exchange of different social classes (Senate of Berlin, 2004). Around 250,000 inhabitants cultivate allotments in Berlin (Koch-Klauke, 2017). Allotments play a crucial role in the network of green spaces in Berlin for (climatic) compensation and recreational functions. Moreover, allotments are seen as retreat areas for fauna and flora. It is the intention to secure allotments permanently in sufficient extent by Berlin’s Senate and the House of Deputies for urbanistic, social and health benefits of Berlin (Senate of Berlin, 2004, 2014b).

Three fourth of allotments of in total 2990.1 ha are owned by the State of Berlin. However, only 411.8 ha (13.8%) are permanently protected by development plans (Senate of Berlin, 2015). In practice, they shall be partly converted for housing, commercial, and services development particularly in the privileged located inner city areas and fringes (Senate of Berlin, 2004, 2014b). Allotments have therefore faced a similar planned conversion development as cemeteries contrary to their expressed biodiversity values by the Senate of Berlin. About 1600 allotments were already lost in Berlin from 2004 to 2014: 30% for new housing estates and equally 30% for road constructions, 25% for business parks, and the rest for other development projects (Koch-Klauke, 2017).

2.3.2. Overview of applied values and criteria of Berlin’s major green space planning tools and strategies to assess green space

I analysed also the text parts of the different major green space planning tools and strategies of Berlin to comparably sort out and to visualize in an overview which common evaluation criteria and related biodiversity values (Zisenis 2006, 2008) were particularly used to assess green space in Berlin’s major green space planning tools and strategies. I used an ordinal classification scheme of 1 to 5 for the classified assessment of the consideration of the different biodiversity values and criteria by each urban planning tool and strategy (Table 3; Zisenis, 2006, 2008).

Table 3 - Legend of the ordinal classification of the different biodiversity values and common evaluation criteria which are used in Berlin's major green space planning tools and strategies (Zisenis, 2008).

Degree of application/ Degree of concretised implementation	**Ordinal classification mark**

Extensively	5
A lot	4
Moderate	3
Low	2
Very little	1

Table 4 shows the results of the classification of the text parts of major urban and landscape planning schemes in Berlin.

Table 4 - Ordinal classification of the different biodiversity values and common evaluation criteria to evaluate green space in Berlin's major urban green space planning tools and strategies.

Used biodiversity values and related criteria/Major urban green space planning tools and strategies of Berlin	Landscape and Species Protection Programme	Land Use Plan	Biodiversity Strategy	Urban Landscape Strategy	Local Agenda 21	Urban Develop-ment Concept 2030	Cemetery Develop-ment Plan	Allotment Develop-ment Plan
Ethical	4/2	3/2	4/1	2/1	4/1	1/1	3/1	2/1
Economic	1/1	4/2	1/1	2/1	4/3	4/1	4/2	4/2
Psychological (including health)	4/2	4/2	4/1	4/1	4/2	4/1	4/1	4/1
Culture-historical	3/2	3/2	2/1	3/1	1/1	1/1	4/2	2/1
Social	1/1	1/1	2/1	3/1	2/1	1/1	1/1	3/1
Educational	1/1	1/1	2/1	1/1	2/1	2/1	1/1	2/1
Scientific	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
Rarity and endangerment	4/2	2/1	4/1	1/1	1/1	1/1	2/1	2/1
Naturalness/ degree of human impacts	4/2	2/2	4/1	2/1	3/2	1/1	1/1	1/1
Typicalness	4/3	2/2	3/1	1/1	1/1	1/1	2/1	1/1
Vulnerability	2/1	2/1	1/1	1/1	1/1	1/1	1/1	1/1
Re-establishment ability	2/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
Ecological	4/2	4/2	3/1	3/1	4/3	4/1	4/1	2/1

functions								
Usability	4/2	5/2	4/1	4/1	4/2	4/1	5/2	5/2

Note: The ordinal classification marks are the result of the analysis of the extent of the use of the different values of biodiversity and their commonly used related criteria versus the concretion of them in the respective text of each of Berlin's major urban green space planning tool and strategy.

Mainly recreational (psychological, health) values were a lot considered in all urban and landscape planning schemes of Berlin. Ethical values were also a lot taken into account in Berlin’s Landscape and Species Protection Programme, Biodiversity Strategy, and Local Agenda 21. However, there is a clear tendency that Berlin’s purely urban development planning strategies (Urban Landscape Strategy, Urban Development Concept 2030) did consider to a much lower extent ethical values of urban green space and their fauna and flora.

Economic values of urban green space were mainly a lot applied in Berlin’s Land Use Plan, Berlin’s Local Agenda 21, Berlin’s Urban Development Concept 2030, Berlin’s Cemetery Development Plan, and Berlin’s Allotment Development Plan. Berlin’s Land Use Plan concretised to a low extent economic values of urban green space in competition with other land use types for the projected economic and population growth. The Local Agenda 21 referred among others moderately to economic aspects of land use management such as certified forestry. The Cemetery Development Plan saw released burial grounds mainly as potential estates for commercialisation as well as the Allotment Development Plan.

The Urban Landscape Strategy and the Allotment Development Plan included in their consideration also moderately social values of urban green space. Culture-historical values could be moderately found in assessments of urban green space in Berlin’s Landscape and Species Protection Programme, Land Use Plan, Urban Landscape Strategy, and a lot in Berlin’s Cemetery Development Plan particularly regarding protected garden monuments. Educational values were of low or very little importance in assessments of urban green space in all urban and landscape planning schemes, even less the only marginally assessed scientific values.

There was a clear tendency visible to apply a lot common evaluation criteria of biodiversity to assess the quality of urban green space, particularly rarity and endangerment, naturalness/degree of human impacts, and typicalness in Berlin’s Landscape and Species Protection Programme, as well as in Berlin’s Biodiversity Strategy. Typicalness was applied to a moderate extent in the latter. Nevertheless, the usability of green space was the most considered criterion. It was extensively or a lot applied in all investigated urban land use and landscape planning tools and strategies of Berlin. The evaluation criterion ecological functions was also a lot or moderately used in all urban land use and landscape planning schemes apart from a low extent for allotments, although rather limited to different (biophysical) ecosystem services than regarding biological processes. However, the practical degree of concretion of all evaluation criteria of green space in Berlin was low or very little, except of being moderate regarding the criterion ecological functions by the Local Agenda 21.

The linkage between common evaluation criteria and the related biodiversity of values was weak. There was no comprehensive evaluation framework detectable of the different values of green space as part of urban biodiversity in Berlin. Furthermore, there is a lack of indicators and survey and analysis methods of these common criteria and values of urban green space. The individual evaluation of the sites of urban green space was rather intransparent and segregated for the different values and criteria. Survey and analysis methods of natural sciences and humanities were widely missing of the particular biodiversity values and evaluation criteria of urban green space. The texts repeated more or less in the different urban and landscape planning schemes schematically well-known sectoral benefits of urban green space over time without weighing them up for particular planning decisions. It was unclear why certain sites were designated as urban green space or missing for other land uses within this planning context of urban growth and development. It is not mentioned nor justified which role in particular each urban green space preferably played for its surroundings and Berlin as a whole. This means that also the scale of assessment of each urban green space was unclear. One reason is the widely lack of quantitative assessment data of the different values of urban green space, apart from some quantified measures in Berlin’s Local Agenda 21.

2.3.3. Prices of real estates and rents as main drivers with an impact on green space

Berlin's current urban planning strategy does not differ much from the approach of the first “gold rush” speculation after the break through of Berlin's wall in 1989 when investors from all over the world came to the city searching for profitable building projects (Colomb, 2012). For example, Urban Development Areas were created for a surface area of about 950 ha (Senate of Berlin, 2007), based on the same prognosis of rapid population growth and economic prosperity of the city of Berlin as nowadays. In the end, EUR 1.56 billion public tax money was invested in contrast to only about EUR 407 million revenues from selling the real estates (Paul, 2007). In practice, the net population increase of the city of Berlin in 10 years was just by 3.35% (113,500) inhabitants from 3,388.4 million in 2001 to 3,501.9 million in 2011 or by 3.60% (128,800) in 25 years from 3,446.0 million in 1991 to estimated 3,574.8 million in 2016 respectively (Amt für Statistik Berlin-Brandenburg, 2017a) (Fig. 2).

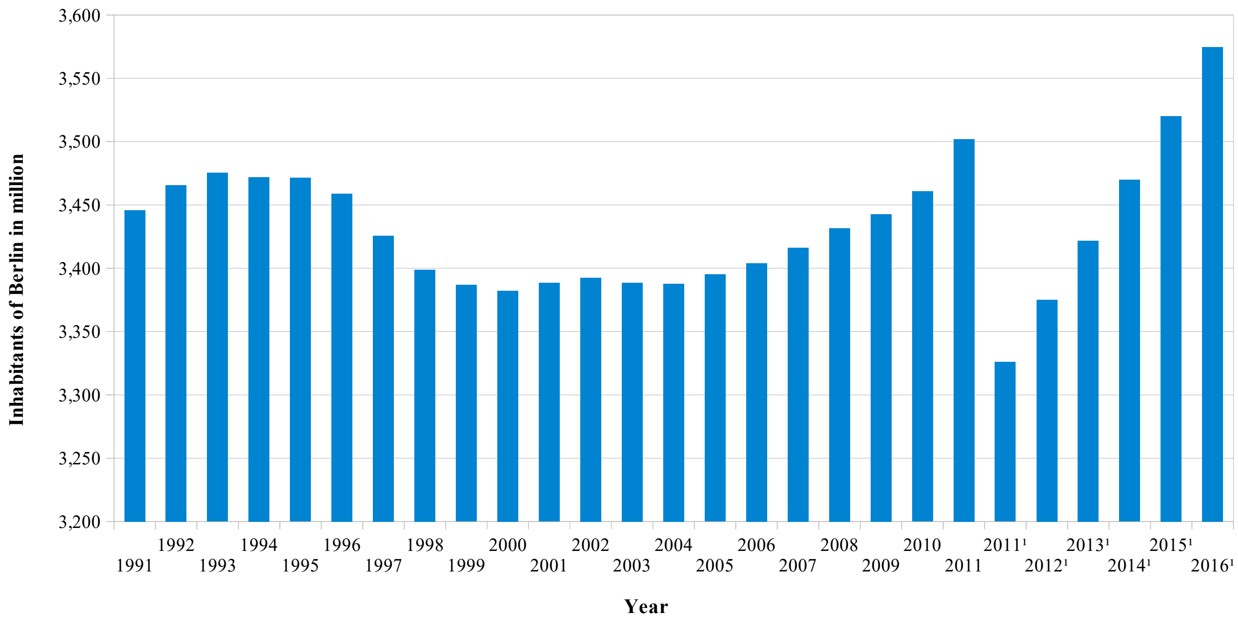


Fig. 2 - Berlin's population development from 1991-2016 (Amt für Statistik Berlin-Brandenburg, 2017). Note: 1 – provisional prognosis for 2011-2016 based on the population census in 2011; corrected figures for 2011-2013.

The number of apartments increased in Berlin by 9.79% (168,656) from 1,723,142 in 1991 to 1,916,517 in 2016 within the period of 25 years, which was combined with an increase by 18.1% of available room from 33.8 m²/inhabitant to 39.9 m²/inhabitant by 2016 (Amt für Statistik Berlin-Brandenburg, 2017b). However, the average net cold rent[4] increased in the meantime by 30.25% from EUR 4.00 to EUR 5.21 from October 1999 to October 2010 (Fig. 3), i.e. about 14 times as much as the net increase of inhabitants of the city of Berlin within the same period of time by 74,000 (2.19%) from 3,386.7 million inhabitants in 1999 to 3,460.7 million inhabitants in 2010 (Amt für Statistik Berlin-Brandenburg, 2017a) (Fig. 2). 18.33% was the increase of the index of the net cold rents in Berlin from 2005 to 2016 (Statista, 2018) while the net inhabitants increased just by about 5.29% (179,600) from 3395.2 million in 2005 to estimated 3574.8 million in 2016 (Amt für Statistik Berlin-Brandenburg, 2017a), i.e. less than one-third during the same period (Fig. 4).

[4] Without running costs such as heating and electricity.

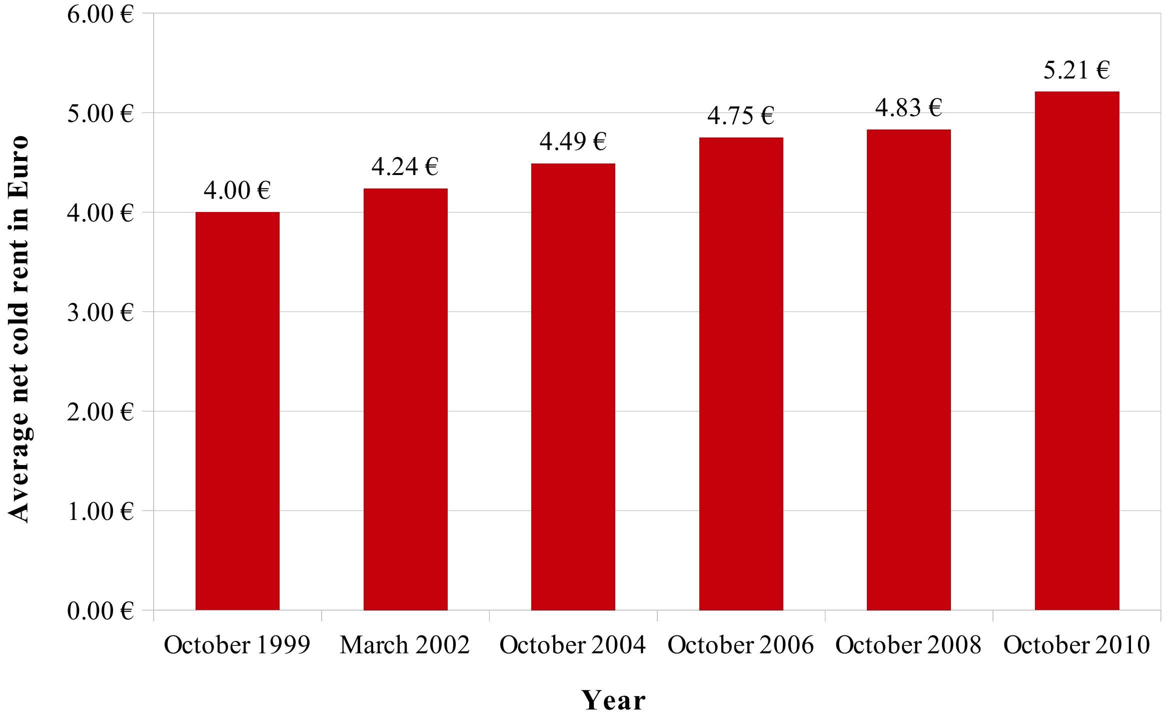


Fig. 3 - Development of the average net cold rent in the city of Berlin from 1999-2010 (Senate of Berlin, 2011d).

There has been an increase notified by 20.58% of the index of the net cold rents in Berlin from 2005 to 2017, i.e. at average by 1.72% per annum from 2005 to 2017 (Fig. 4).

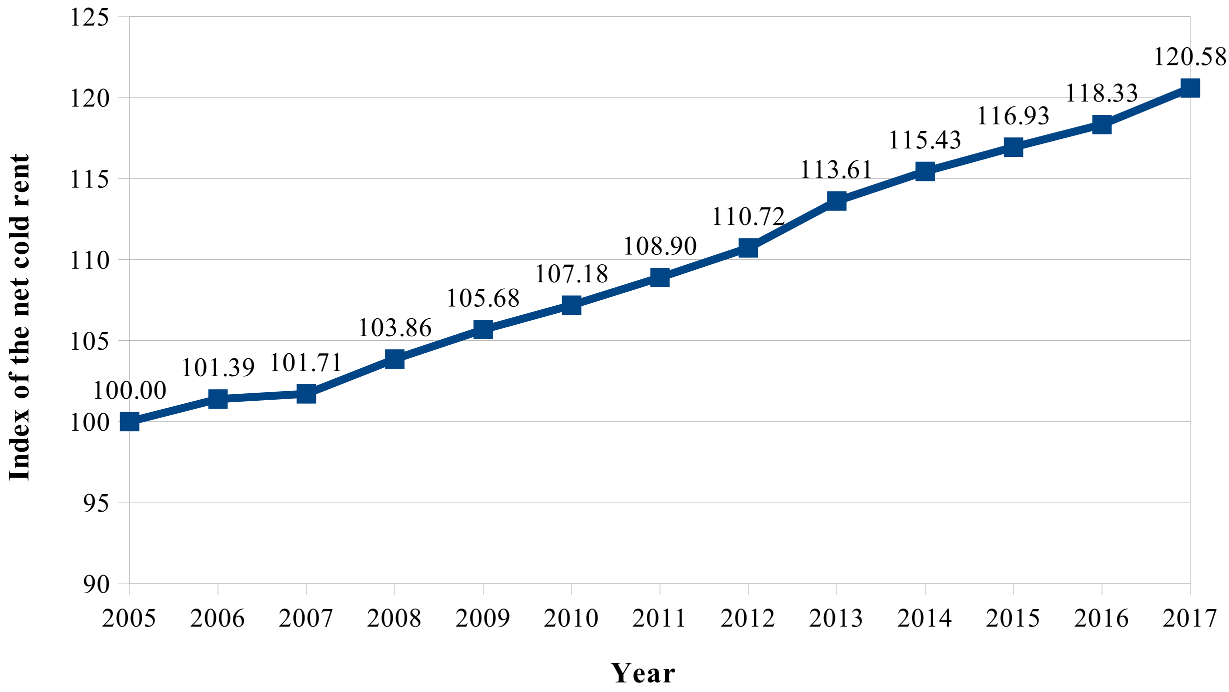


Fig. 4 - Increase of the index of the net cold rent in Berlin from 2005-2017 (Statista, 2018). Note: The starting point is an index of 100 of the year 2005.

The reason can be found in the abolishment of thresholds to increase rents (rent control) in Western Berlin in 1988 (Hentschel, 2008) as well as of the state controlled housing market in the former German Democratic Republic of the other Eastern half of the city.

An increase can be notified also of the median (Fig. 5) and arithmetic mean (average) (Fig. 6) standard land value of Berlin's estates of building grounds from 2002-2018, in particular within the central district “Mitte” of Berlin (Fig. 7 and Fig. 8). At median, there was a rise in “Mitte” with an emphasis on housing from 530€/m² to 2350€/m² (343.40%), for mixed (building) areas from 1300€/m² to 5000€/m² (284.62%), and for core (building) areas from 3400€/m² to 7000€/m² (105.88%) from 2002-2018 (Fig. 7).

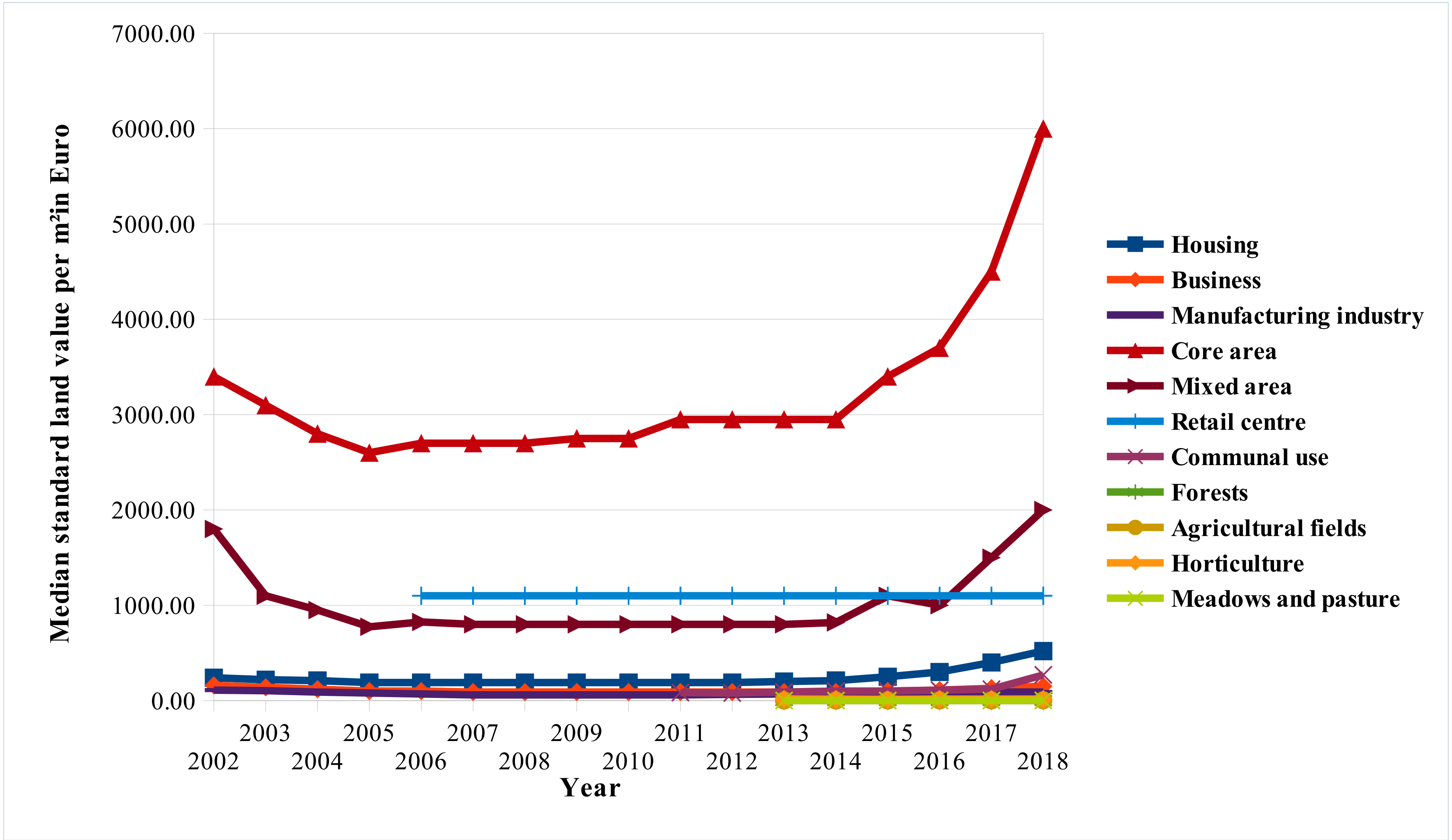


Fig. 5 - Median standard land value per m² of the city of Berlin from 2002-2018 (own calculation based on data of the Gutachterausschuss für Grundstückswerte in Berlin, 2018; Senate of Berlin, 2017a).

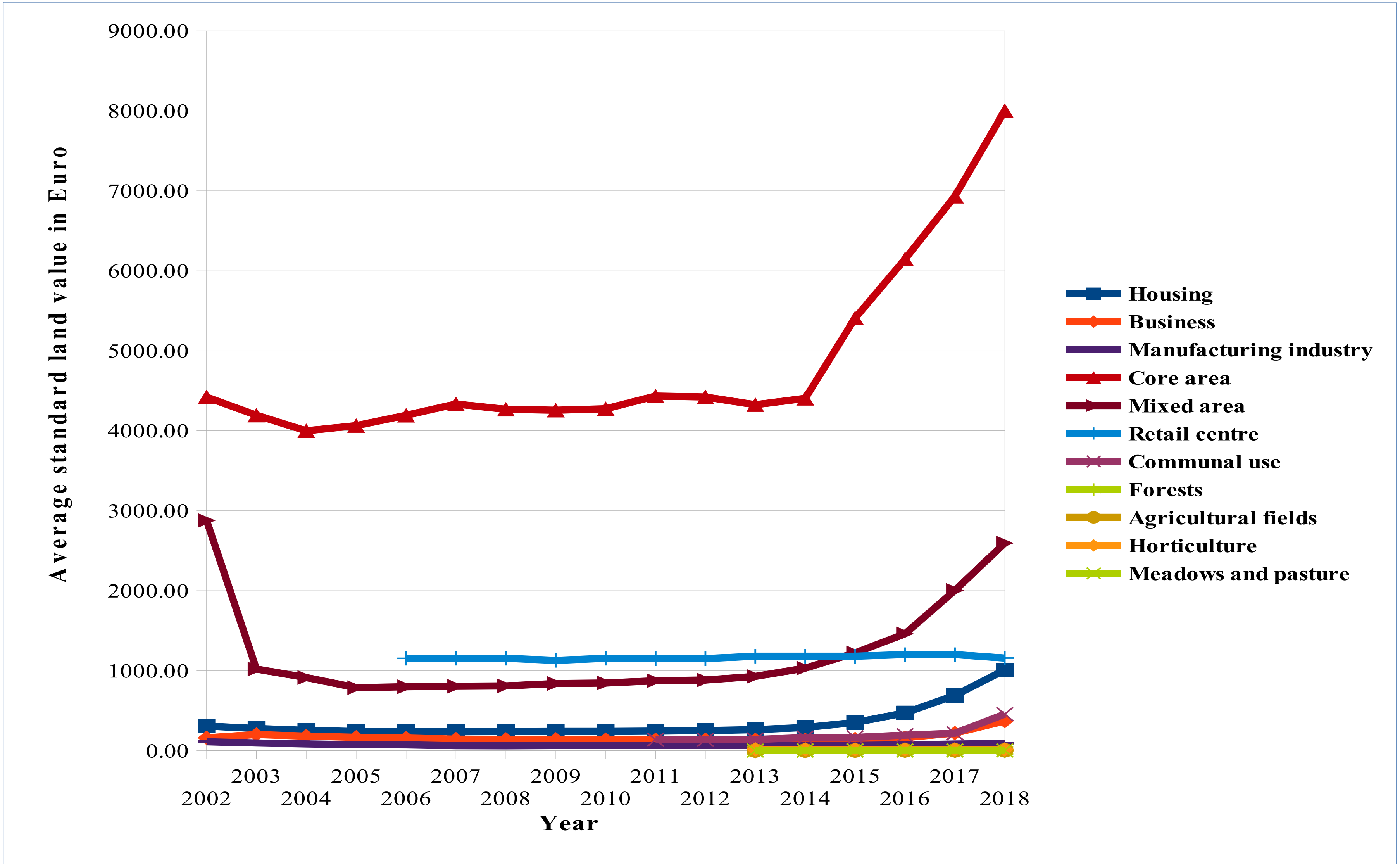


Fig. 6 - Average standard land value per m² of the city of Berlin from 2002-2018 (own calculation based on data of the Gutachterausschuss für Grundstückswerte in Berlin, 2018; Senate of Berlin, 2017a).

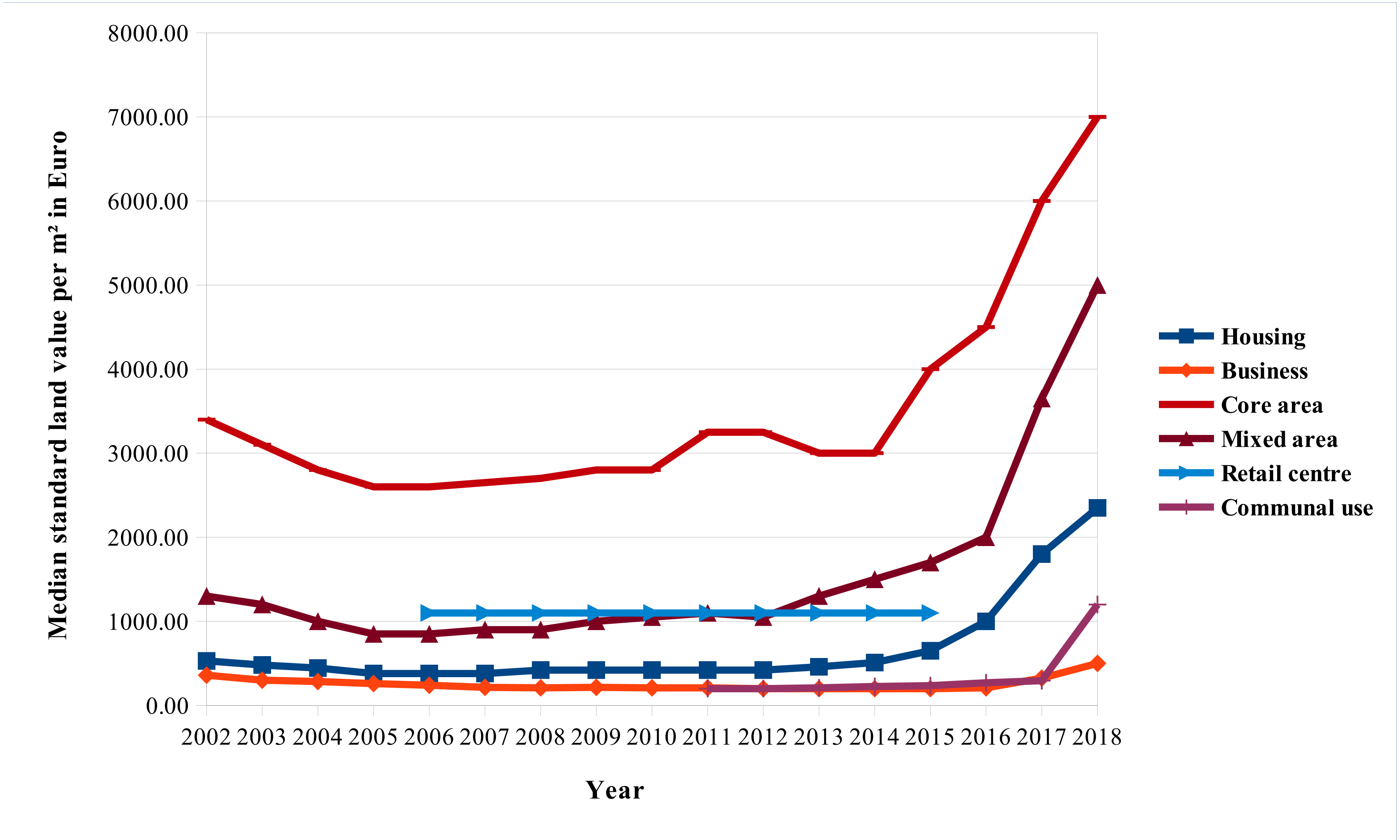


Fig. 7 - Median standard land value per m² of the central district "Mitte" of the city of Berlin from 2002-2018 (own calculation based on data of the Gutachterausschuss für Grundstückswerte in Berlin, 2018; Senate of Berlin, 2017a).

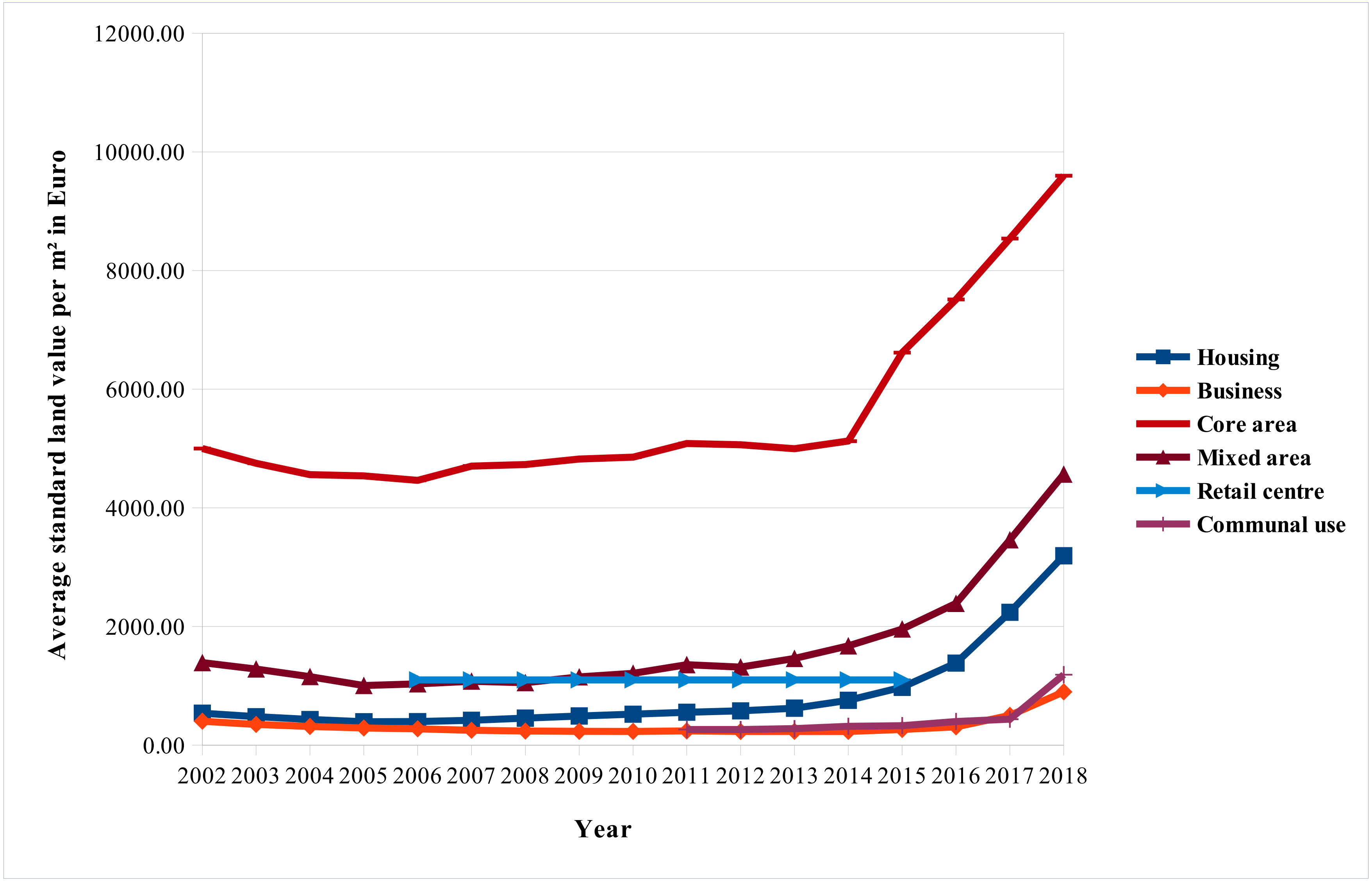


Fig. 8 - Average standard land value per m² of the central district "Mitte" of the city of Berlin from 2002-2018 (own calculation based on data of the Gutachterausschuss für Grundstückswerte in Berlin, 2018; Senate of Berlin, 2017a).

The real estate fund of Berlin was another overlapping driver of the management of open green space in Berlin. It was founded in 2001 to sell public property to market prices without taking into account other than monetary values of the sold real estates (Hammerschmidt, 2006). Just from September 2012 on, further economic (e.g. jobs), housing, cultural, and urban development aspects (e.g. climate, energy efficiency, social infrastructure of schools and kindergartens) should have become relevant parts of the selling procedure of real estate property of the city of Berlin with an emphasis on housing development. By the year 2012, public property was already sold out to an amount of €2 billion and there were still about 5,000 real estates in the portfolio of the real estate fund of Berlin (Senate of Berlin, 2013a).

The CA Immo Deutschland GmbH[5] has been another crucial actor on the real estate market in Berlin which has converted former grounds adjacent to railways for building estate projects on open (green) space (Villinger, 2008). In a short term monetary win-win-situation for the state of Berlin and the investor, master plans and other development plans have been developed over the existing planning schemes (Fig. 1; Section 2.3.1. Planning strategies after the breaking down of Berlin's wall by the public in 1989 on page 18) to convert non-constructable open green space into valuable real estates for constructions (Senate of Berlin, 2015e, 2015f).

2.4. Availability of public green urban areas

2.4.1. Deficits of public green space

Because of the speculation with housing and office real estates, the building pressure on open green space has increased in Berlin since the breaking down of the wall in 1989. As consequence, the deficit of accessible public green space has not been significantly altered by 2016 (Fig. 9) in particular in the inner city districts of Berlin (Fig. 10, Fig. 11, Fig. 12, Fig. 13). The share of private or semi-public open space was equally low in the inner city, i.e. inner S-Bahn railway circle, in comparison to more suburban districts in 2016 (Fig. 9).

[5] From 2001 to 2007 owned by the public as Vivico Real Estate GmbH.

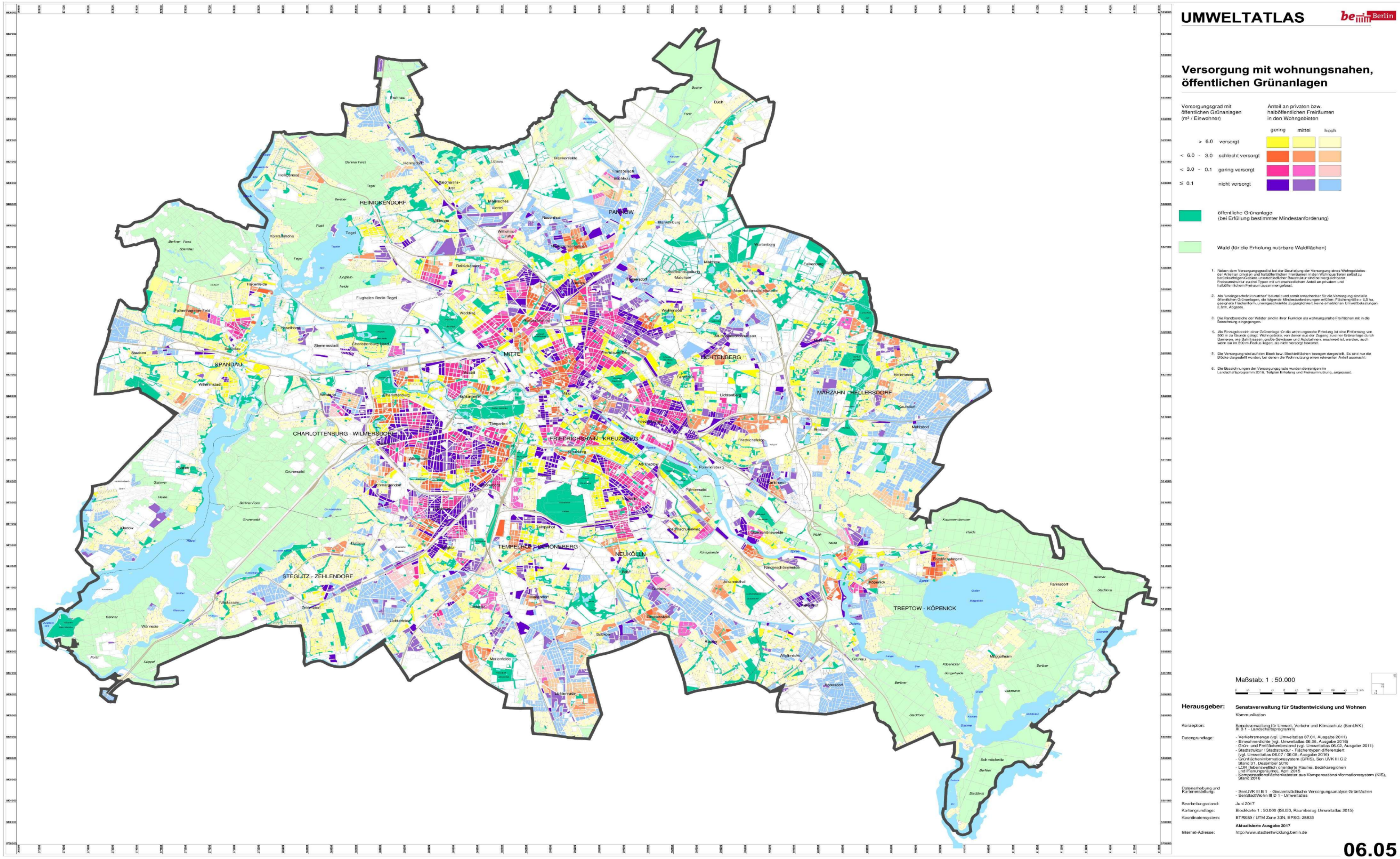


Fig. 9 - Available public green space and share of private or semi-public open space in the near residential neighbourhood of Berlin in 2016 (Senate of Berlin, 2017a).

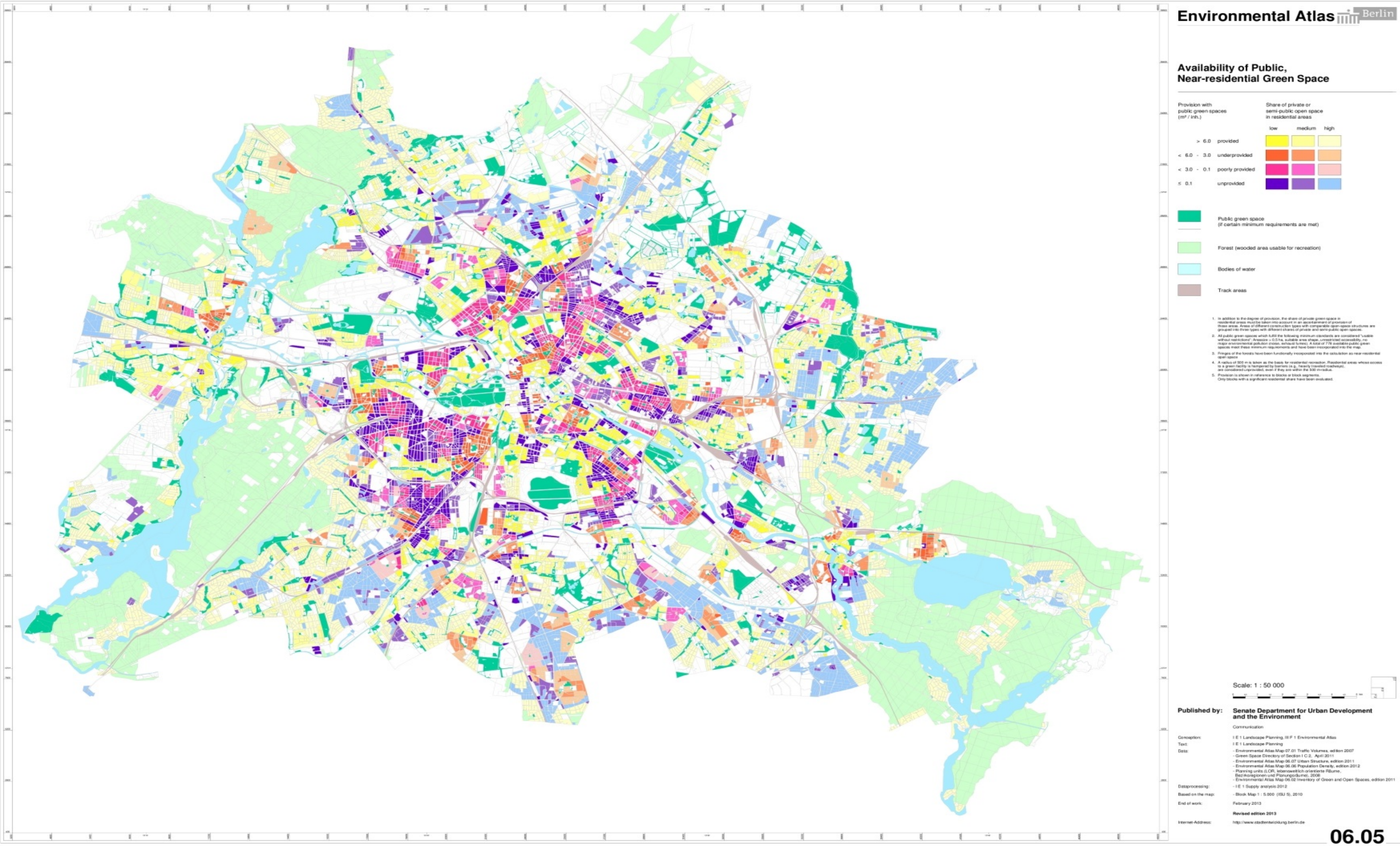


Fig. 10 - Available public green space and share of private or semi-public open space in the near residential neighbourhood of Berlin in 2010 (Senate of Berlin, 2013b).

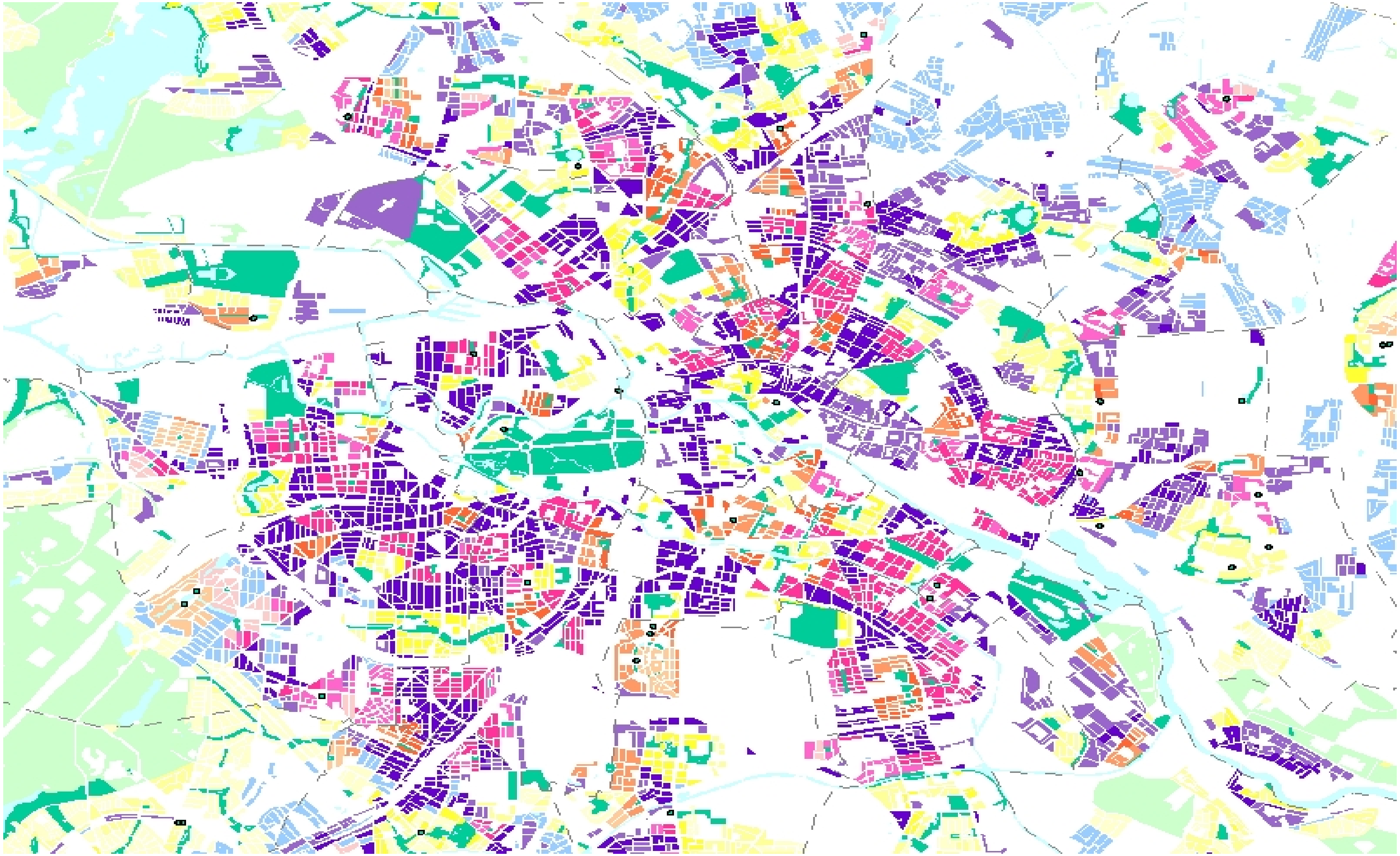


Fig. 11 - Available public green space in the near residential neighbourhood of the centre of Berlin in 1990 (Senate of Berlin, 1995).

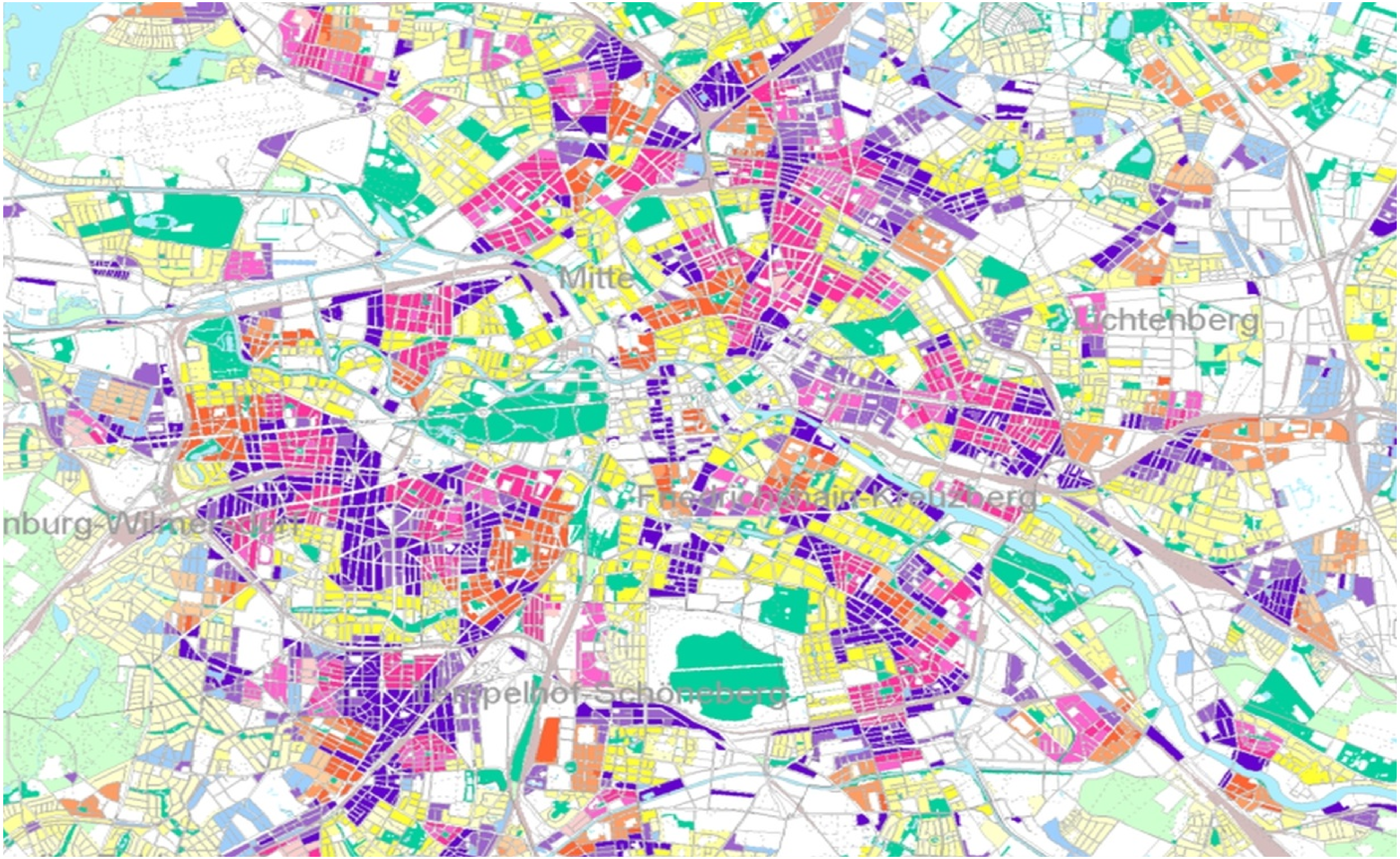


Fig. 12 - Available public green space in the near residential neighbourhood of the centre of Berlin in 2010 (Senate of Berlin, 2013b).

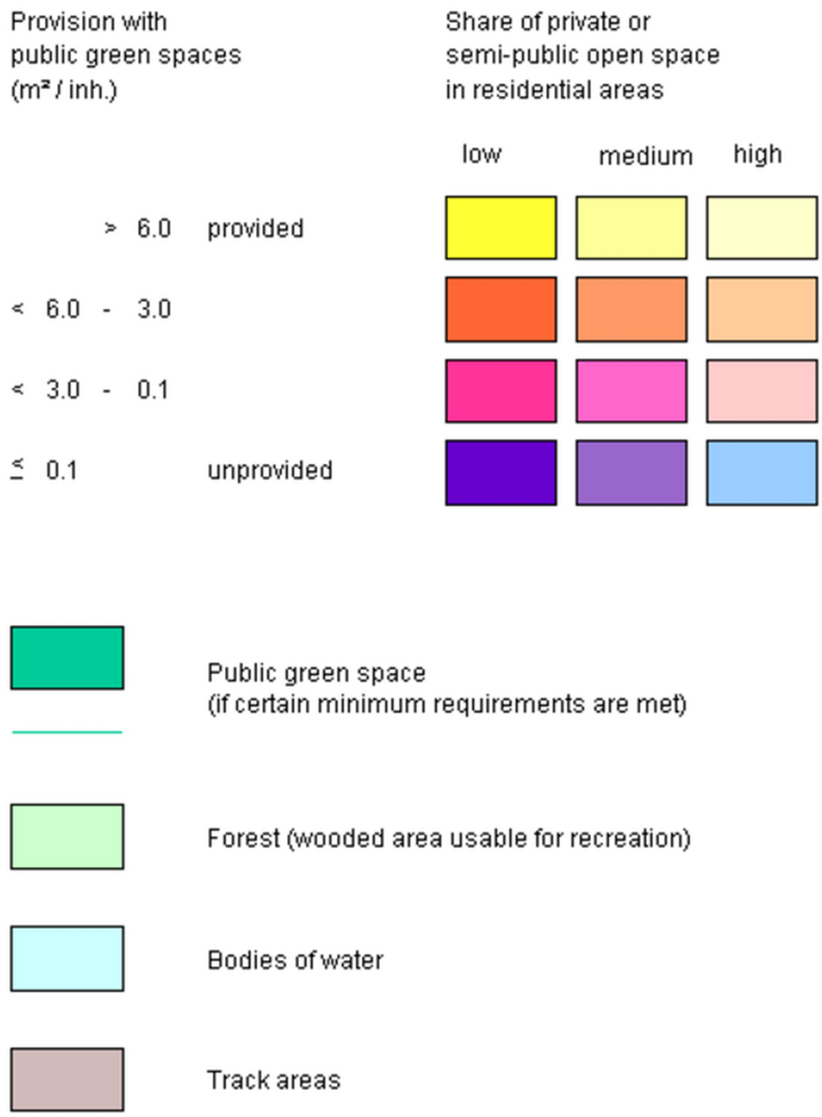


Fig. 13 - Legend to the accessible public green space in the near residential neighbourhood of the centre of Berlin in 2010 (Senate of Berlin, 2013b).

Table 5 - Accessible public green space in the near residential neighbourhood of the districts of Berlin in 1995 (adapted from Senate of Berlin, 1995).

Old districts of Berlin before 2001	**Number of inhabitants**	**Near residential public green space in m²**	**Nearby available public green space in m²/inh.**	**Fusioned districts of Berlin since 2001**	**Number of inhabitants**	**Near residential public green space in m²**	**Nearby available public green space in m²/inh.**
Mitte	82,061	359,153	4.38				
Tiergarten	94,841	165,810	1.75	Mitte	344,585	827,403	2.40
Wedding	167,683	302,440	1.80				
Prenzlauer Berg	145,900	241,879	1.66				
Pankow	106,547	295,078	2.77	Pankow	305,204	607,693	1.99
Weissensee	52,757	70,736	1.34				
Friedrichshain	105,766	115,260	1.09	Friedrichshain-Kreuzberg	262,434	591,937	2.26
Kreuzberg	156,668	476,677	3.04				
Charlottenburg	183,242	343,760	1.88	Charlottenburg-Wilmersdorf	328,481	543,532	1.65
Wilmersdorf	145,239	199,772	1.38				
Spandau	217,458	1,804,864	8.30				
Steglitz	190,244	753,121	3.96	Steglitz-Zehlendorf	290,122	1,670,022	5.76
Zehlendorf	99,878	916,901	9.18				
Schöneberg	155,408	268,598	1.73	Schöneberg-Tempelhof	346,242	944,003	2.73
Tempelhof	190,834	675,405	3.54				
Neukölln	314,123	936,136	2.98				
Treptow	106,271	207,320	1.95	Treptow-Köpenick	215,014	664,401	3.09
Köpenick	108,743	457,081	4.20				
Lichtenberg	165,579	516,294	3.12	Lichtenberg	284,850	681,264	2.39
Hohenschönhausen	119,271	164,970	1.38				
Reinickendorf	254,793	1,339,752	5.26				
Marzahn	163,497	540,947	3.31	Marzahn-Hellersdorf	298,115	637,960	2.14
Hellersdorf	134,618	97,013	0.72				
East Berlin	1,291,010	3,065,731	2.37				
West Berlin	2,170,411	8,183,236	3.77				
Berlin in total	3,461,421	11,248,967	3.25				

Contrary to the real absolute figures for Berlin in 1995 (Table 5), 2011 (Table 6), and 2016 (Table 7) the subjectively determined minimum availability of public green space per inhabitant in Berlin is 6 m² within a maximum distance of 500 m of a minimum size of 5,000 m² (0.5 ha) in the near neighbourhood as adopted by Berlin's parliament. The threshold of public accessible green space close to settlements is a minimum of 7 m² per inhabitant within at maximum 1 km distance of 100,000 m² (10 ha) minimum size, and equally 7 m²/inhabitant for a maximum distance of 1.5 km and a minimum size of 500,000 m² (50 ha) (Senate of Berlin, 2016a, 1994a, 2013b).

Please note that the methods for the generic calculations were different for accessible public green space in the near residential neighbourhood of the districts of Berlin in 1995 (Table 5), 2011 (Table 6) and 2016 (Table 7) which makes it impossible to compare them directly. For instance, the barrier effect of streets was not considered anymore of more than 15,000 vehicles per day as in 2009 for the calculation of the accessibility of public green space in case there are traffic lights to cross over (Senate of Berlin, 2013b). However, the direct street noise was newly considered in 2016 for the calculation. No barrier effect was estimated when highly frequented streets of more than 70 dB (A) were more than 100 m away or the accessible public green space larger than 1 ha (Senate of Berlin, 2017a). Therefore, the maps Fig. 9, Fig. 10, Fig. 11, and Fig. 12 better visualize the general deficits of accessible public and private green space in the near residential neighbourhood in Berlin in 1995, 2011, and 2016. Nevertheless, the databases of 1995, 2011, and 2016 show much higher deficits of accessible public green space within the near residential neighbourhood in the inner city area of Berlin than in the more suburban districts. Furthermore, also the non-urbanized accessible public and private green space at the rural-urban fringe should be taken into account which extends the official boundaries of Berlin (La Rosa and Privitera, 2013; Mori and Christodoulou, 2012), if the spatial data were available.

Table 6 - Accessible public green space in the near residential neighbourhood of the districts of Berlin in 2011 (Senate of Berlin, 2013b).

Districts of Berlin	**Number of inhabitants**	**Inhabitants not counted <10 Inh./ha**	**Inhabitants with good availability**	**Inhabitants without availability**	**Effective public green space in m²**	**Share of inh. without availability**
Mitte	332,893	978	266,649	65,266	4,664,376	20%
Friedrichshain-Kreuzberg	265,082	467	187,441	77,174	1,219,109	29%
Pankow	363,652	2,967	246,434	114,251	5,605,955	32%
Charlottenburg-Wilmersdorf	314,896	1,687	196,326	116,883	2,019,845	37%
Spandau	220,379	1,926	193,801	24,652	6,595,949	11%
Steglitz-Zehlendorf	293,640	2,162	201,155	90,323	3,476,507	31%
Tempelhof-Schöneberg	329,371	1,641	198,786	128,944	2,739,735	39%
Neukölln	313,208	1,388	204,832	106,988	3,897,500	34%
Treptow-Köpenick	241,108	3,417	175,111	62,580	3,917,881	26%
Marzahn-Hellersdorf	248,875	899	202,261	45,715	6,148,647	18%
Lichtenberg	256,249	1,829	199,904	54,516	5,366,352	21%
Reinickendorf	244,677	1,723	188,442	54,512	4,887,213	22%
Berlin in total	3,424,030	21,084	2,461,142	941,804	50,539,069	28%

Table 7 - Accessible public green space in the near residential neighbourhood of the districts of Berlin in 2016 (Senate of Berlin, 2017).

Districts of Berlin	Number of inhabitants	Inhabitants not counted <10 Inh./ha	Supplied inhabitants	Badly supplied inhabitants	Lowly supplied inhabitants	Not supplied inhabitants	Effective public green space in m²	Share of inh. without availability
Mitte	368,116	930	50,074	72,140	102,931	142,041	5,017,579	39%
Friedrichshain-Kreuzberg	281,076	412	26,321	92,821	51,974	109,548	1,684,218	39%
Pankow	394,721	3,687	125,126	65,009	79,497	121,402	5,674,984	31%
Charlottenburg-Wilmersdorf	334,351	2,150	68,081	45,541	95,540	123,039	3,174,998	38%
Spandau	238,278	2,230	172,248	30,922	13,497	19,381	5,523,528	8%
Steglitz-Zehlendorf	302,495	2,079	199,203	16,611	51,780	32,822	4,324,425	11%
Tempelhof-Schöneberg	345,021	1,447	99,063	61,120	93,292	90,099	5,220,526	26%
Neukölln	328,042	1,335	109,130	62,240	54,157	101,180	3,788,349	31%
Treptow-Köpenick	257,688	3,088	152,326	43,359	40,336	18,579	4,600,689	7%
Marzahn-Hellersdorf	261,954	940	197,237	36,759	23,770	3,248	6,714,431	12%
Lichtenberg	280,721	1,544	139,505	63,440	53,544	22,688	5,271,461	8%
Reinickendorf	260,253	1,586	162,981	27,457	49,970	18,259	4,829,327	7%
Berlin in total	3,652,716	21,428	1,501,295	617,419	710,288	802,286	55,824,515	22%

Moreover, the share of accessible private or semi-private open green space in Berlin per inhabitant is practically also related to the quality and price of the building type of real estates to live and to work (Table 8). This means with a higher income for private property or for paying higher rents, there is the opportunity to compensate deficits of public green space to a certain extent by private accessible green space up to living in an own villa with a corresponding garden. This discrepancy between densely built inner city areas and more suburban districts is clearly visible, apart from public accessible green space, also for private and semi-private open green space in Berlin (Fig. 12 and its legend Table 8; Section 2.4.4. Social and further environmental factors on page 53).

Table 8 - Share of private or semi-private open space depending on the structural estate type (Senate of Berlin, 2013b).

Structure Types	Share of private or semi-public open spaces
Structure Types With Predominantly Residential Use	
Late 19th-century block development with wings and rear buildings	low
Late 19th-century block-edge development with few wings / rear buildings	
Late 19th-century block-edge development with major changes	
Twenties and thirties block-edge and row development	medium
Fifties and later row development	
Postwar high-rise development	
Eighties and nineties block-edge and row development in East-Berlin	
Compact high urban living development of the nineties	
Urban living development with low density of the nineties	high
Low buildings with yards	
Development with yards and semi-private re-greening	
Villa development with park-like gardens	
Village-like development	
Structure Types with Predominantly Commercial, Service Use, Small Business and Industrial Use	Threshold value: 10 inh./ ha
Development with predominantly commercial and service use	low
Low development with predominantly small business and industrial use	
Heavily built-up with predominantly small business and industrial use	
Structure Types with Special Use	
Development with predominantly public facilities and special use, traffic areas without streets and building lots	medium
Green and open spaces	high
Water	

2.4.2. Development of green space over time after the breaking down of the wall in 1989

The folk-initiated bottom-up break through of Western Berlin's surrounding and Germany's equally dividing wall of the cold war in 1989 made a unified Germany and Berlin possible with open grounds for new purposes as no other European metropolis had the chance before in the 20th century. However, the planning of a green belt in Berlin to preserve the green space of naturally grown up ruderal woodlands and open green space along the former wall was abolished in favour of selling the open non-building grounds for construction purposes, which was heavily subsidized by tax allowances and under price deals with private investors from all over the world (Strom, 1996).

This conversion was carried out throughout the inner city of Berlin for new buildings, for example, at the Potsdamer Platz, Leipziger Platz, Gleisdreieck and for logistics or temporary commercial use such as a golf course (Aktionsgemeinschaft Gleisdreieck, 2001, 2009). Rather sterile parks were realized between them as so called compensation (Grün Berlin GmbH, 2016). Only a little area "Schöneberger Südgelände", 18 ha large, was preserved on former railway grounds south of the Potsdamer Platz of Berlin in contrast to the widely destruction of the natural rest of urban wild fauna & flora on ruderal grounds in this neighbourhood and beyond (Aktionsgemeinschaft Gleisdreieck, 2001, 2009; Zisenis et al., 2013; Lachmund, 2013).

Regarding the development of green space over time of the centre of Berlin, the inner S-Bahn railway circle line distinguishes the inner city of Berlin from the more suburban districts. In 2006, the Senate of Berlin, Berlin's district authorities and the Statistical Office Berlin-Brandenburg introduced planning areas for statistical purposes to geometrically standardise the available data of the city of Berlin (Senate of Berlin, 2006b). I selected these planning areas for this research of the inner city of Berlin within the inner S-Bahn railway circle line by using GIS software (gvSIG Association, 2015; QGIS, 2015). I GIS clipped then the geometric land use data for 1990, 2000, 2001, 2005, 2010, and 2015 of Berlin by this inner city template of central planning areas to allow statistical analysis. Thereby, I could calculate the proportion of different land use categories of the inner city planning areas of Berlin based on data from the Senate of Berlin (2011e; 2016, personal communication). However, the land use classification of these geometrical statistics of Berlin has been changed over time. In order to minimise this side effect and to allow a standardised comparison, I allocated all land use categories to nine new main land use classes.

As a result, Fig. 14 shows that since 1990 mainly the proportion of "brownfields" was reduced by about 90% from 7.31% in 1990 to 0.77% in the inner city planning areas of Berlin in 2015. "Public accessible managed green areas/parks"[6] gained around 18% from 10.07% in 1990 to 11.85% in 2015. However, different classification categories in the raw data make more detailed comparisons difficult. For instance, the category "waters" just appeared in 2010, as well as "woodlands and forests" at the 2010's fifth mapping cycle since 1990.

[6] Includes also managed green space of traffic areas, smaller urban squares and promenades, as well as children playgrounds as long as the degree of soil sealing is below around a third of the surface. In addition, zoological and botanical gardens are included. Excluded in this land use category are private gardens in settlements, private children playgrounds, and other private green spaces in settlements (Senate of Berlin, 2015g).

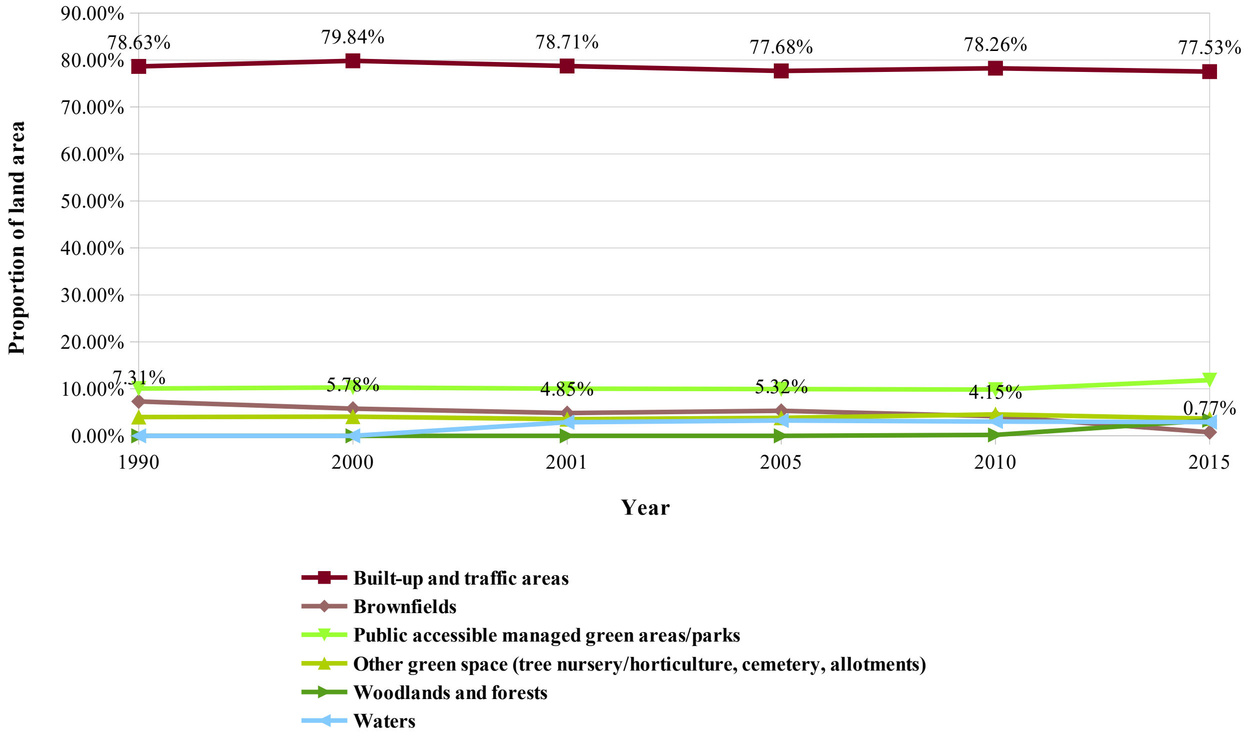


Fig. 14 - Proportion of different land use categories of the inner city of Berlin from 1990 to 2015 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication). Note: the percentage is shown for built-up and traffic areas, as well as brownfields. „Woodlands and forests“ were just mapped from 2010 on, as well as „Waters“ from 2001 on.

Fig. 15, Fig. 16, Fig. 17, Fig. 18, Fig. 19, and Fig. 20 provide a more detailed view of the land use trends over time within the inner city of Berlin from 1990 to 2015.

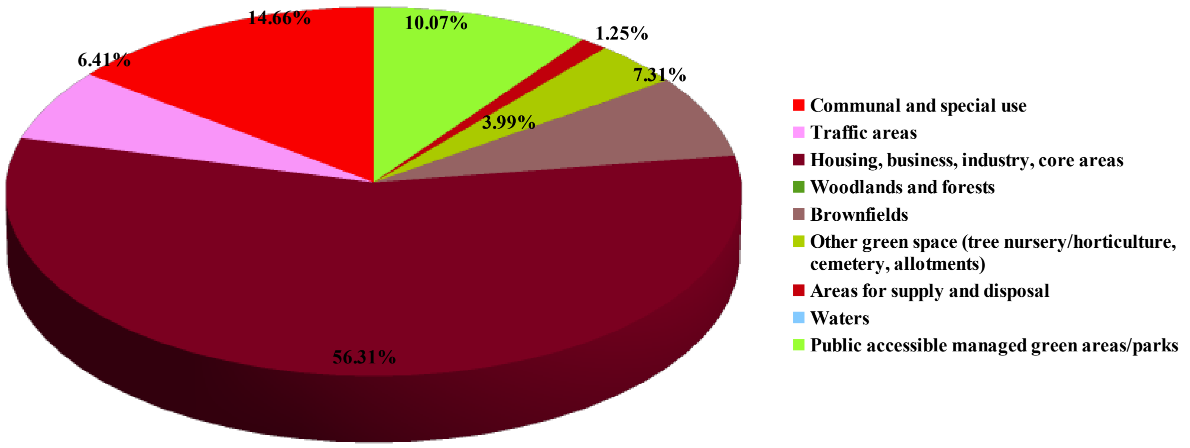


Fig. 15 - Proportion of different land use categories of the inner city of Berlin in 1990 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

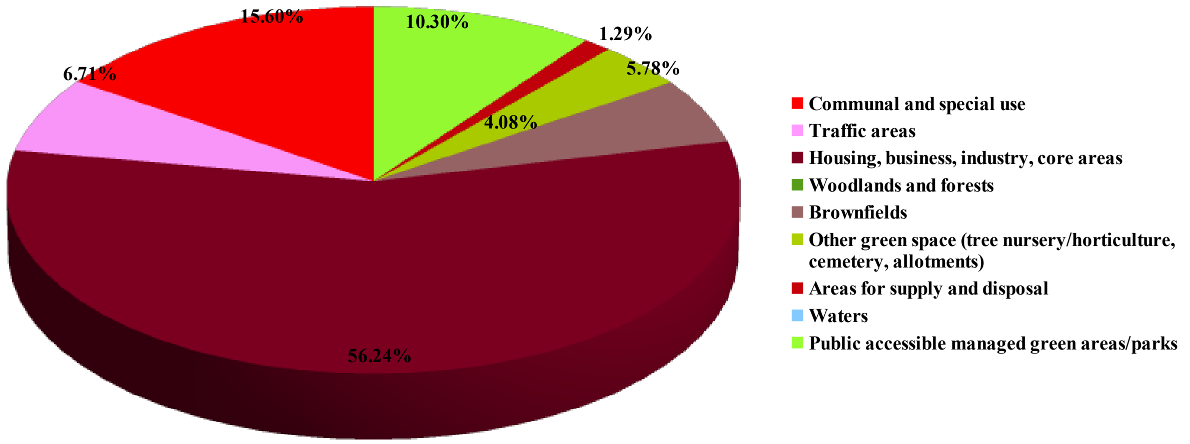


Fig. 16 - Proportion of different land use categories of the inner city of Berlin in 2000 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

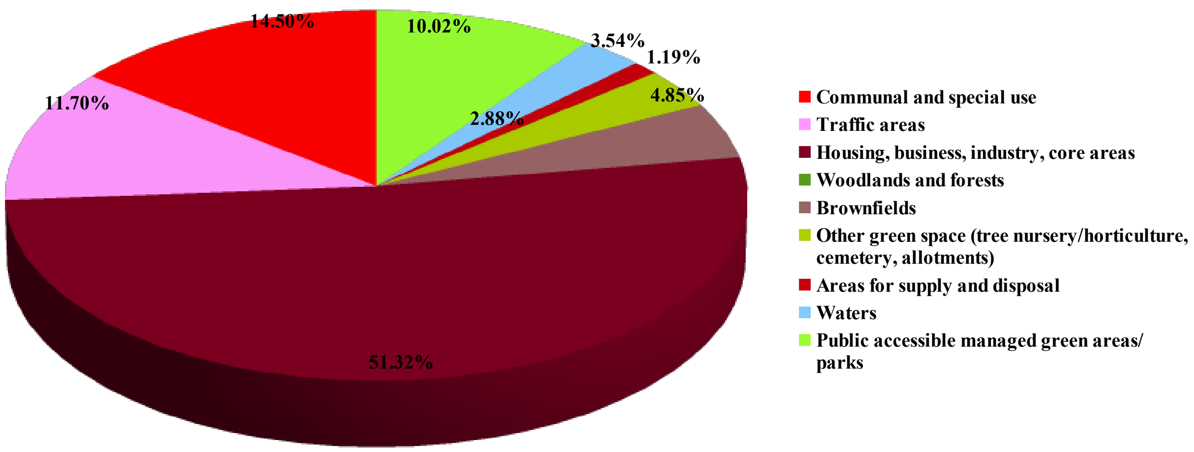


Fig. 17 - Proportion of different land use categories of the inner city of Berlin in 2001 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

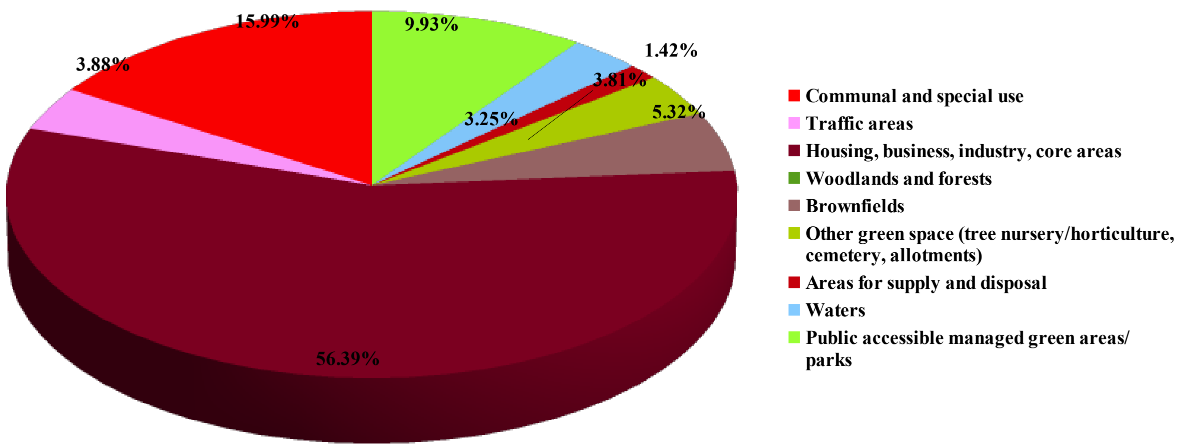


Fig. 18 - Proportion of different land use categories of the inner city of Berlin in 2005 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

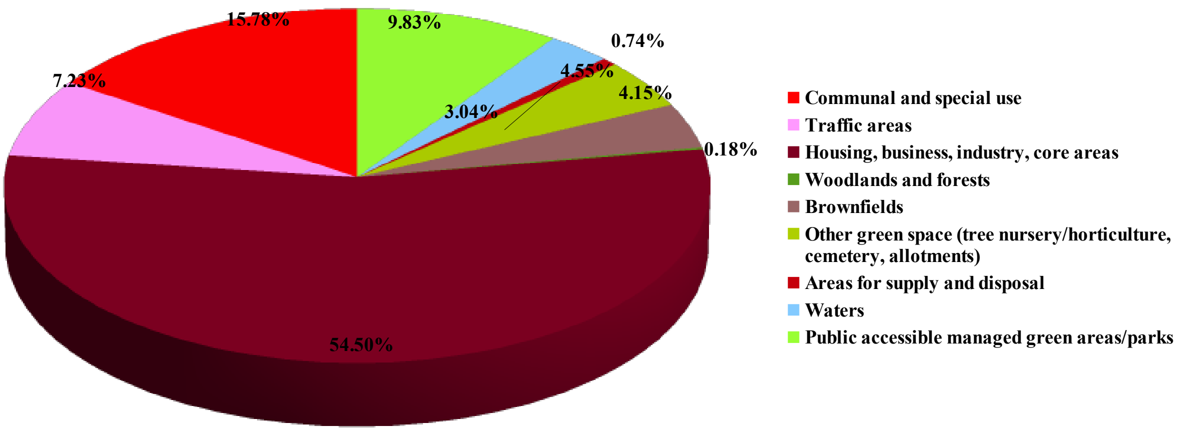


Fig. 19 - Proportion of different land use categories of the inner city of Berlin in 2010 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

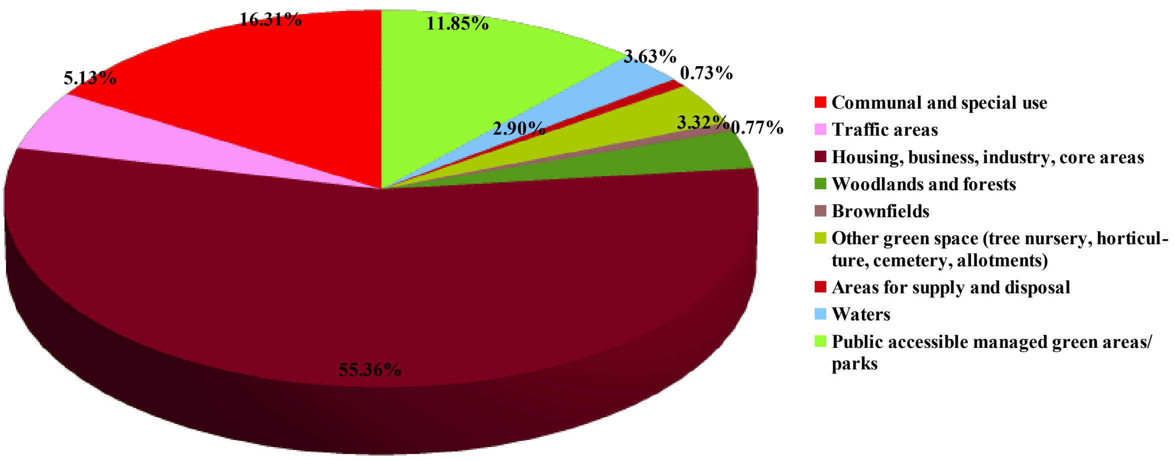


Fig. 20 - Proportion of different land use categories of the inner city of Berlin in 2015 (own calculation based on data from the Senate of Berlin, 2011e; Senate of Berlin, 2016, personal communication).

2.4.3. Degree of soil sealing

The available urban indicator of the degree of soil sealing of Berlin shows similar deficits of green space within the central districts in 2016 (Fig. 21), 2011 (Fig. 22) and 1990 (Fig. 23). 63.5% and 69.9%, respectively, of the soils of the central districts “Mitte” and “Friedrichshain-Kreuzberg” (excluding waterbodies) were in a concreted state in 2016 (Fig. 24) in comparison to already 36.1 % (30,192 ha) of the soils in the whole city of Berlin in 2016 (Fig. 24), after 34.9% (29,190 ha) in 2011 (Fig. 25). The degree of soil sealing increased (including waterbodies and streets) in Berlin in total from 31.9% (28,408 ha) in 2005, 32,8% (29,190 ha) in 2011 to 33.9% (30,192 ha) in 2016 according to the improved available data (Senate of Berlin 2017b; Coenradie and Haag, 2016), i.e. there was an annual increase at average of about 298 ha per year from 2005 to 2016.

Also in this case, the methods for the calculation of the soil sealing differ from 1991 to 2011/2016. This can be noticed, for example, in the different ordinal classification of the former southern inner city airport Tempelhof despite of the same concreted areas as shown as >70% - 80% sealed in 2011 (Fig. 22) in comparison to 91% - 100% in 1990 (Fig. 23), and more differentiated in 2016 (Fig. 21).

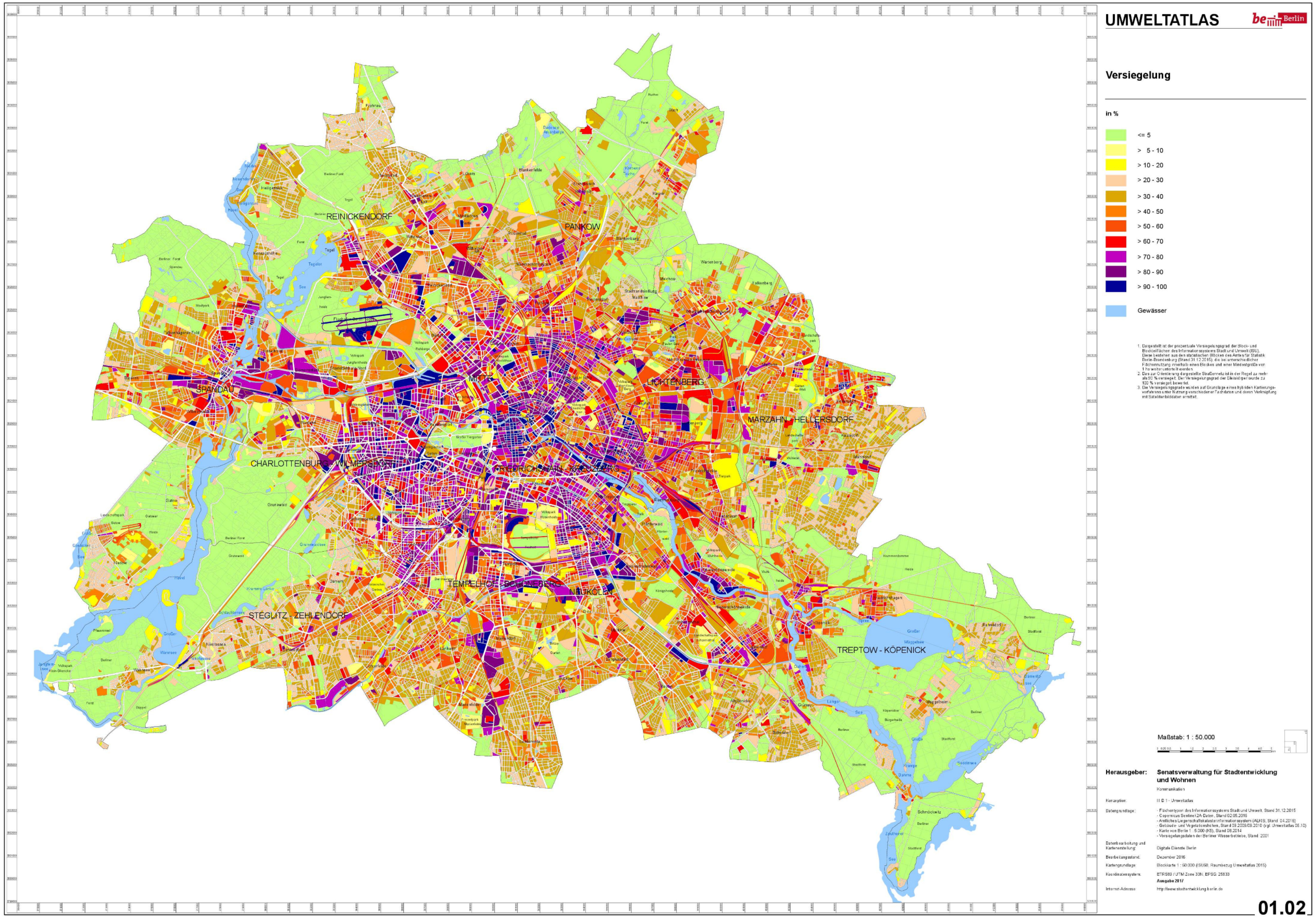


Fig. 21 - Degree of soil sealing of Berlin in 2016 (Senate of Berlin, 2017b).

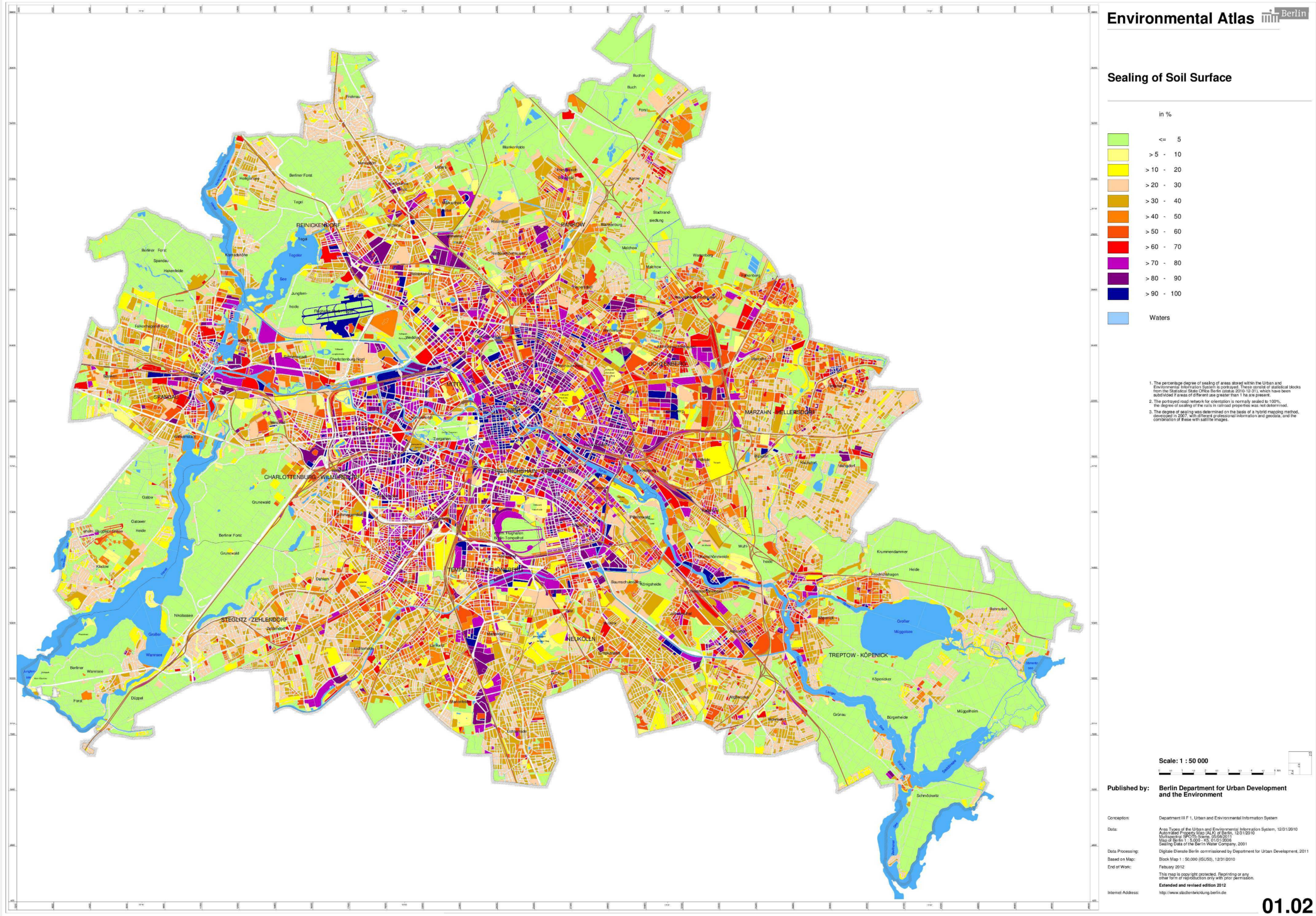


Fig. 22 - Degree of soil sealing of Berlin in 2011 (Senate of Berlin, 2012c).

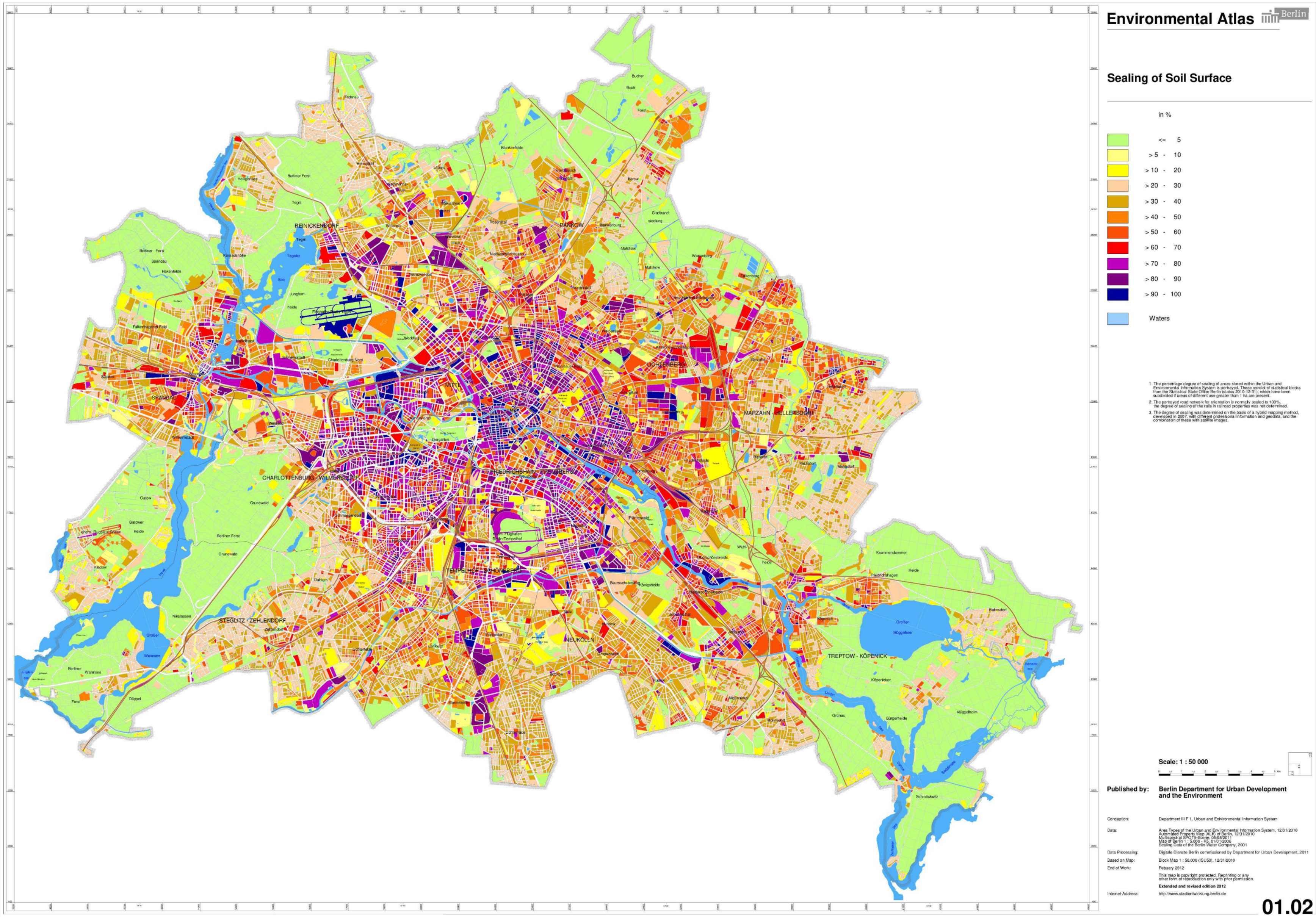


Fig. 23 - Degree of soil sealing of Berlin in 1990 (Senate of Berlin, 1993).

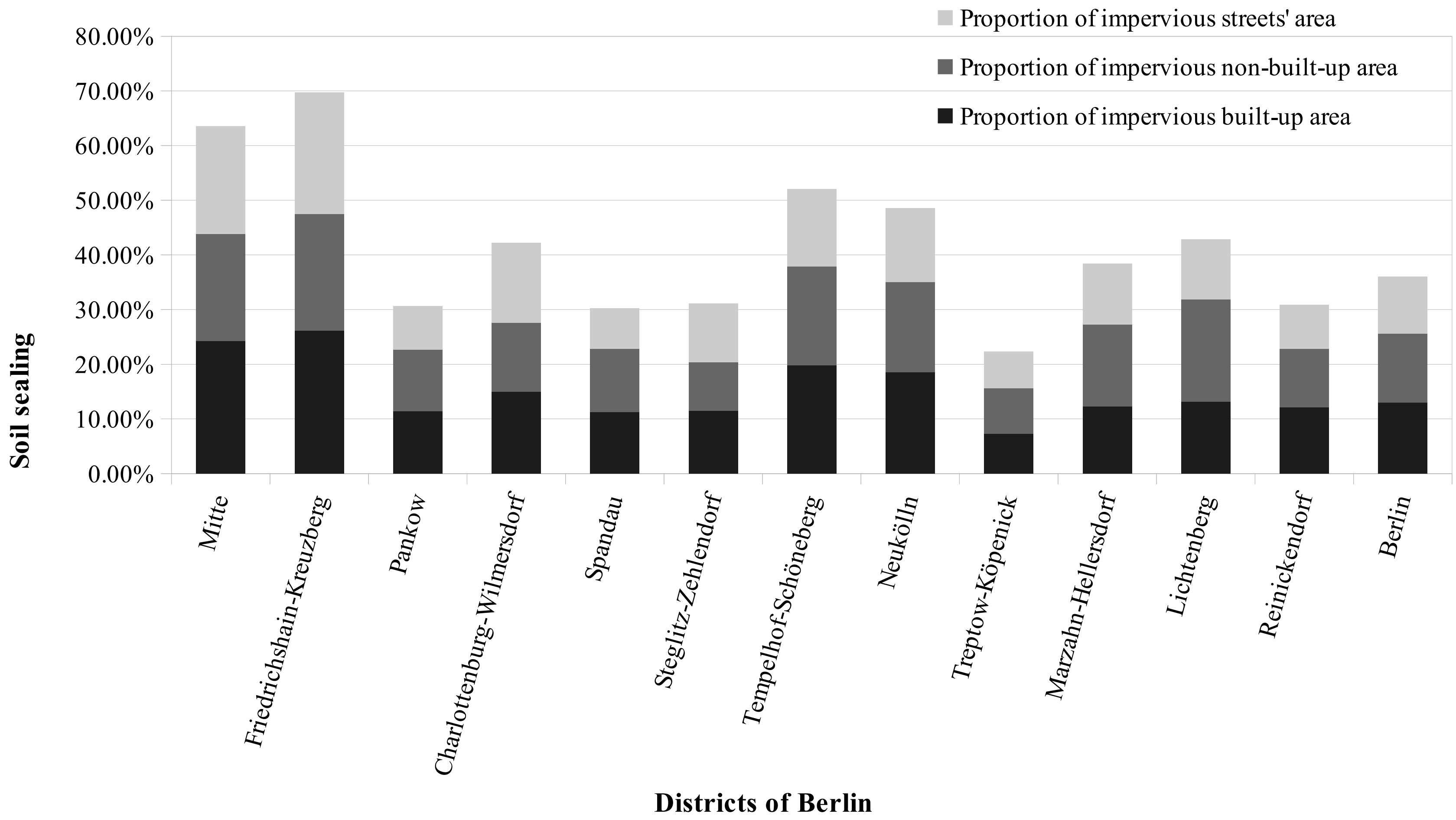


Fig. 24 - Proportion of soil sealing of the different districts of Berlin in 2016, not including water bodies (Senate of Berlin, 2017b). Note: railway-track gravel was calculated as 100 % impervious.

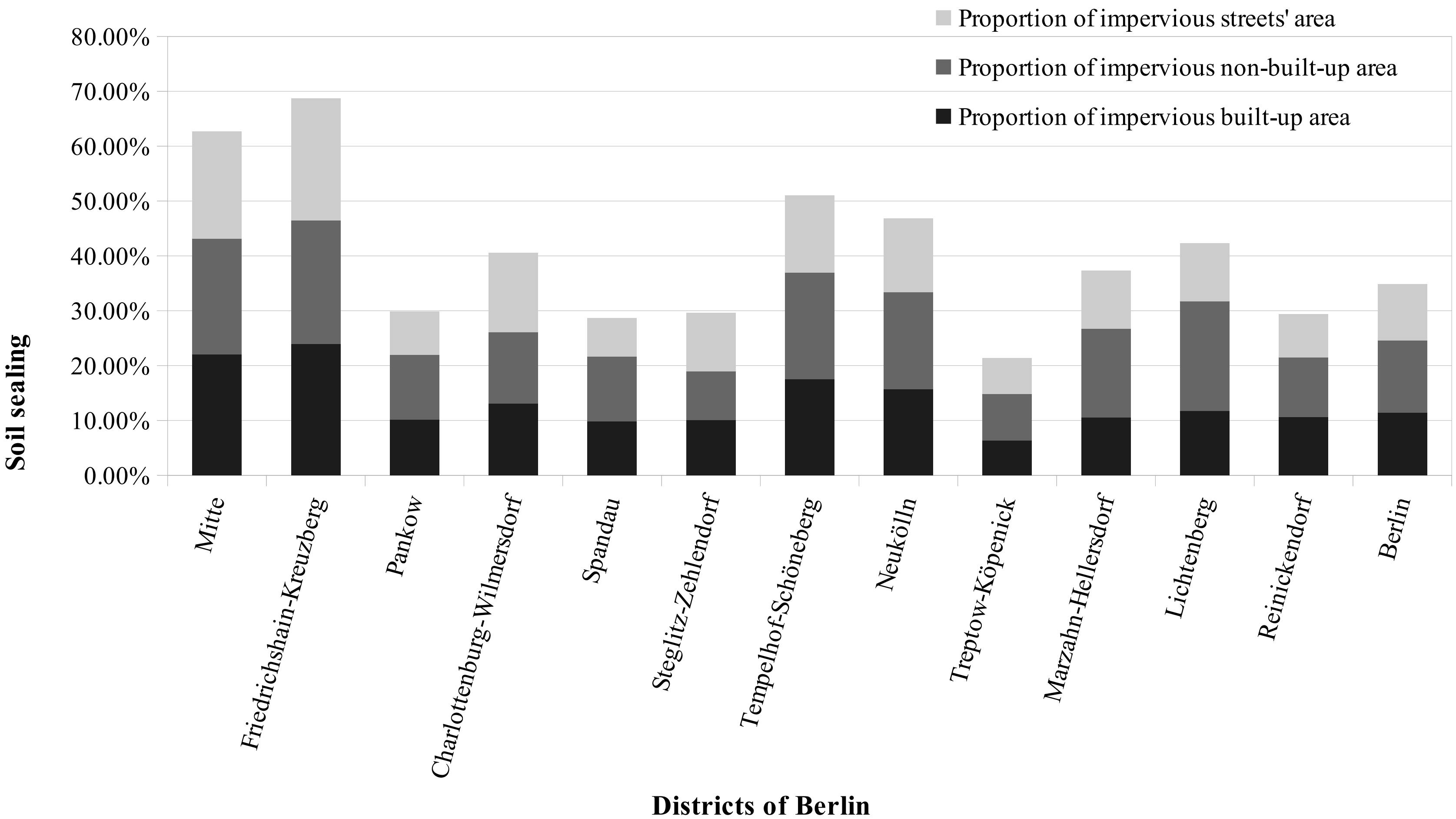


Fig. 25 - Proportion of soil sealing of the different districts of Berlin in 2011, not including water bodies (Senate of Berlin, 2012c). Note: railway-track gravel was calculated as 100 % impervious.

2.4.4. Social and further environmental factors

The accessibility of public green space is also related to certain social factors such as mobility, personal income to reach public green space by public or private transport, as well as population density and thereby the way and intensity of use by neighbours and other visitors. In addition, overlapping factors are air pollution, microclimate and noise, as well as the practical accessibility at all and use restrictions. To those belong also the availability of recreational facilities (Gomez-Baggethun et al., 2013). Private and semi-public open and green space contribute as well to the different values of biodiversity in urban areas, but they are restricted to those who have access to them (Fig. 9, Fig. 12; Fig. 13; Fig. 21, Fig. 26).

According to an analysis of the different planning areas in Berlin, the inner city district parts of about 100 km² in total are worst impacted of these four environmental impacts on the quality of life. Furthermore, they are also characterised by social factors (Senate of Berlin, 2015g) such as unemployment, recipients of transfer payments, poverty, inhabitants with migration background, foreigners, migration flow, as well as proportion of municipal houses, inhabitants of simple housing standards, and tenants of more than five years (Seidel-Schulze et al., 2013). Fig. 27 shows this increase of overlapping environmental impacts combined with lower social standards on a map in darkening red combined with the population density of inhabitants per km². Fig. 26 highlights the proportion of the number of overlapping impacts per district of Berlin. Most impacted are inner city planning areas (Fig. 26, Fig. 27).

Kabisch and Haase (2014) concluded that areas of high population density and high proportion of immigrants in Berlin are faced with less available green space per person, in particular in the inner city districts. Kabisch et al. (2016b) found correlations between children living in areas in Berlin of lower housing quality, lower social standard and health problems negatively correlated to the distance of green and water areas within maximum 300 m of at least 2 ha. Self-reported health was linked to the residential distance of citizens to urban green space in Berlin (Coppel and Wüstemann, 2017). Unequal access to public green space is a global problem in many cities worldwide (Wolch et al., 2014).

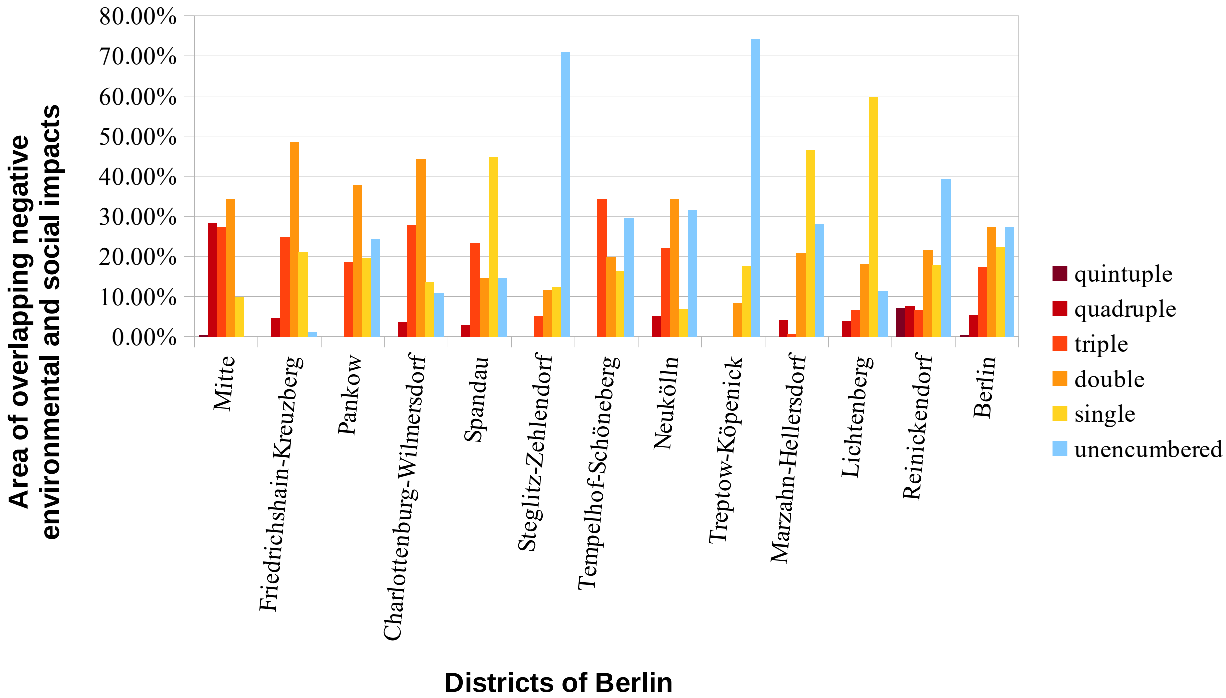


Fig. 26 - Proportion of overlapping environmentally and socially impacted planning areas of Berlin (Senate of Berlin, 2015g).

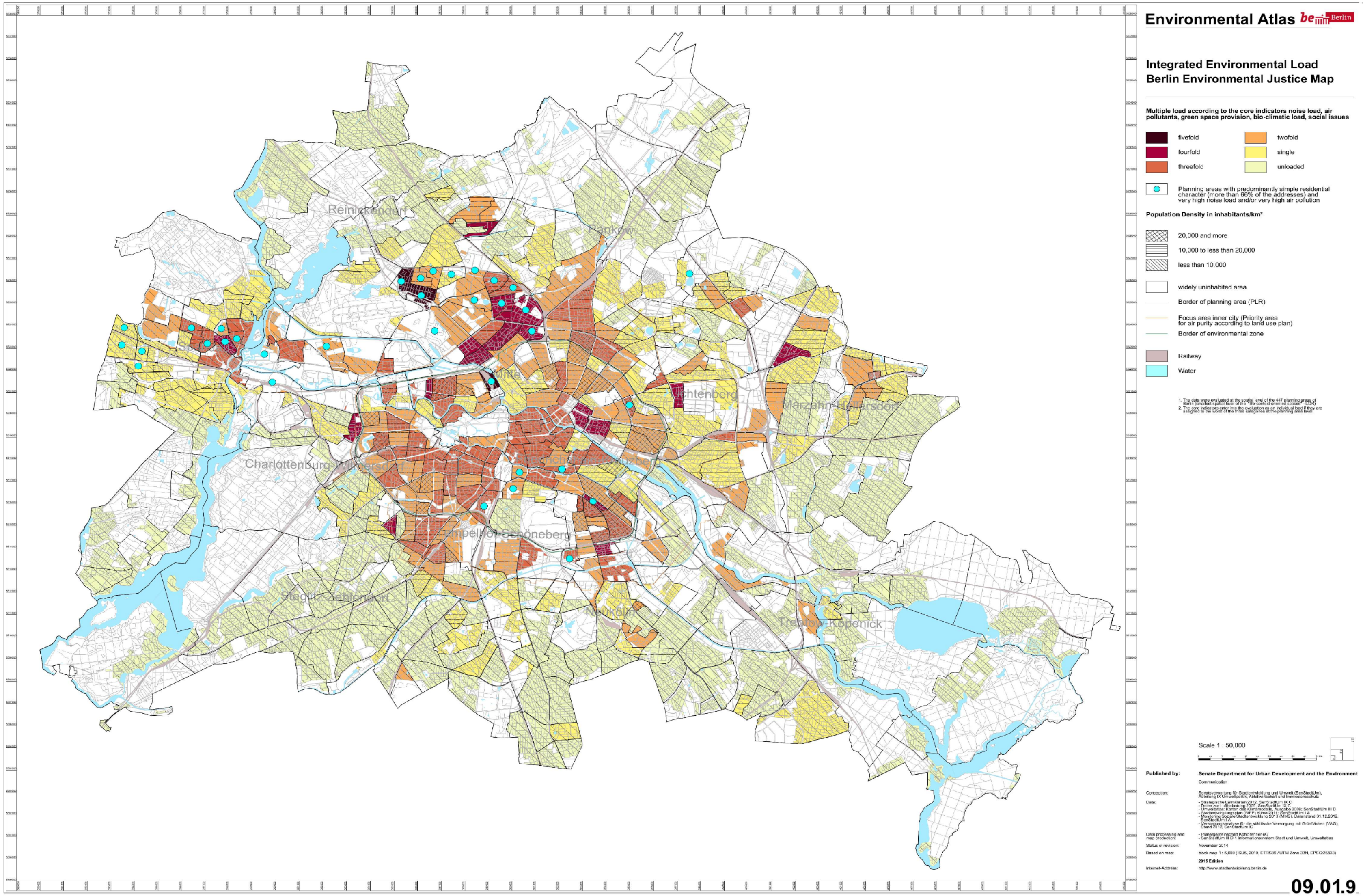


Fig. 27 - Integrated map of overlapping environmental and social impacts on planning areas on different levels of population density per km² of Berlin (Senate of Berlin, 2015g). Note: increasing darkness in red indicates worsening environmental and social conditions.

2.4.5. Participation tools with an influence on planning decisions

Public hearings instead of participation in decision-making dominate urban planning (BauGB, 2017) and landscape planning (NatSchGBln, 2013) in Berlin as participatory process. This is also the case for green space governance in other European metropolises (van der Jagd et al., 2015) and different types of non-binding civic participation in urban green space management in cities on global scale (Fors et al., 2015). Moreover, it refers also to Environmental Impact Assessments (EIA) of certain projects (Zisenis, 2008) and Strategic Environmental Assessments (SEA) of planning decisions in Germany (UVPG, 2017).

One exception is the 2006 introduced direct democratic opportunity of initiating a referendum by the public which, if adopted by the simple majority at least of 25% eligible voters in Berlin, becomes a mandatory act according to Articles 59, 61-63, 100 of Berlin's Constitution (Constitution of Berlin, 2014). So it happened in 2014 when 739,124 out of 2,491,365 eligible voters of Berlin decided in favour of a draft law proposal to keep the former inner city airport Tempelhof free from housing development as foreseen by Berlin's Senate (Landeswahlleiterin für Berlin, 2014).

Similar at Berlin's district level, the right of petitions and referendums was introduced in 2005 which allows also amendments of a development plan or a landscape plan or other urban development decisions. In addition, inhabitants got the opportunity to decide on a limited financial budget for some project initiatives and to comment on the total budget on district level (BezVG, 2011; Senate of Berlin, 2017c).

However, Berlin's Land Use Plan was not adjusted according to the new public act of the “Tempelhofer Feld” (Tempelhof's field). The Senate of Berlin handed in a draft amending act itself to Berlin's parliament already in November 2015 in order to allow temporary housing constructions for refugees on the former planned building grounds which could now be easily converted to permanent constructions in the future (Senate of Berlin, 2016g; Demokratische Initiative 100% Tempelhofer Feld, 2016).

In February 2016, Berlin's parliament decided, based on the initiative of the Senate of Berlin (Senate of Berlin, 2015h), to abolish the idea of the “Tempelhofer Freiheit” (Tempelhof's freedom) of the open green space purely for recreational and artistic use of the public as well as for habitat and species protection. It amended the public voted act to allow temporary housing constructions for up to 7000 refugees and asylum seekers on already concreted grounds, which is theoretically limited for a period of time until 31 December 2019 (GVBl. Berlin, 2016; Beitzer, 2016; Demokratische Initiative 100% Tempelhofer Feld, 2016). Thereby, it paved the way for the original interest of Berlin's government and investors to convert the temporary constructions into short-term more profitable building grounds as time goes by. The character and the atmosphere of the public open green space will likely change as the recreational and artistic use of the open grounds by visitors is played off against the urgent need for cover, integration, and accommodation of war refugees (Parsloe, 2017). In 2017, first containers were planned to be erected for about 1100 refugees, as well as new training halls for a children circus’ initiative in Berlin on Tempelhof's freedom (Keitel, 2017). However, the question by the public was not answered by the Senate of

Berlin why these new refugee containers shall not be build on the already concreted movement area of the former airport hall (Demokratische Initiative 100% Tempelhofer Feld, 2017a). The Senate of Berlin carried out these new building projects without the consent of the public as required by the Charta of Participation which was developed together with the public (Demokratische Initiative 100% Tempelhofer Feld, 2017b).

Another public referendum was intentionally not connected to the public election of the German Bundestag (Germany's parliament) by Berlin's Senate. It failed consequently to gain the 25% pass threshold of eligible voters by 0.9%, despite a great majority of 83% (Landeswahlleiterin für Berlin, 2013) decided in favour of the remunicipalisation of Berlin's electricity supply for 100% renewable energy and energy savings (Berliner Energietisch, 2012).

A further tool to undermine direct democracy in public planning and other decisions in Berlin by Berlin's government is the amendment of the voting act to allow now financing campaigns by public tax money against initiatives of public referenda (Gürgen, 2016). No surprise, the politically driven discussion came up again on building on the margins of Tempelhof's freedom against the majority vote of the public (Paul, 2018).

Therefore, the grassroots “Initiative Volksentscheid retten” (2016) carried out another collection of signatures of Berlin’s inhabitants to support a referendum of a law proposal to make public referendums more stable like already established in the city of Hamburg. Among others, 50.000 collected votes should have been enough in four months for the need of a public referendum on amendments of Berlin’s parliament and the requirement to hold generally referendums in conjunction with public elections. However, the “Initiative Volksentscheid retten” gave up its initiative after the collection of about 58,000 supporting valid of 20,000 necessary signatures of Berlin’s inhabitants to initiate a referendum (Senate of Berlin, 2016h). The reason was that the Senate of Berlin intended to appeal the referendum initiative at Berlin’s Constitutional Court, which would have delayed the possibility to combine it with general elections of the German Bundestag in September 2017 (Initiative Volksentscheid retten, 2017).

2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin

In practice, there is only limited data available on the different values (ecosystem services) of green spaces of Berlin and other European metropolises. As target for urban development of public green space, there is simply the indicator of available urban green area in m² per capita used of a minimum arbitrary threshold within certain walking distance (Section 3.3.2. Accessible green space in walking distance on page 172; Kabisch et al., 2015, 2016a, 2016b). For instance, there are other thresholds applied for similar reasons in the UK: for every citizen there should be at least 2 ha accessible natural green space available not more than 300 m far away, 20 ha within 2 km, and 100 ha within 5 km distance (Handley et al., 2003).

However, this purely quantitative indicator tells nothing about the quality of different ecosystem services (values) of public accessible urban green space (Moseley et al., 2013; Handley et al., 2003). Furthermore, it does not distinguish between the different demands for the quality of living and working around public urban green space. Only recently, Berlin’s Environmental Atlas included some integrative data for so called environmental justice (Section 2.4.4. Social and further environmental factors on page 53). However, urban biodiversity data has not yet been systematically gathered on European level for a systematic framework of comparative, reliable, and validate indicators for urban biodiversity in general and green spaces in particular. Berlin’s Environmental Atlas provides the most comprehensive spatial data on environmental conditions of the city of Berlin. It has historically grown to a unique database in Europe and likely beyond as the scientists were fenced in by the wall around Western Berlin from 1961 to 1989. An internationally leading urban ecology movement developed in Western Berlin (Lachmund, 2013; Sukopp, 1990, 2008, 2011).

As a case study, this research shall use the selective information provided by Berlin’s Environmental Atlas to allow a more differentiated view of the different values of Berlin’s public urban green space types. In accordance with the research targets (Chapter 1. Introduction on page 10), I investigated the different ecosystem services provided by public urban green space types in the inner city area compared to those of whole city of Berlin. The systematic of ecosystem services is applied for the reason that it is the currently favoured analytical approach in science, as well as of planning tools and strategies in Europe (Schröter et al., 2016), despite its limitations and unsolvable systemic deficiencies (Section 3.2.2. Ecosystem services on page 162). However, Berlin’s Environmental Atlas describes almost exclusively different ecological conditions and functions of the environment of Berlin. It does not analyse the overlapping multiple interacting impacts similar to the concept of ecosystem services.

The same systemic problem faces the EU’s European Ecosystem Assessment which is purely based on mapping including a proposed range of biophysical indicators of urban ecosystems (Maes et al., 2016a, 2016b, 2018; Burkhard and Maes, 2017), instead of a more comprehensive set of biodiversity evaluation framework related indicators which involves the people concerned and their values attributed to the urban and rural environment (Zisenis et al., 2013; Zisenis, 2009). A first set of 10 structural, functional, and material indicators for evaluations of urban biodiversity has been proposed as a result of this research in Table 16 (Chapter 3.4. Discussion of a new first set of indicators for evaluations of urban biodiversity on page 175). However, the data behind is not yet available for European metropolises and beyond on global level.

Therefore, this case study of Berlin focuses on the mainly biophysical information, supplemented by social and economic data, which is provided as ecosystem services by Berlin’s Environmental Atlas for urban development.

2.5.1. Material and Methods

I analysed the spatial GIS data of Berlin’s Environmental Atlas of different urban green space land use types for biophysical, social, and economic data through classifying their covered area (Table 9). Public parks, allotments, and cemeteries are of particular human use from the social and psychological point of view. They are integral part of urban and landscape planning as public social meeting points and targeted areas of relaxation, reflection, and inspiration for citizens apart from other managed green spaces in the inner city such as private front and back gardens of settlements or green spaces along roads and waterways. They provide different biophysical ecosystem services for the microclimate, water cycle, clean oxygen rich air, and habitat for species (Sukopp, 1990, Sukopp and Wittig, 1998). Public parks have a crucial role in urban and landscape planning on European and international level as their accessibility per inhabitant is used as an indicator for the sufficient supply of accessible public green space in Berlin and other European metropolises (Chapter 1. Introduction on page 10, Chapter 2.6. Available public green urban areas in the inner city parts of other European metropolises on page 149). I spatially distinguished for this research, as mentioned above, urban green space types within the inner S-Bahn railway circle line from the whole territory of Berlin (Chapter 1. Introduction on page 10).

Table 9 - Spatial biophysical data of different urban green space land use types, as well as spatial social and economic data of their inhabitants within 500 m distance to selected urban green space land use types of particular human use of a minimum size of 5,000 m² (0.5 ha) in Berlin (Senate of Berlin, 2017a).

Urban green space type	**Date of the area boundaries**	**Biophysical data**	**Social and economic data**
Public parks	2015	- microclimate - soil functions - groundwater recharge - hemeroby of biotope types	- standard land value[7] - unemployment - children poverty - age - social assistance beneficiaries - migrants - quality of the housing area - migration - single households - state owned flats
Public accessible managed green areas/parks	2010		
Allotments	2015		
Cemeteries	2010		

The subjectively determined minimum availability of public green space per inhabitant in Berlin is 6 m² within a maximum distance of 500 m of a minimum size of 5,000 m² (0.5 ha) in the near neighbourhood as adopted by Berlin's parliament (Senate of Berlin, 2016a, 1994a, 2013b). I used GIS software (QGIS, 2015) for the spatial analysis. First, I selected from the shapefiles those urban green space types of public parks, public accessible managed green areas/parks, allotments, and cemeteries with a minimum size of 5,000 m² (0.5 ha). I clipped then the surrounding area within 500 m (GIS buffer) distance to their (polygon) boundaries. I analysed the urban green space type area of 0.5 ha itself for biophysical data, but also the outer clipped area within 500 m boundary distance for biophysical, social, and economic data as available from Berlin’s Environmental Atlas.

The spatial GIS data was only available at different scale in mainly blocks for biophysical data and planning regions for social and economic data (Senate of Berlin, 2017a). This did not allow further comparable sophisticated statistical analysis. Instead of quantified figures, I used the clipped covered area as proportion of the classified data of the different indicators for comparison.

[7] Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24.

2.5.2. Results

The results of the analysis are shown for public parks in the following, for public accessible managed green area/parks, allotments, and cemeteries in appendix on page 251.

2.5.2.1. Microclimate

Public parks in the inner and whole city of Berlin of 0.5 ha and more are surrounded to 66.06% and 62.38%, respectively, by concreted soil of a degree ranging from 60% to 100% within 500 m walking distance (Fig. 28).

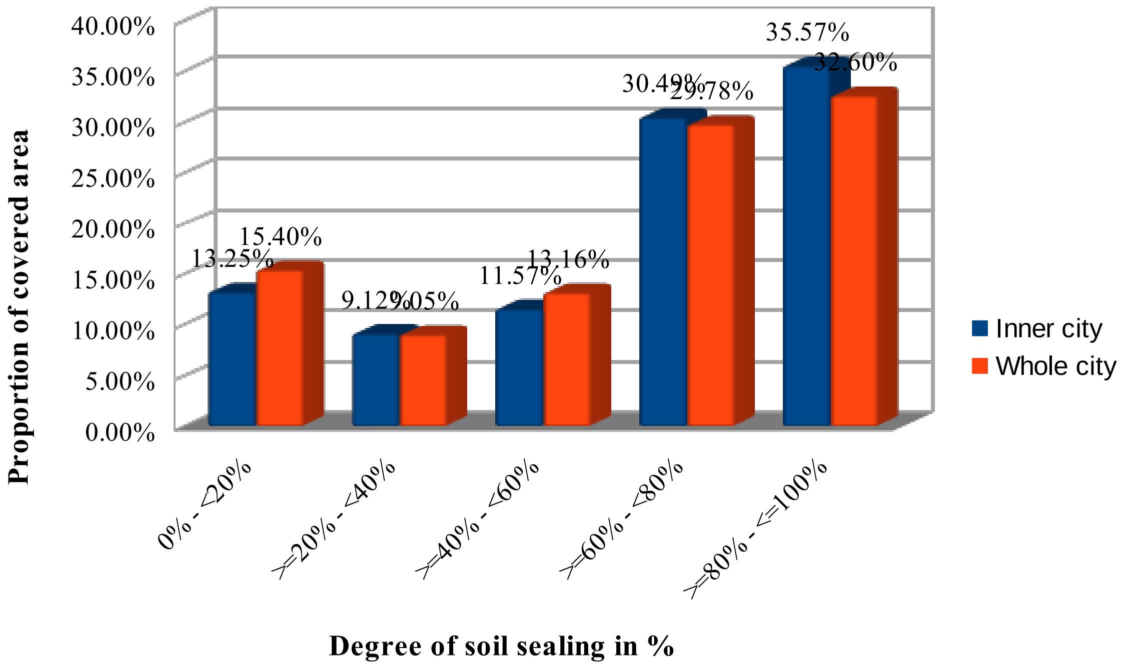


Fig. 28 - Degree of soil sealing in % in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

This difference is also reflected in the cooling rate at night which ranges to 57.05% of the area from -0.60 K to less than -0.40 K per hour for public parks of equally or more than 0.5 ha in the inner city of Berlin within 500 m distance between 10:00 pm and 4:00 am. In the entire city of Berlin, it cools further down from -0.8 K to less than -0.6 K per hour in 63.65% of the area of 500 m distance to public parks of a minimum size of 0.5 ha between 10:00 pm and 4:00 am (Fig. 29).

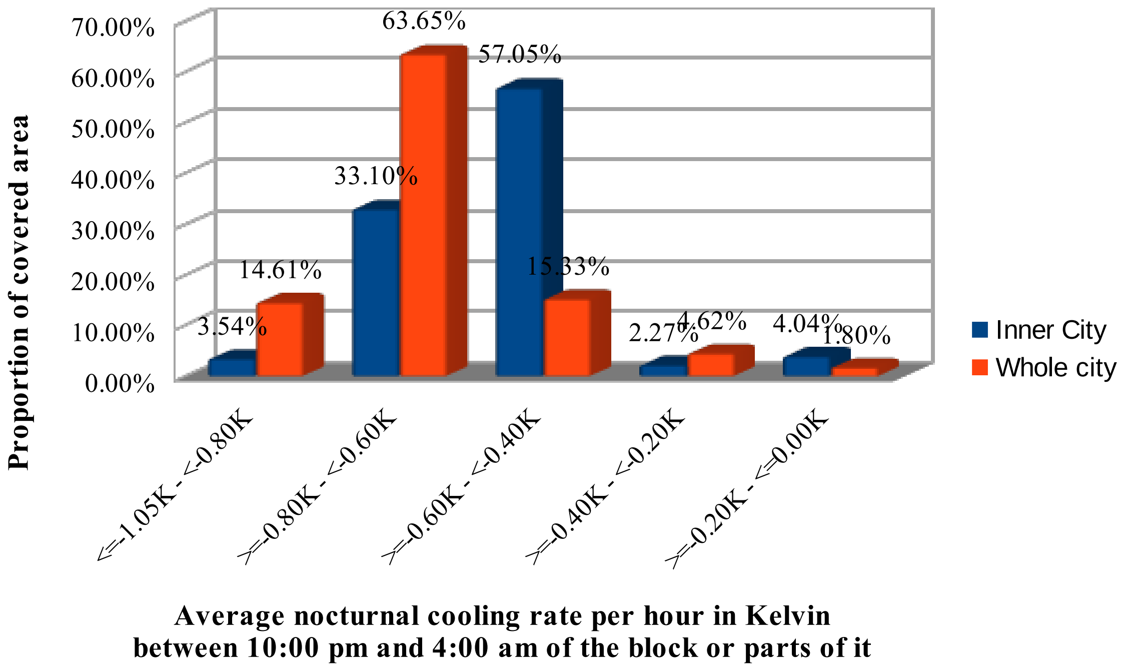


Fig. 29 - Average nocturnal cooling rate per hour in Kelvin between 10:00 pm and 4:00 am of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

It is not surprising after these results that the average evaluation index of the Physiological Equivalent Temperature (PET) to humans still ranges between 20°C to less than 25°C at 95.59% of the surrounding area within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in the late evening at 10:00 pm (Fig. 30). However, it is the same range of 20°C to less than 25°C at 95.65% of the corresponding surrounding area of public parks for the whole city of Berlin at 10:00 pm (Fig. 31).

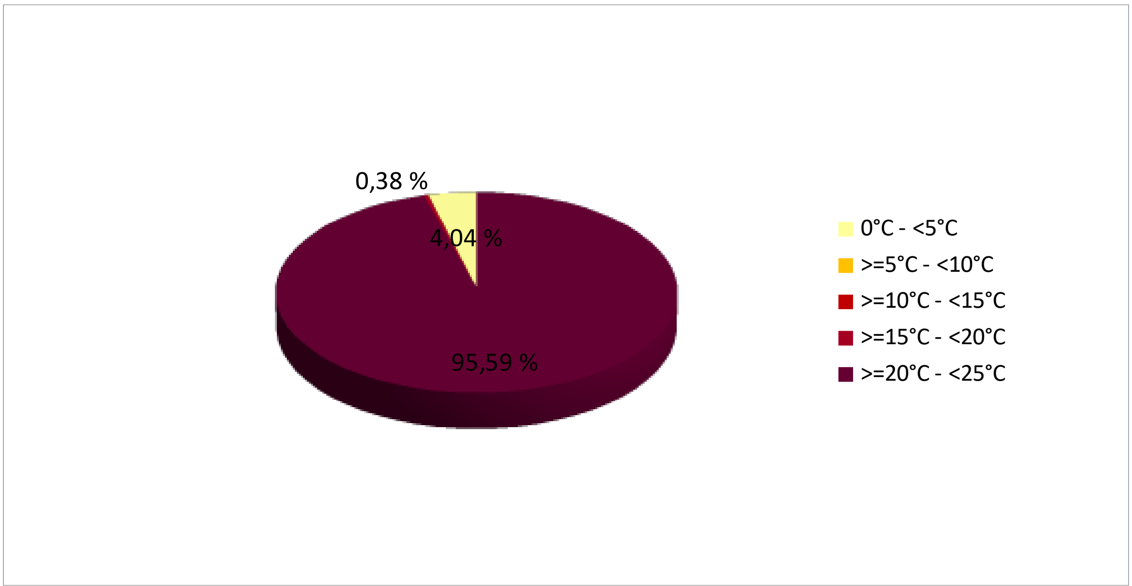


Fig. 30 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

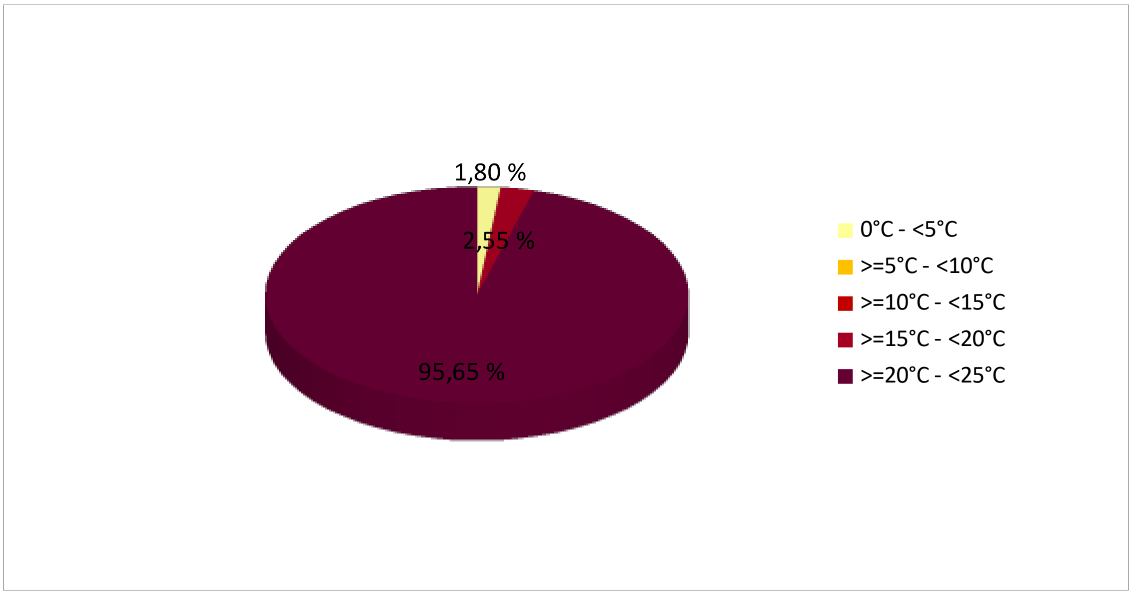


Fig. 31 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

During the night, the average evaluation index of the PET cools down at 4:00 am to a range of 15°C to less than 20°C at 53.76% of the corresponding surrounding area of public parks in the inner city of Berlin, but it ranges still from 20°C to less than 25°C at 41.58% of the area. It is, however, cooler in the whole city of Berlin at 4:00 am with a PET range from 15°C to less than 20°C within 74.25% of the corresponding surrounding area of public parks, and from 20°C to less than 23°C just at 13.21% of the area (Fig. 32).

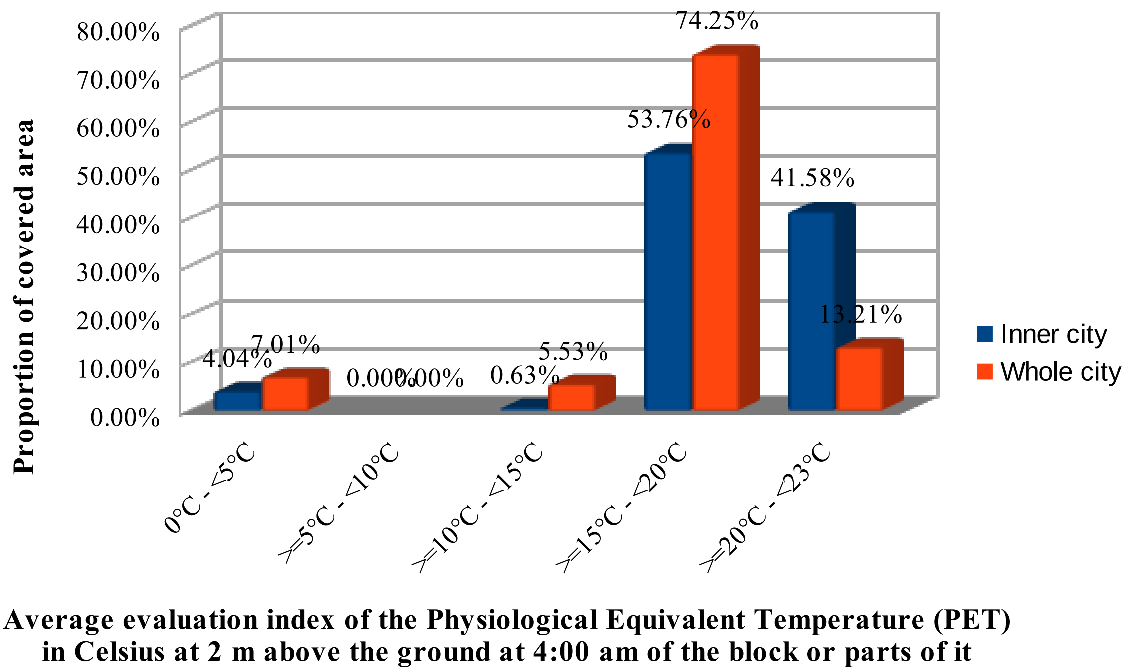


Fig. 32 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 4:00 am of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

During the day, the average evaluation index of the PET is even higher ranging from 28°C to less than 36°C at 94.07% of the corresponding surrounding inner city area of public parks at 2:00 pm. Similar conditions of the average evaluation index of the PET, however, can be found in the whole city of Berlin during the day at 2:00 pm: 93.26% of the corresponding surrounding inner city area of public parks ranges from 28°C to less than 36°C (Fig. 33).

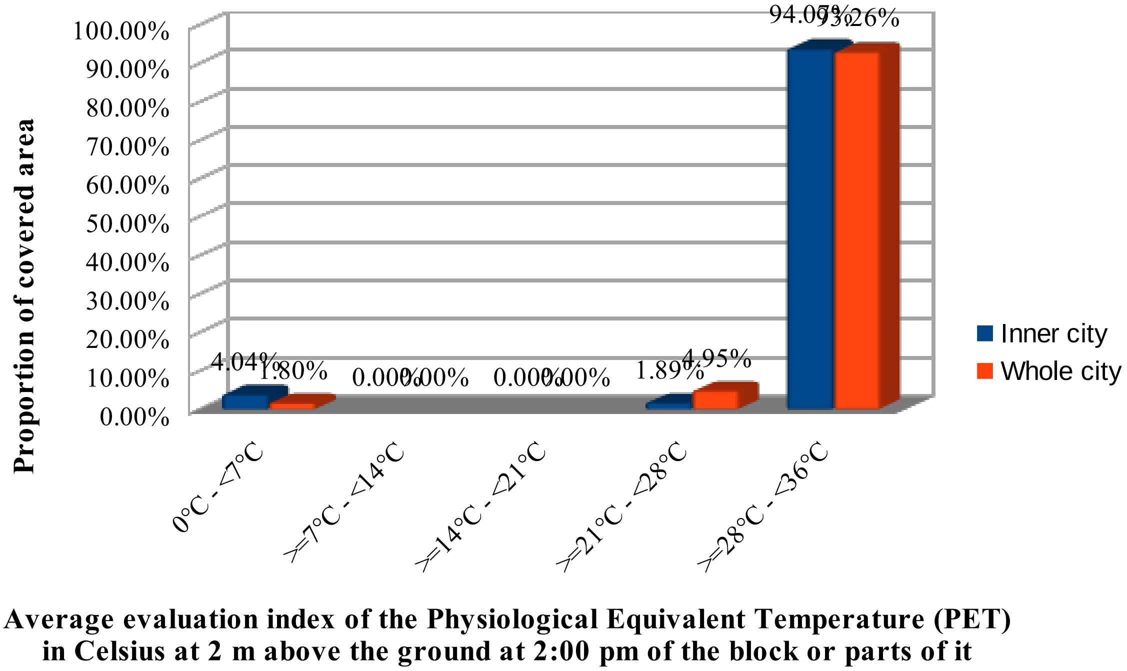


Fig. 33 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 2:00 pm of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The average cold air volume flow in m³/s at 4:00 am of the block or parts of it in 2015 of the corresponding surrounding inner city area of public parks ranges for 80.98% of the area from 0 m³/s to less than 66 m³/s. The average cold air volume flow is much stronger at the corresponding surrounding area of public parks at 4:00 am from a whole city perspective which ranges at 47.30% of the area from 0 m³/s to less than 66 m³/s, and at further 35.54% from 66 m³/s to less than 132 m³/s (Fig. 34).

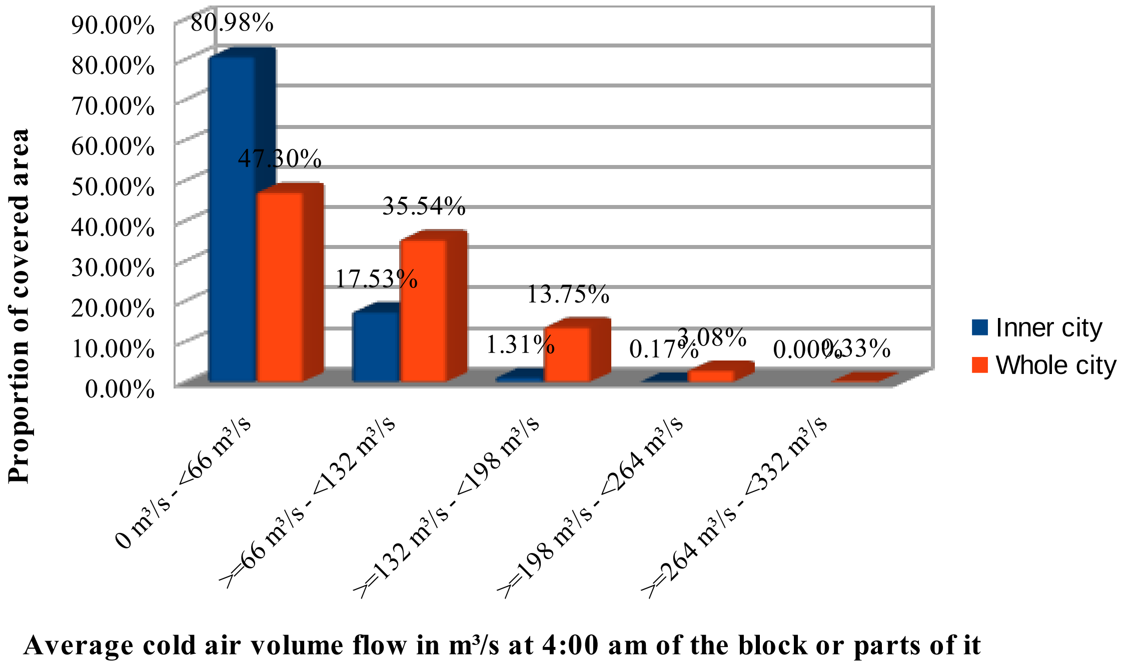


Fig. 34 - Average cold air volume flow in m^3/s at 4:00 am of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

At 10:00 pm, the figures of the average cold air volume flow range at 99.50% of the corresponding surrounding area of public parks from 0 m^3/s to less than 55 m^3/s in the inner city. In the whole city, the average cold air volume flow at 10:00 pm goes less down to 85.28% of the corresponding surrounding area of public parks ranging from 0 m^3/s to less than 55 m^3/s, and at 13.40% of the surrounding area still having a range from 55 m^3/s to less than 110 m^3/s (Fig. 35).

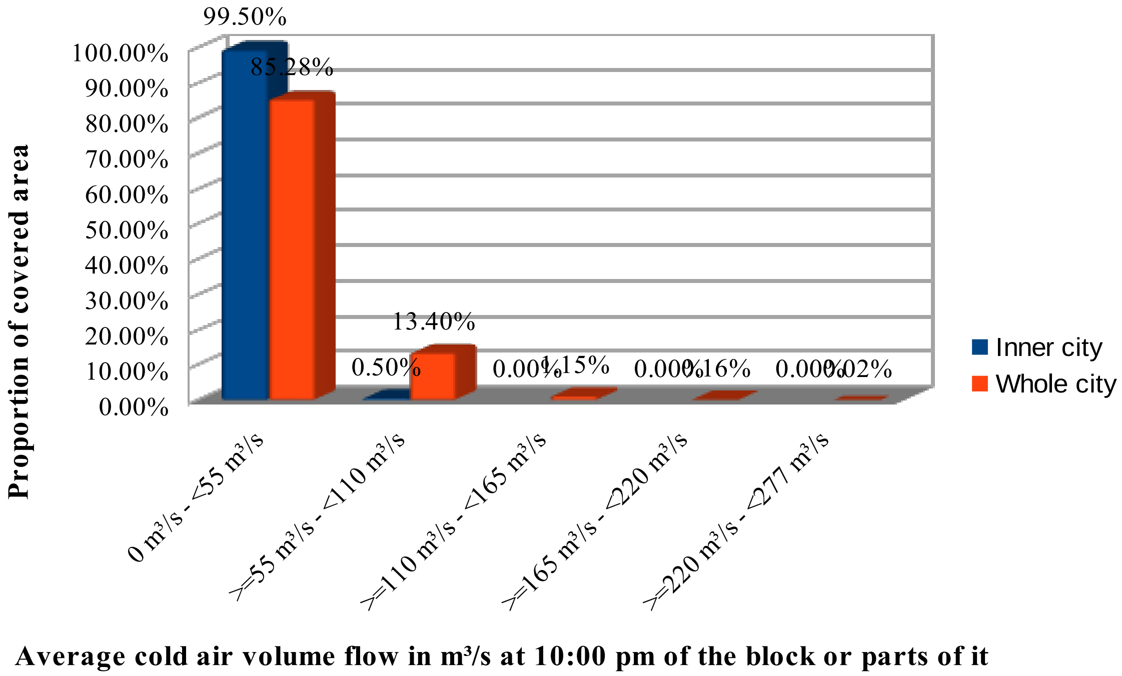


Fig. 35 - Average cold air volume flow in m³/s at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The average number of tropical nights (minimum temperature of 20°C or more) per year of the block or parts of it is also lower at 46.75% of the corresponding surrounding area of public parks in the inner city of Berlin from 2001-2010 where it ranged from 5.2 to less than 7.8 tropical nights per year. Whereas it ranges just at 60.12% of the corresponding surrounding area of public parks from 5.2 to less than 7.8 tropical nights at average per year in the whole city of Berlin from 2001-2010, but at further 19.76% of the area from 2.6 to less than 5.2 tropical nights (Fig. 36).

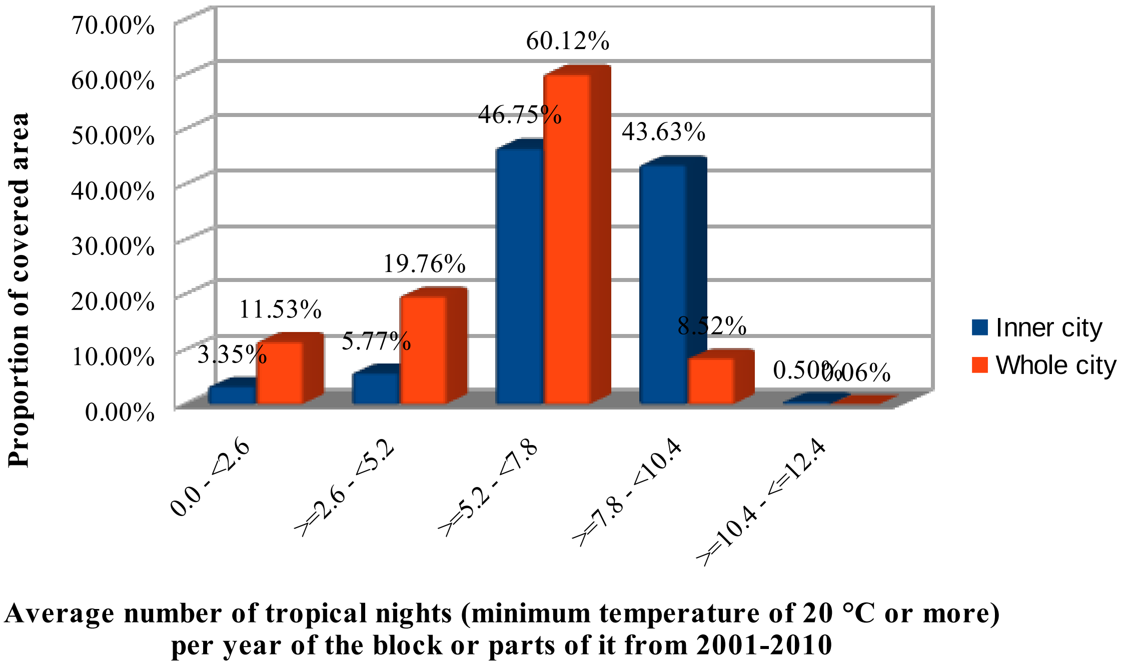


Fig. 36 - Average number of tropical nights (minimum temperature of 20 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The average number of summer days of a minimum temperature of 25°C ranges at 90.57% of the corresponding surrounding area of public parks from 44 summer days to less than 55 summer days in the inner city of Berlin from 2001-2010 whereas the same range refers to 79.52% of the area for the whole city of Berlin (Fig. 37).

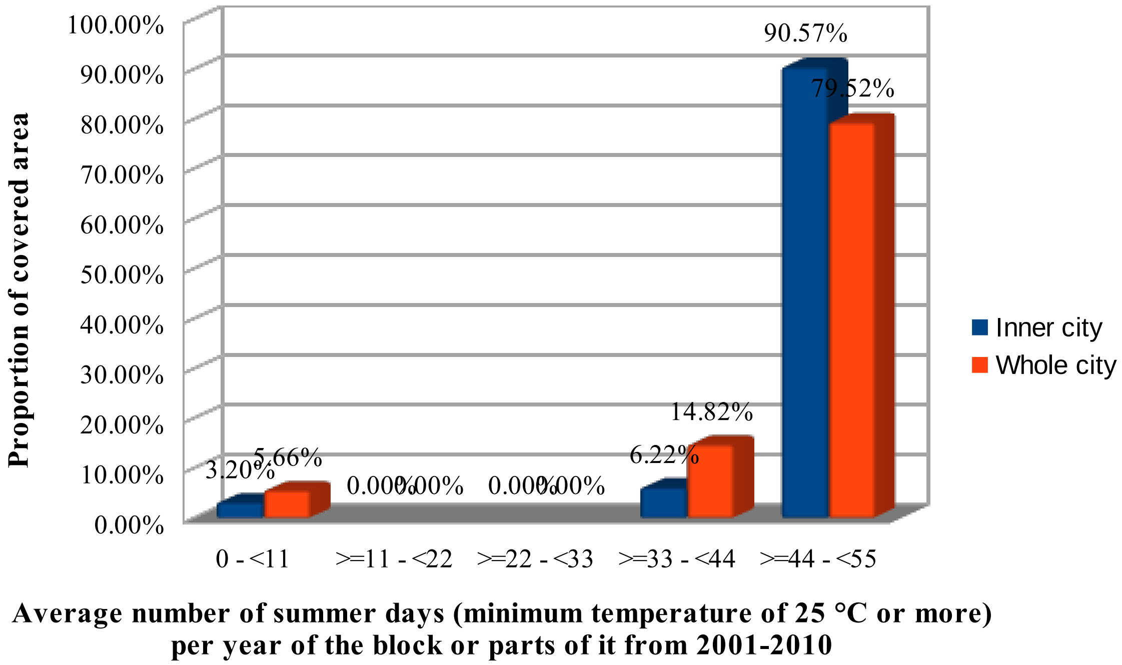


Fig. 37 - Average number of summer days (minimum temperature of 25 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The same temperature difference is also reflected in the average number of heat days of a minimum temperature of 30 °C per year from 2001-2010. 20.17% of the corresponding surrounding area of public parks in the inner city of Berlin has 10.4 to 13.7 heat days at average per year, 74.52% of the area still ranging from 7.8 to less than 10.4 heat days. Whereas it is much lower for 63.94% of the surrounding area ranging from 7.8 to less than 10.4 heat days of the whole city of Berlin, but similar 20.43% of the corresponding surrounding area of a range from 10.4 to 13.7 heat days at average per year (Fig. 38).

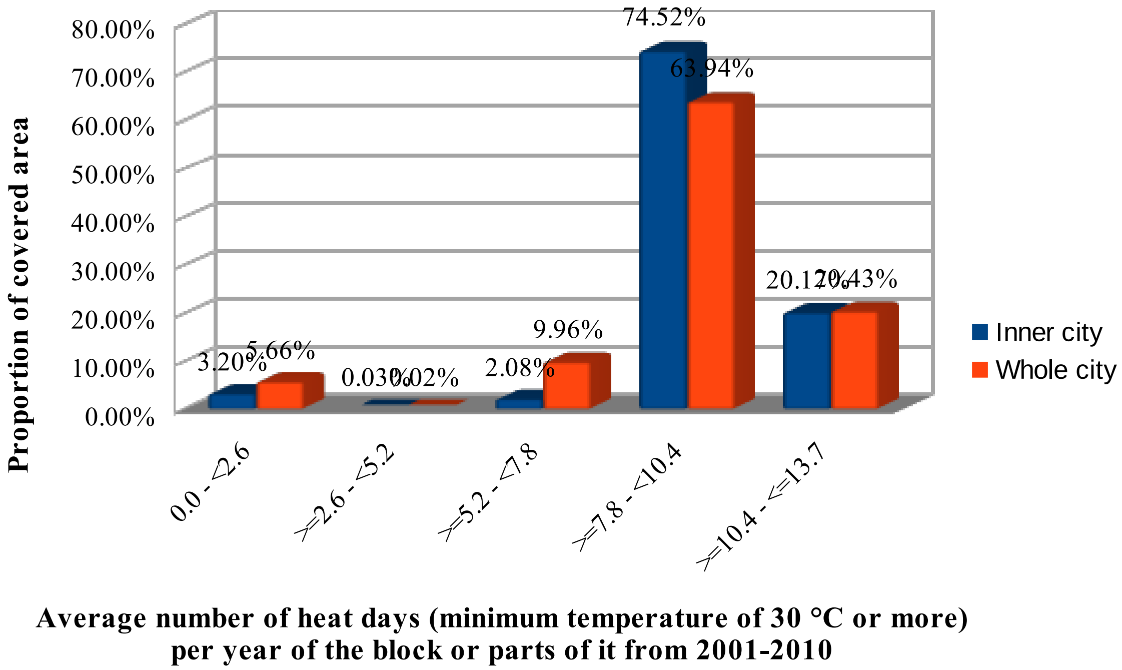


Fig. 38 - Average number of heat days (minimum temperature of 30 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The overall evaluation of the thermal situation in settlements is unfavourable for 52.29% of the surrounding area of public parks in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016, still less favourable for 39.28% of the surrounding area. The figures are almost equal for the whole city of Berlin: 51.28% of the corresponding surrounding area has an unfavourable overall thermal situation, 40.26% a less favourable (Fig. 39).

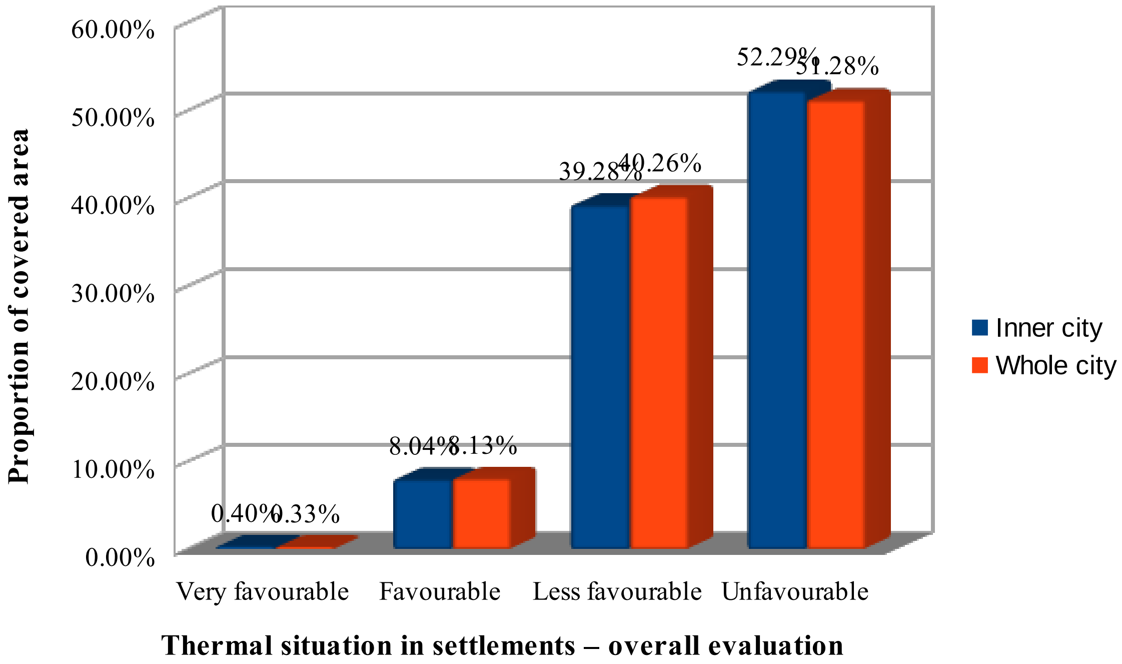


Fig. 39 - Thermal situation in settlements – overall evaluation in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

At 4 am, at least 38.28% of the corresponding surrounding area of public parks has an unfavourable, 21.77% a less favourable overall evaluation of the thermal situation in settlements in the inner city area of Berlin. The figures are even worse for the whole city of Berlin of 42.44% unfavourable and 26.27% less favourable. However, there is a similar high proportion of about one-third undefined covered areas in the inner and whole city of Berlin (Fig. 40).

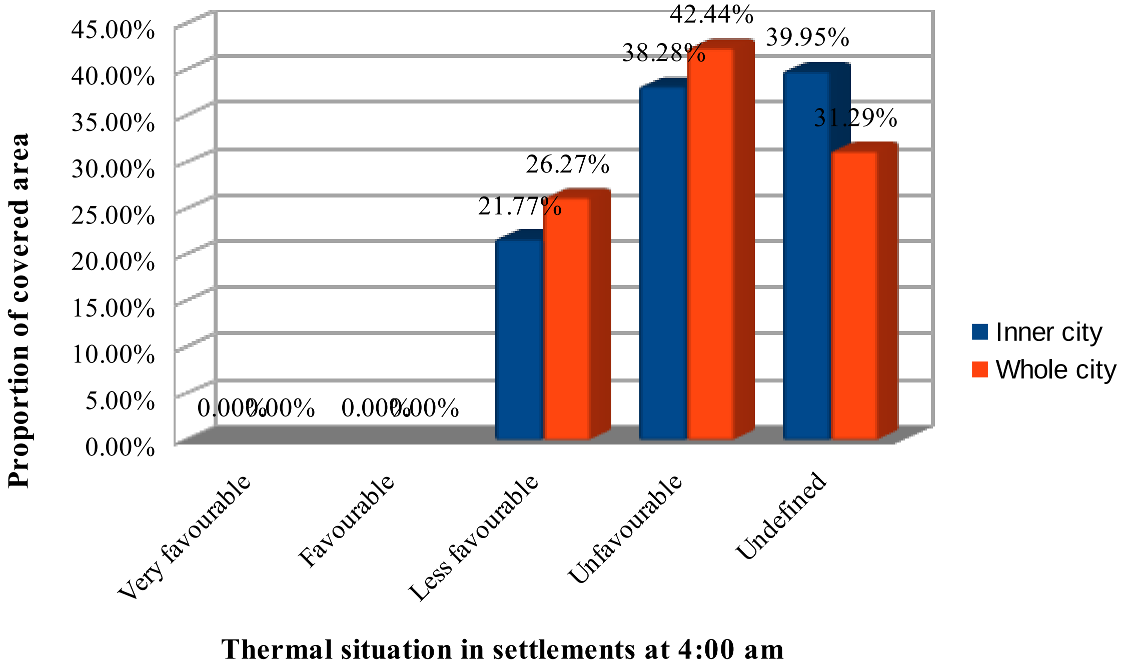


Fig. 40 - Thermal situation in settlements at 4:00 am in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

At 2 pm, the overall evaluation of the thermal situation in settlements is slightly better in the inner city of Berlin of 37.22% of the surrounding area being unfavourable in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016, and 29.31% less favourable. For the whole city of Berlin, the corresponding figures are again similar with 36.82% of the corresponding surrounding area being unfavourable, and 24.38% less favourable (Fig. 41).

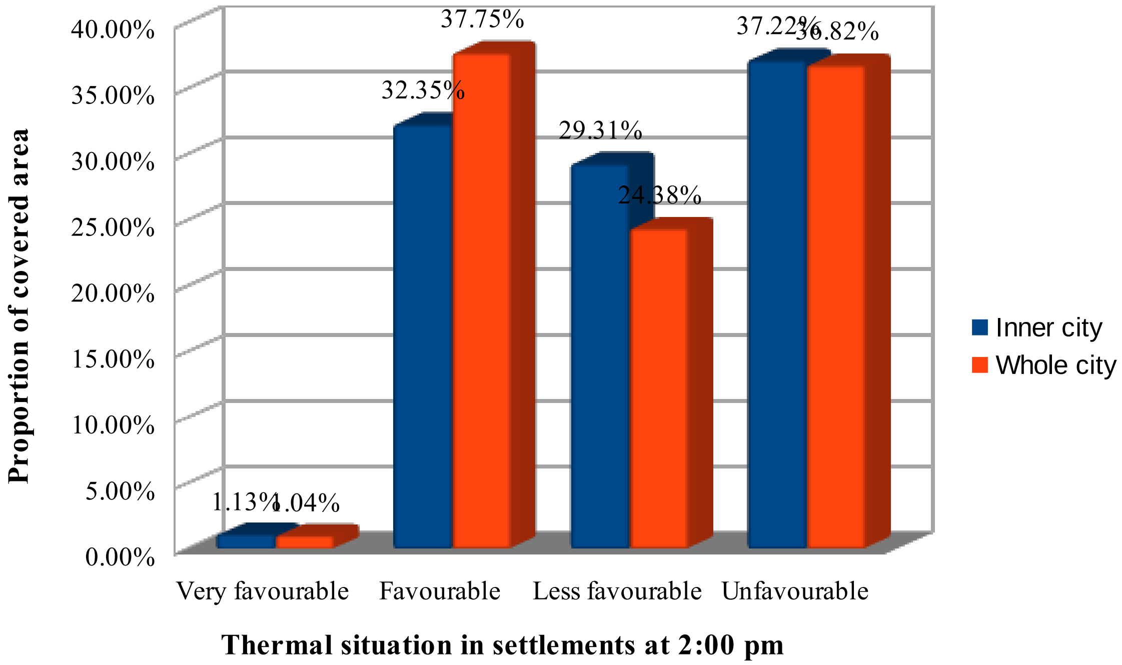


Fig. 41 - Thermal situation in settlements at 2:00 pm in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

Almost 100% of the surrounding area of green and open space has the highest evaluated worthiness of being protected for their climatic functions in 2015 within 500 m distance of public parks of a minimum size of 0.5 ha equally in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

The degree of soil sealing in % in 2015 of public parks ranges from 0% to less than 20% for 71.90% of the inner area in the inner city of Berlin and for further 16.29% of the area of public parks from 20% to less than 40%. The figures are 71.32% and 16.21% within the same range of the area of public parks in entire Berlin (Fig. 42).

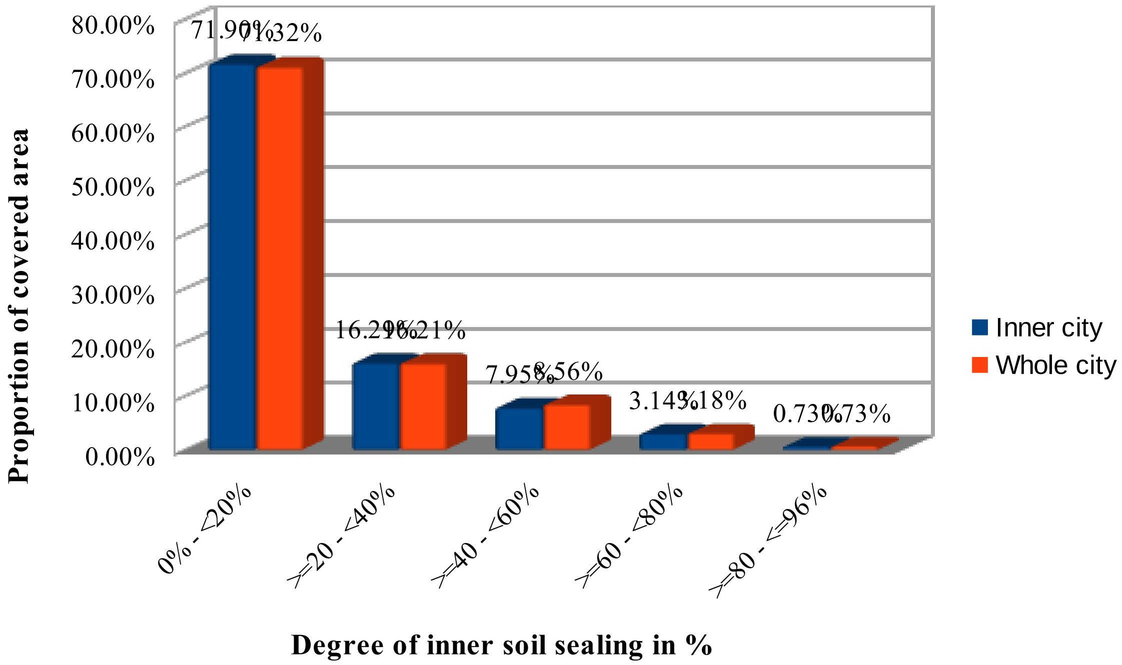


Fig. 42 - Degree of soil sealing in % in 2015 of public parks in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

Almost 100% of the interior area of public parks in the inner city and the whole city of Berlin was evaluated to be overall of the highest worthiness of protection of the green and open space for their climatic functions (own calculation based on data of the Senate of Berlin, 2017a).

Table 10 provides an overview of the results of the microclimatic analysis for public parks, public accessible managed green areas/parks, allotments, and cemeteries.

Table 10 - Overview of the results of the microclimatic analysis for public parks, public accessible managed green areas/parks, allotments, and cemeteries in Berlin (own calculation based on data of the Senate of Berlin, 2017a).

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Degree of soil sealing in % in 2015**		**Average nocturnal cooling rate in Kelvin between 10 pm and 4 am of the block or parts of it in 2015**		**Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015**						**Average cold air volume flow in m^3/s of the block or parts of it in 2015**			
	Inner city	Whole city	Inner city	Whole city	Inner city			Whole city			Inner city		Whole city	
					10:00 pm	4:00 am	2:00 pm	10:00 pm	4:00 am	2:00 pm	10:00 pm	4:00 am	10:00 pm	4:00 am
Public parks (2015)	66% of the area: >=60% to 100%	62% of the area: >=60% to 100%	57% of the area: -0.60K to <-0.40K	64% of the area: -0.80K to <-0.60K	96% of the area: 20°C to <25°C	54% of the area: 15°C to <20°C	94% of the area: 28°C to <36°C	96% of the area: 20°C to <25°C	74% of the area: 15°C to <20°C	93% of the area: 28°C to <36°C	100% of the area: 0 m^3/s to <55 m^3/s:	81% of the area: 0 m^3/s to <66 m^3/s	85 % of the area: 0 m^3/s to <55 m^3/s	47% of the area: 0 m^3/s to <66 m^3/s
Public accessible managed green areas/parks (2010)	53% of the area: >=60% to 100%	52% of the area: >=60% to 100%	52% of the area: -0.60K to <-0.40K	63% of the area: -0.80K to <-0.60K	96% of the area: 20°C to <25°C	54% of the area: 15°C to <20°C	95% of the area: 28°C to <36°C	98% of the area: 20°C to <25°C	83% of the area: 15°C to <20°C	93% of the area: 28°C to <36°C	99% of the area: 0 m^3/s to <55 m^3/s	78% of the area: 0 m^3/s to <66 m^3/s	89 % of the area: 0 m^3/s to <55 m^3/s	52% of the area: 0 m^3/s to <66 m^3/s
Allotments (2015)	54% of the area: >=60% to 100%	48% of the area: >=60% to 100%	43% of the area: -0.80K to <-0.60K	70% of the area: -0.80K to <-0.60K	89% of the area: 20°C to <25°C	69% of the area: 15°C to <20°C	92% of the area: 28°C to <36°C	93% of the area: 20°C to <25°C	87% of the area: 15°C to <20°C	95% of the area: 28°C to <36°C	98% of the area: 0 m^3/s to <55 m^3/s	70% of the area: 0 m^3/s to <66 m^3/s	82 % of the area: 0 m^3/s to <55 m^3/s	49% of the area: 0 m^3/s to <66 m^3/s
Cemeteries	67% of	60% of	52% of	66% of	94% of	54% of	96% of	95% of	84% of	96% of	99% of the	80% of the	88 % of the	54% of the

(2010)	the area: >=60% to 100%	the area: >=60% to 100%	the area: -0.60K to <-0.40K	the area: -0.80K to <-0.60K	the area: 20°C to <25°C	the area: 20°C to <22°C	the area: 28°C to <36°C	the area: 20°C to <25°C	the area: 15°C to <20°C	the area: 28°C to <36°C	area: 0 m³/s to <55 m³/s	area: 0 m³/s to <66 m³/s	area: 0 m³/s to <55 m³/s	area: 0 m³/s to <66 m³/s

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Average number of tropical nights (minimum temperature of 20°C or more) per year of the block or parts of it from 2001-2010**		**Average number of summer days (minimum temperature of 25°C or more) per year of the block or parts of it from 2001-2010**		**Average number of heat days (minimum temperature of 30°C or more) per year of the block or parts of it from 2001-2010**		**Thermal situation in settlements**					
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city			Whole city		
							Overall evaluation	4:00 am	2:00 pm	Overall evaluation	4:00 am	2:00 pm
Public parks (2015)	44% of the area: 7.8 to <10.4 nights, 47% of the area: 5.2 to <7.8 nights	9% of the area: 7.8 to <10.4 nights, 60% of the area: 5.2 to <7.8 nights	91% of the area: 44 to <55 days	80% of the area: 44 to <55 days	75% of the area: 7.8 to <10.4 days	64% of the area: 7.8 to <10.4 days	52% of the area: unfavourable, 39% of the area: less favourable	38% of the area: unfavourable, 22% of the area: less favourable	37% of the area: unfavourable, 29% of the area: less favourable, 32% of the area: favourable	51% of the area: unfavourable, 40% of the area: less favourable	42% of the area: unfavourable, 26% of the area: less favourable	37% of the area: unfavourable, 24% of the area: less favourable, 38% of the area: favourable

Public accessible managed green areas/parks (2010)	39% of the area: 7.8 to <10.4 nights, 49% of the area: 5.2 to <7.8 nights	18% of the area: 7.8 to <10.4 nights, 67% of the area: 5.2 to <7.8 nights	97% of the area: 44 to <55 days	94% of the area: 44 to <55 days	72% of the area: 7.8 to <10.4 days	65% of the area: 7.8 to <10.4 days	50% of the area: unfavourable, 40% of the area: less favourable	39% of the area: unfavourable, 21% of the area: less favourable	34% of the area: unfavourable, 32% of the area: less favourable, 33% of the area: favourable	48% of the area: unfavourable, 43% of the area: less favourable	37% of the area: unfavourable, 25% of the area: less favourable	33% of the area: unfavourable, 26% of the area: less favourable, 40% of the area: favourable
Allotments (2015)	23% of the area: 7.8 to <10.4 nights, 55% of the area: 5.2 to <7.8 nights	4% of the area: 7.8 to <10.4 nights, 65% of the area: 5.2 to <7.8 nights	97% of the area: 44 to <54 days	96% of the area: 44 to <54 days	61% of the area: 7.8 to <10.4 days	63% of the area: 7.8 to <10.4 days	55% of the area: unfavourable, 37% of the area: less favourable	13% of the area: unfavourable, 23% of the area: less favourable	48% of the area: unfavourable, 19% of the area: less favourable, 31% of the area: favourable	51% of the area: unfavourable, 40% of the area: less favourable	22% of the area: unfavourable, 29% of the area: less favourable	22% of the area: unfavourable, 32% of the area: less favourable, 45% of the area: favourable
Cemeteries (2010)	41% of the area: 7.8 to <10.4 nights, 48% of the area: 5.2 to <7.8 nights	10% of the area: 7.8 to <10.4 nights, 64% of the area: 5.2 to <7.8 nights	89% of the area: 44 to <54 days	97% of the area: 44 to <54 days	73% of the area: 7.8 to <10.4 days	69% of the area: 7.8 to <10.4 days	63% of the area: unfavourable, 31% of the area: less favourable	61% of the area: unfavourable, 9% of the area: less favourable	38% of the area: unfavourable, 35% of the area: less favourable, 26% of the area: favourable	57% of the area: unfavourable, 37% of the area: less favourable	46% of the area: unfavourable, 21% of the area: less favourable	35% of the area: unfavourable, 32% of the area: less favourable, 32% of the area: favourable

Public urban green space type	**Overall evaluation of the worthiness of protection of the green and open space for their climatic functions in 2015**		**Degree of soil sealing of the green space land use type in % in 2015**	
	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	100% of the area: highest worthiness	100% of the area: highest worthiness	72% of the area: 0% to <20%	71% of the area: 0% to <20%
Public accessible managed green areas/parks (2010)	100% of the area: highest worthiness	100% of the area: highest worthiness	41% of the area: 0% to >20%, 50% of the area: 20% to <40%	44% of the area: 0% to <20%, 47% of the area: >=20% to <40%
Allotments (2015)	100% of the area: highest worthiness	100% of the area: highest worthiness	97% of the area: 0% to >20%	71% of the area: >=20% to <40%
Cemeteries (2010)	100% of the area: highest worthiness	100% of the area: highest worthiness	72% of the area: 0% to <20%	84% of the area: 0% to <20%

2.5.2.2. Soil functions

Spatial population data on biodiversity is hardly available in Berlin, despite there are legal monitoring obligations of the EU Habitats Directive and the EU Birds Directive (European Commission, 1992, 2009). A monitoring obligation of nature and landscapes has theoretically been implemented in § 6 Federal Conservation Act of Germany (BNatSchG, 2017) and § 6 Nature Conservation Act of Berlin (NatSchGBln, 2013) with particular reference to these two EU directives. However, there is not sufficient biodiversity data available in practice for a comprehensive analysis of the different values of urban biodiversity for citizens and nature on its own for urban and landscape planning purposes in Berlin.

The deficits of monitoring data of the different values of green space in Berlin limit also the possible analysis of this research, particularly regarding the ecosystemic interactions and those values related to Berlin's citizens of the different levels of biodiversity (CBD, 1992). Therefore, I used indirect spatial indicators of soil functions of biodiversity which are related to the living environment as biophysical ecosystem services. Hereby, I analysed the spatial data of the area within the inner boundaries of all public parks, public accessible managed green areas/parks, allotments, and cemeteries of Berlin's Environmental Atlas (Senate of Berlin, 2017a). Also smaller areas than 0.5 ha can provide important ecosystem services in walking distance for citizens' health, reflection, and inspiration, as habitat for species and other biophysical ecosystem (soil based) services.

As a result, the regulation function for the water balance of public parks lacks behind those in the whole city. Just 22.93% of the area of public parks in the inner city have a high, 67.99% a medium regulation function. In contrast, public parks in the whole city are to 44.15% of the area of high and 48.68% of medium importance for the water balance of public parks (Fig. 43) (Table 11).

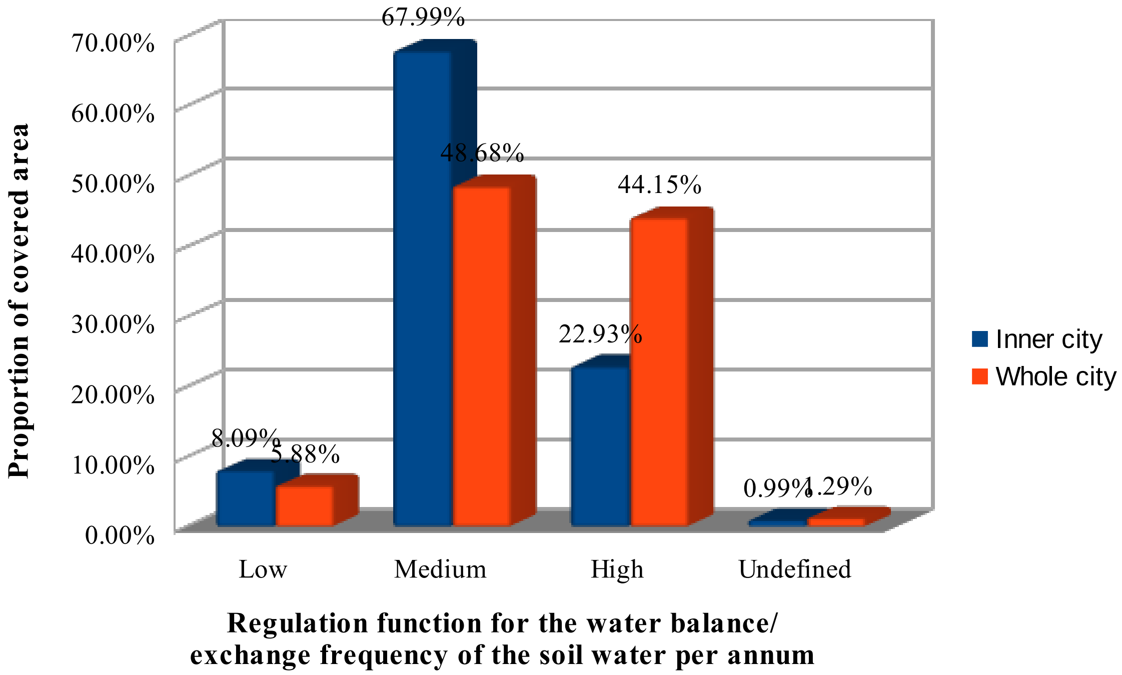


Fig. 43 - Regulation function for the water balance/exchange frequency of the soil water per annum of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The soil buffering and filtration capacity is also lower of public parks in the inner city in contrast to the entire city. Nutrients and heavy metals are kept at medium level for 51.47% of the area of public parks in the inner city of Berlin, low for 46.04% of the area. The figures are medium for 46.27% of the area of public parks in the whole city and low for 32.38% (Fig. 44).

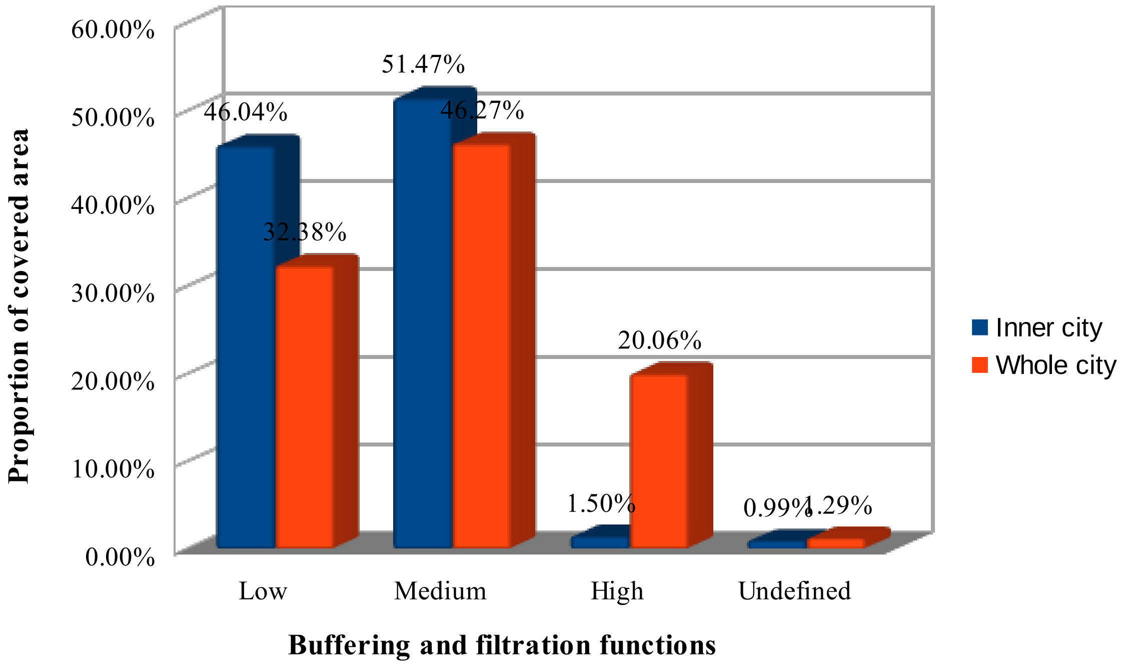


Fig. 44 - Buffering and filtration functions/sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange capacity, and binding capacity of heavy metals of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The habitat function for rare natural vegetation is low for 86.35% of the area of inner city public parks as well as for 74.07% of public parks in whole Berlin (Fig. 45).

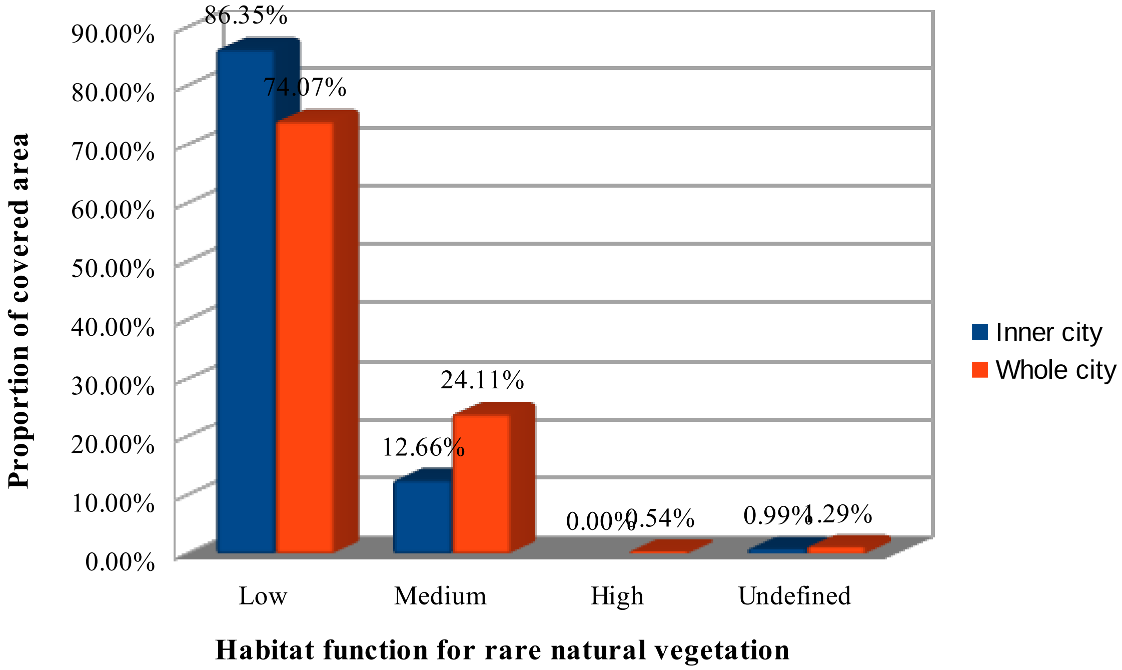


Fig. 45 - Habitat function for rare natural vegetation/indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

In comparison, the yield function for cultivated plants is low for 95.82% of the area of public parks in the inner city as well as low for 83.36% of the whole city (Fig. 46).

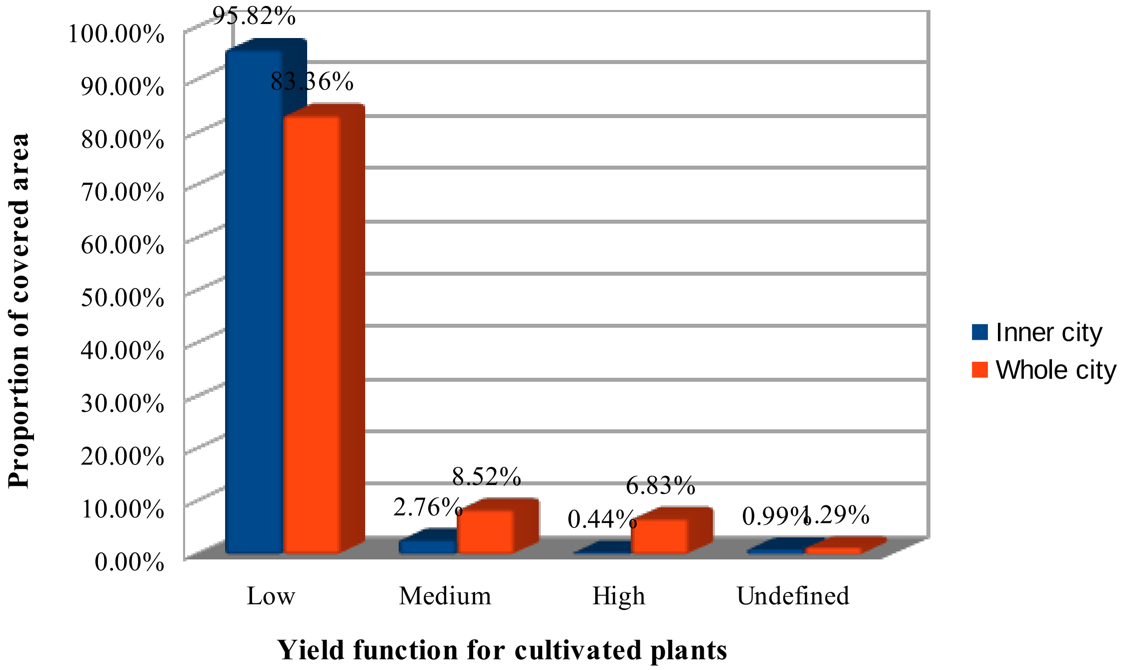


Fig. 46 - Yield function for cultivated plants/sum of water and nutrient supply indicators of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The soil archival function of natural history is low for 97.41% of the area of public parks in the inner city of Berlin. However, it is medium for 21.12% of the area for public parks and for 71.40% low in the whole city (Fig. 47).

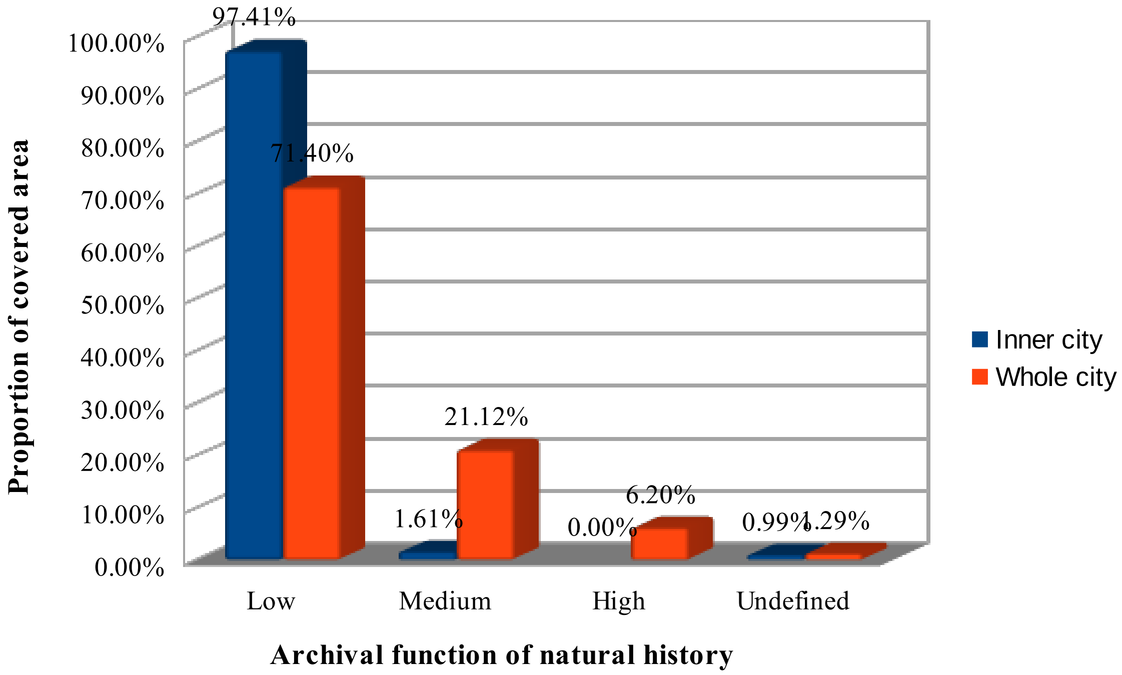


Fig. 47 - Archival function of natural history/rarity of soil associations, and particular soils of the nature region of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The overall performance of natural soil and archival functions is low for 76.03% of the area and for 21.36% medium of public parks in the inner city of Berlin, but high for 23.56% of the area of public parks and medium for 25.72% in whole Berlin (Fig. 48).

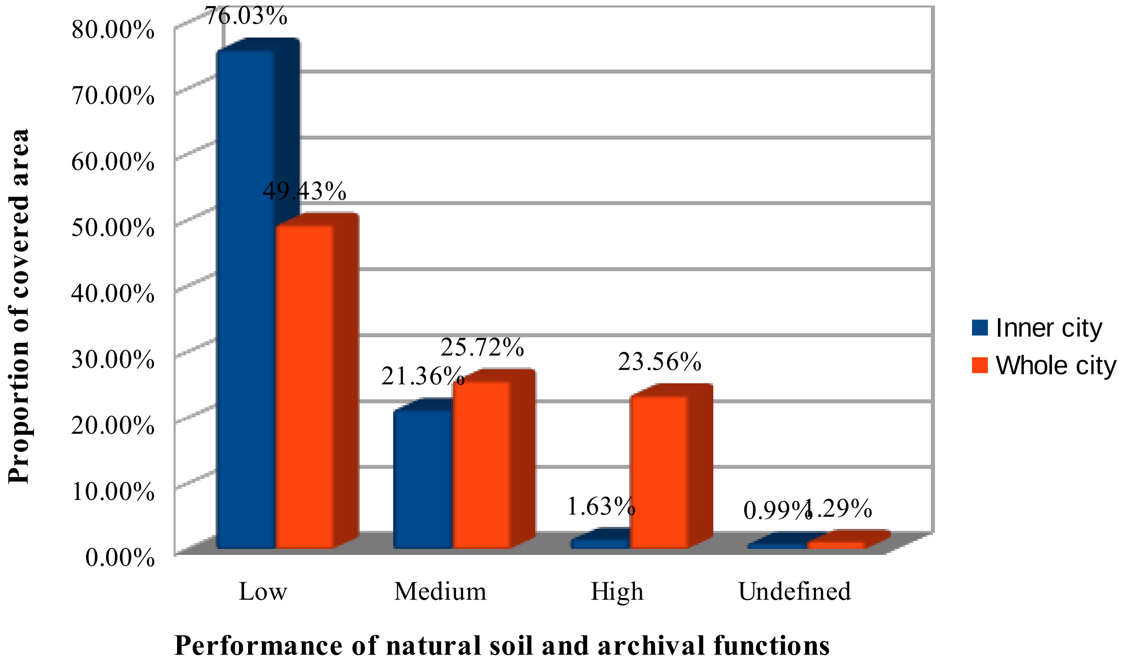


Fig. 48 - Performance of natural soil and archival functions/sum of soil functions of the five analysed soil functions above of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The overall soil protection values are high for 21.20% and very high for 1.78% of the area of public parks in the inner city of Berlin. Instead, they are very high for 17.44% and still high for 16.29% of the area for the whole city of Berlin (Fig. 49).

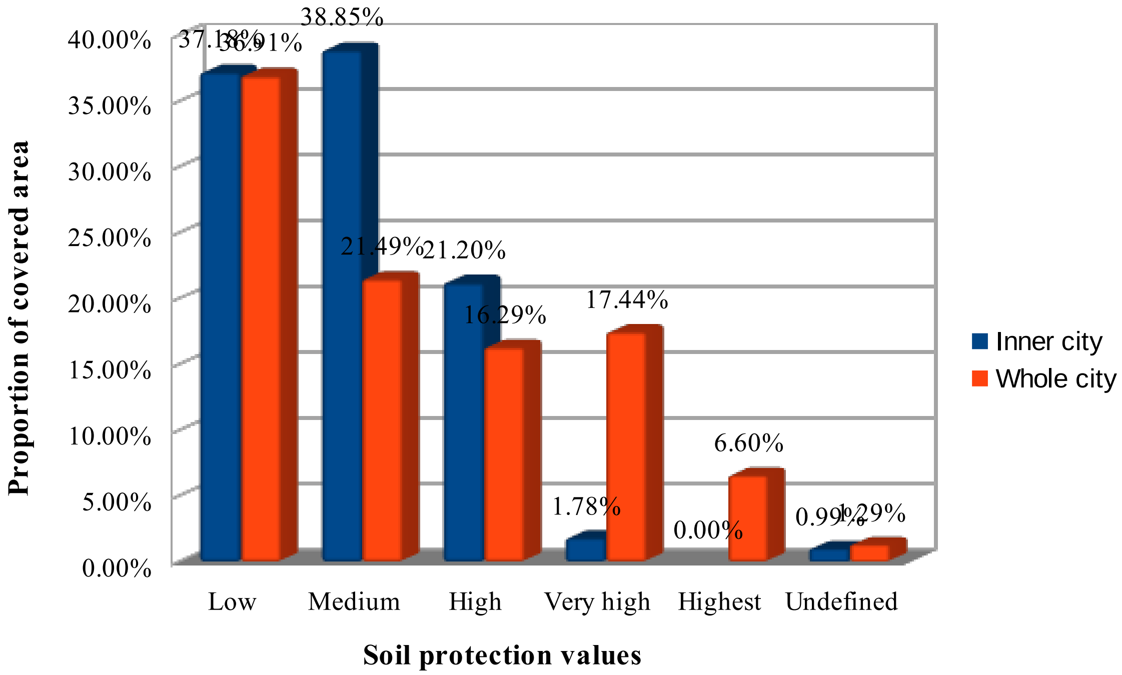


Fig. 49 - Soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance, as well as soil sealing degree of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The naturalness of public parks is low for 53.49% and medium for 25.18% of the area in the inner city, whereas it is for 45.24% low and 38.91% medium of the area of public parks in entire Berlin (Fig. 50).

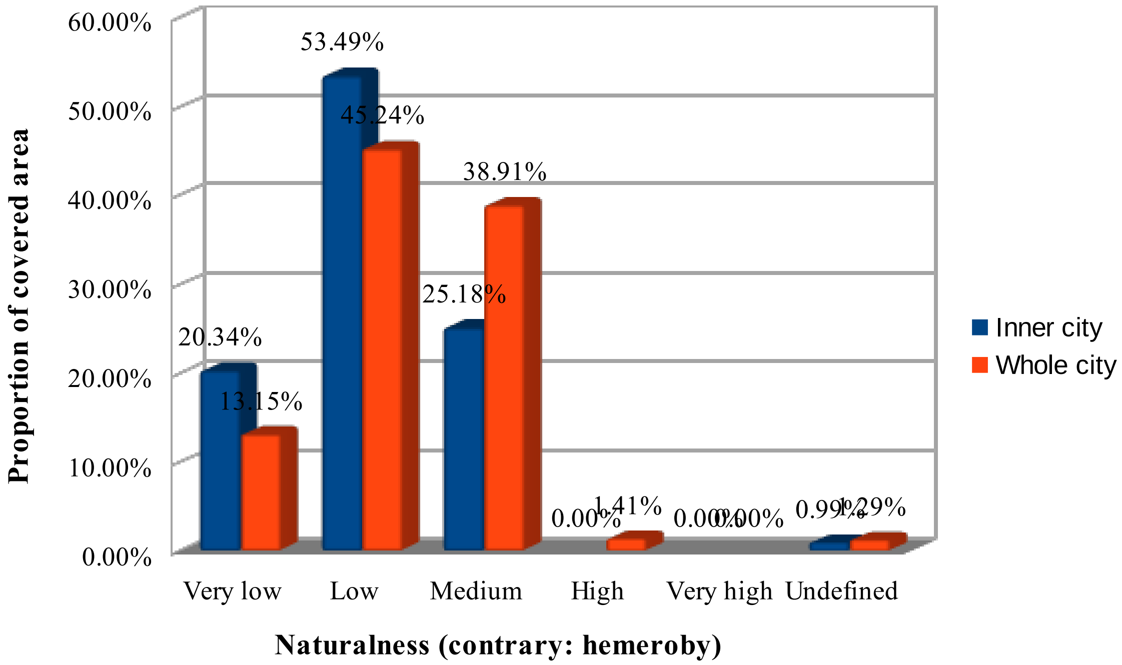


Fig. 50 - Naturalness (contrary: hemeroby) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

In particular, the exchange frequency of groundwater (contrary: water storage capacity) is very low for 22.93% of the area of public parks, low for 27.19%, and medium for 40.80% in the inner city of Berlin. In whole Berlin, the exchange frequency of groundwater is the other way around very low for 44.15% of the area of public parks, low for 27.69% and medium for 21.00% (Fig. 51). The average ground water recharge per m² per annum is 131.82 l in public parks in the inner city compared to 113.04 l in public parks in the entire city of Berlin (Table 11).

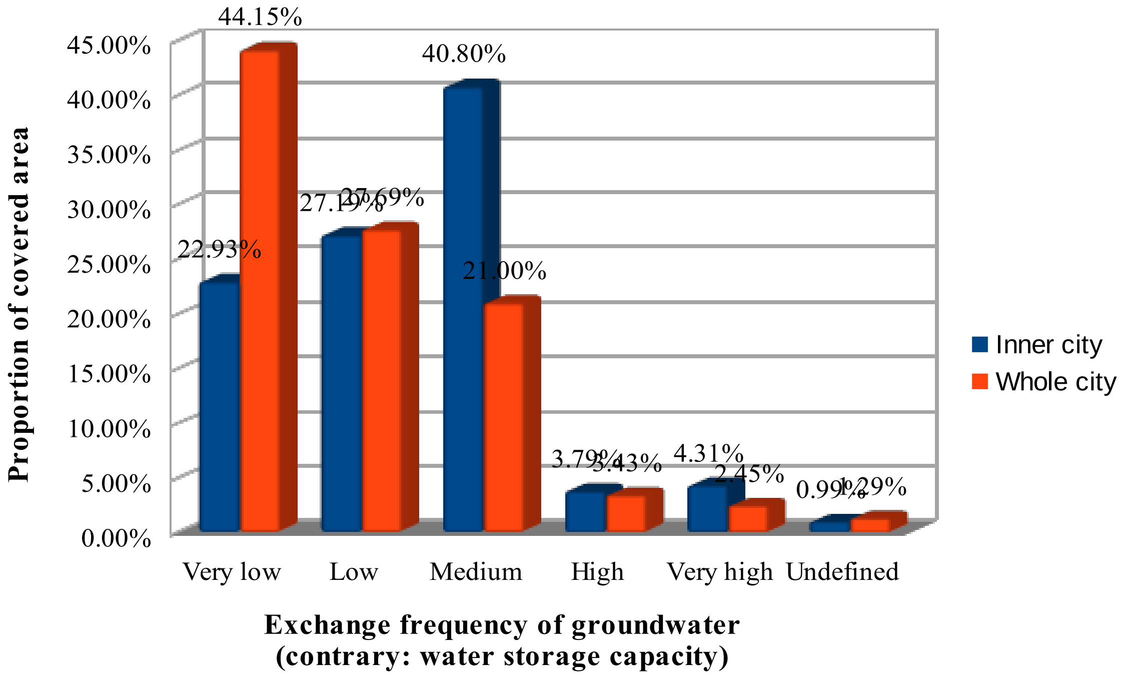


Fig. 51 - Exchange frequency of groundwater (contrary: water storage capacity) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The water supply is equally medium for 70.82% of the area of public parks in the inner and 71.37% whole city of Berlin (Fig. 52). 86.68% of the area of public parks in the inner city are not particularly dry locations, and 84.87% of the whole city of Berlin (Table 11).

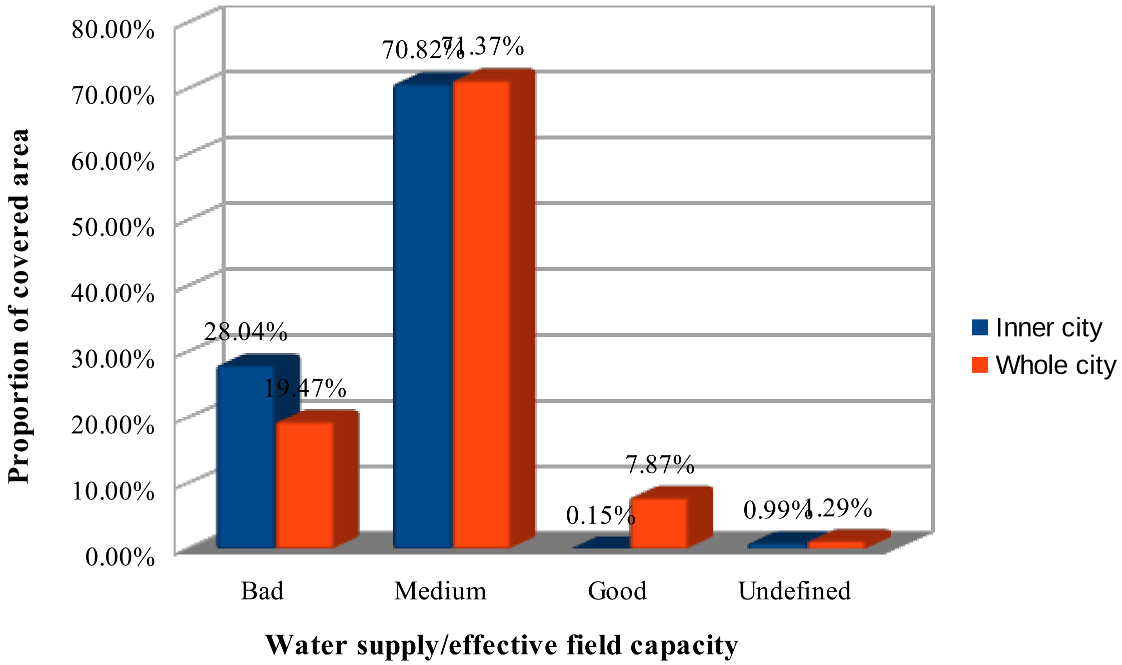


Fig. 52 - Water supply/effective field capacity of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

In the inner city of Berlin, the filtration capacity is low for 97.57% of the area of public parks. However, it is low just for 75.51% of the area and medium for 23.20% of the area of public parks in whole Berlin (Fig. 53).

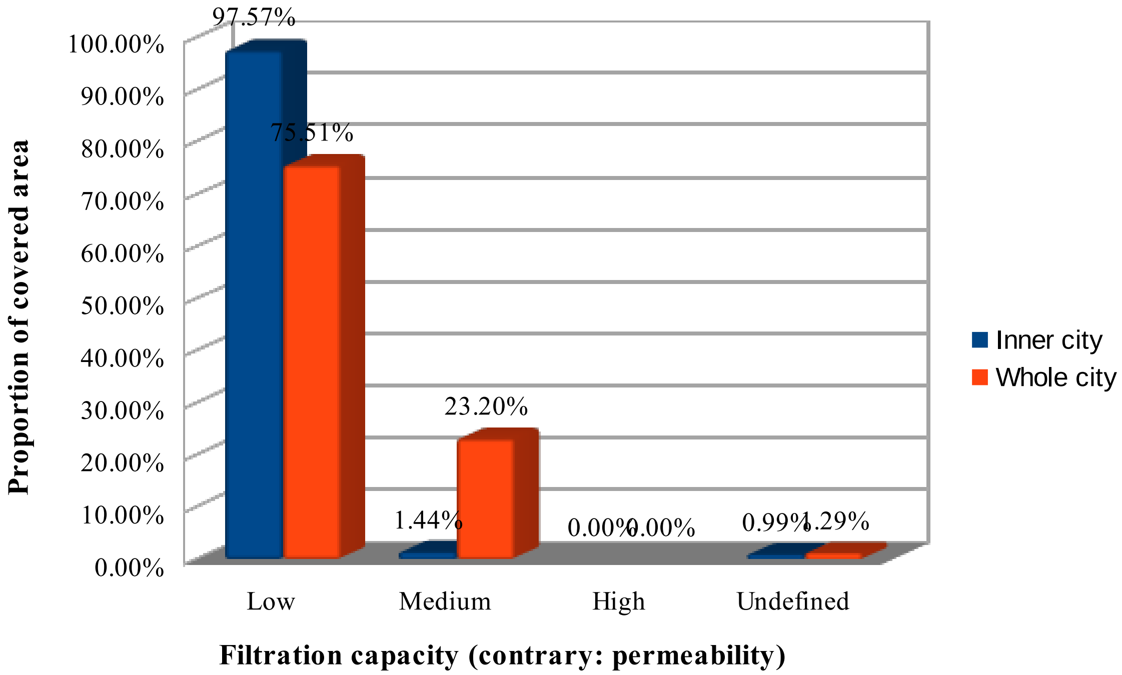


Fig. 53 - Filtration capacity (contrary: permeability) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The occurrence of soil associations of public parks within the area of Berlin is very frequent for 53.27% of the area of public parks and frequent for 39.31% in the inner city of Berlin. It is very frequent for 34.06% and frequent for 48.98% of the area of public parks in entire Berlin (Fig. 54).

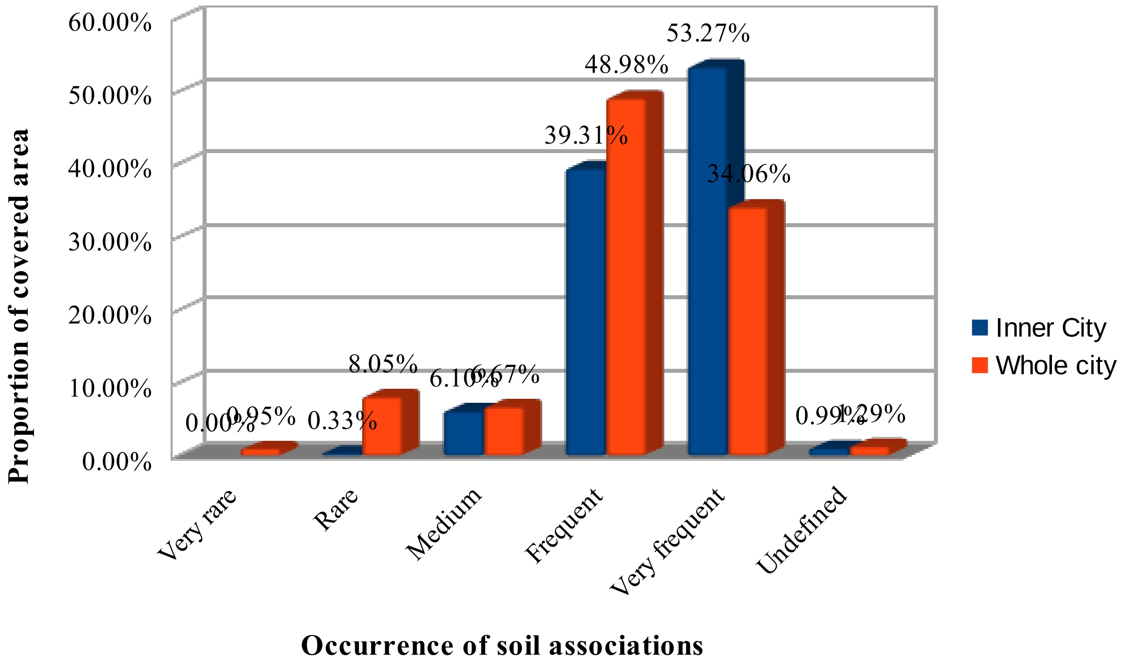


Fig. 54 - Occurrence of soil associations within the area of Berlin of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The binding capacity of heavy metals is very high for 35.37% of the area of public parks, and still high for 57.83% in the inner city of Berlin. At the whole city level of Berlin, it is very high for 23.58% of the area of public parks and high for 61.01% (Fig. 55).

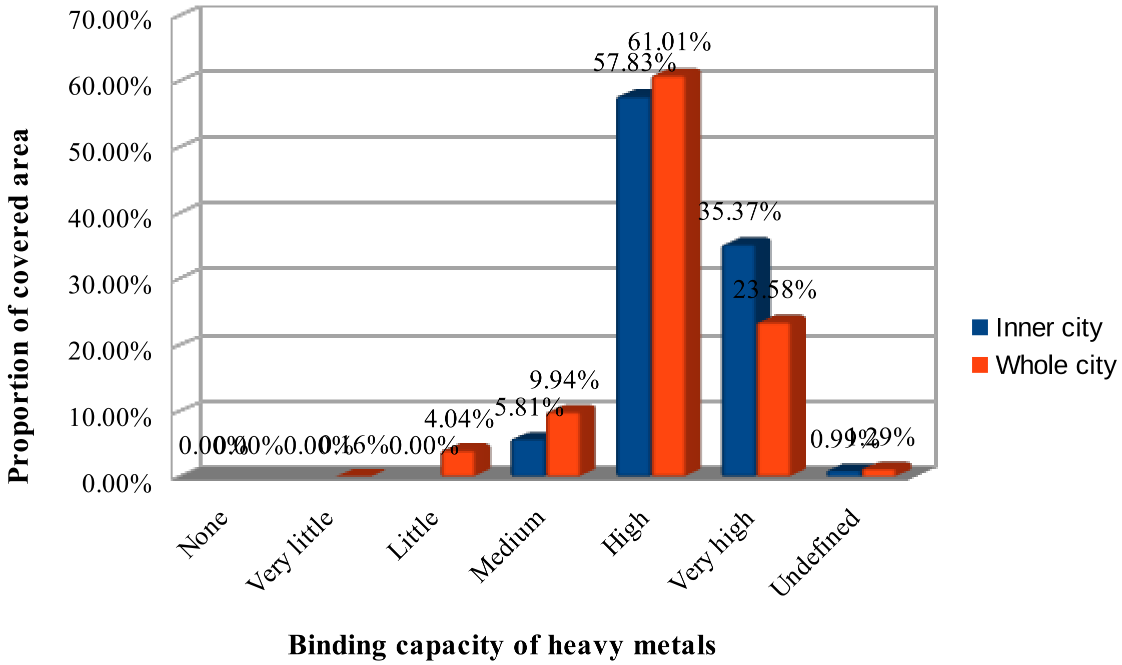


Fig. 55 - Binding capacity of heavy metals of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

The nutrient storage and binding capacity of pollutants is low for 97.31% of the area of public parks and medium for 1.62% in the inner city of Berlin. It is also low for 75.52% of the area of public parks, but medium for 18.27% in whole Berlin (Fig. 56).

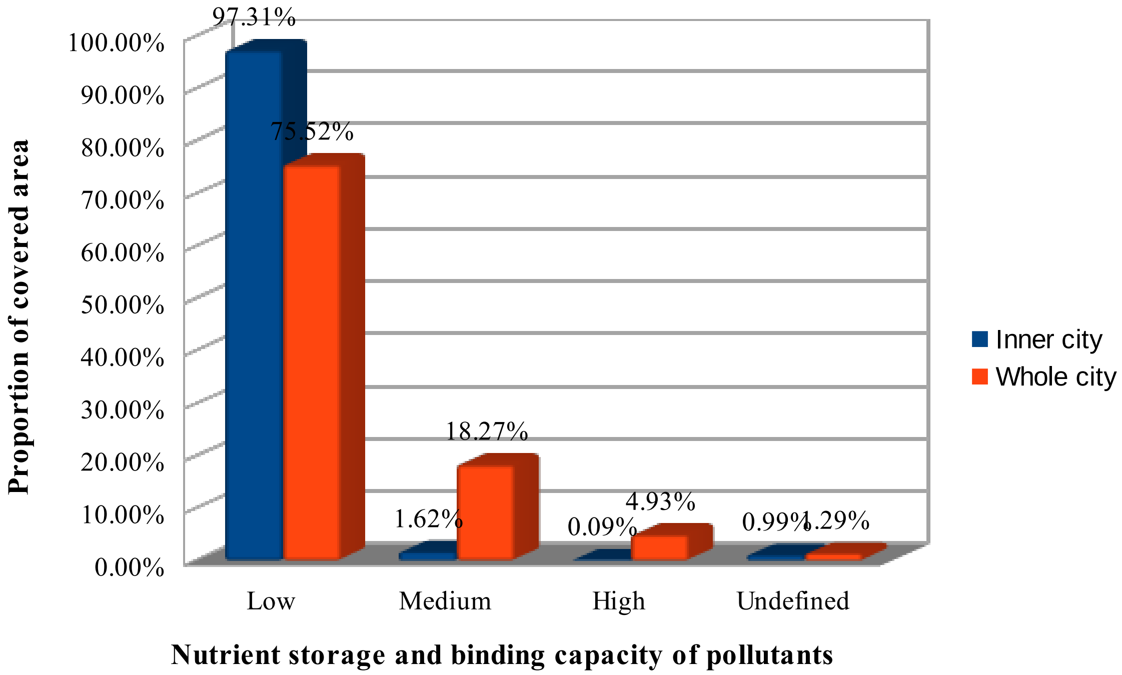


Fig. 56 - Nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

In particular, the filtration capacity of the subsoil is low for 67.75% of the area of public parks, medium for 29.97%, and high just for 1.29% in the inner city of Berlin. The figures are similar low for 64.38% of the subsoil for the area of public parks in whole Berlin, but medium for 18.38% and high for 15.95% (Fig. 57).

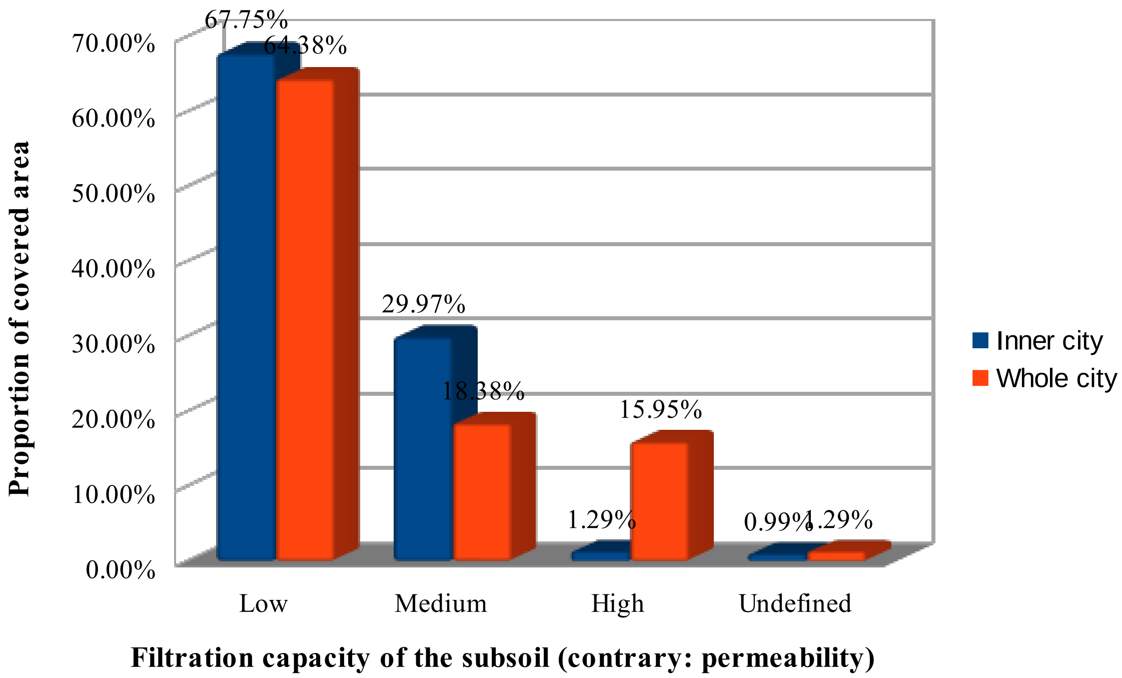


Fig. 57 - Filtration capacity of the subsoil (contrary: permeability) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

Regarding the topsoil, the filtration capacity is low for 97.47% of the area of public parks and medium for 1.54% in the inner city of Berlin. The figures are low for 71.55% of the subsoil for the area of public parks and medium for 27.17% of them in entire Berlin (Fig. 58).

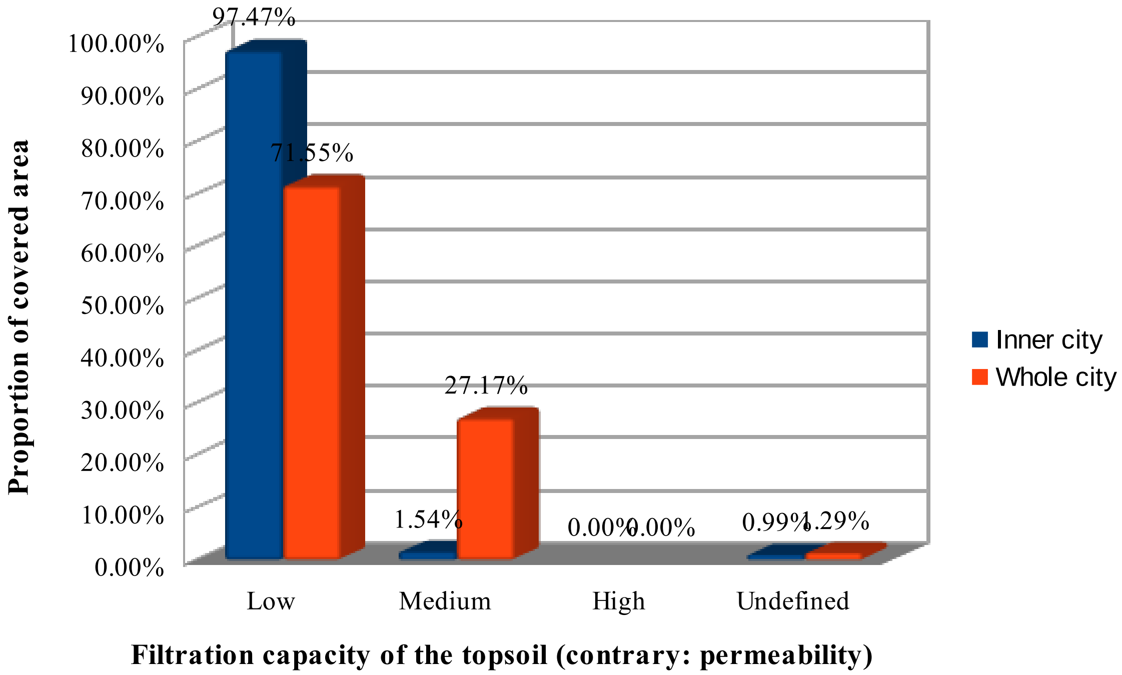


Fig. 58 - Filtration capacity of the topsoil (contrary: permeability) of the proportion of the area of public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

Table 11 - Overview of the results of the soil function analysis for public parks, public accessible managed green areas/parks, allotments, and cemeteries (own calculation based on data of the Senate of Berlin, 2017a).

Green space land use type in Berlin	**Regulation function for the water balance/exchange frequency of the soil water per year in 2010**		**Buffering and filtration functions/sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity, and binding capacity of heavy metals in 2010**		**Habitat function for rare natural vegetation/indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) in 2010**		**Yield function for cultivated plants/sum of water and nutrient supply indicators in 2010**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	High for 23% of the area, medium for 68% of the area	High for 44% of the area, medium for 49% of the area	Medium for 51% of the area, low for 46% of the area	Medium for 46% of the area, low for 32% of the area	Low for 86% of the area	Low for 74% of the area	Low for 96% of the area	Low for 83% of the area
Public accessible managed green areas/parks (2010)	High for 15% of the area, medium for 85% of the area	High for 47% of the area, medium for 53% of the area	Medium for 46% of the area, low for 51% of the area	Medium for 54% of the area, low for 18% of the area	Low for 73% of the area	Low for 74% of the area	Low for 99% of the area	Low for 93% of the area
Allotments (2015)	High for 75% of the area	High for 73% of the area	High for 48% of the area, medium for 34% of the area	High for 51% of the area, medium for 37% of the area	Low for 68% of the area	Low for 74% of the area	High for 82% of the area	High for 73% of the area
Cemeteries (2010)	High for 96% of the area	High for 80% of the area	High for 64% of the area, medium for 23% of the area	High for 33% of the area, medium for 38% of the area	Low for 83% of the area	Low for 66% of the area	Medium for 65% of the area	Medium for 61% of the area

Green space land use type in Berlin	Archival function of natural history/rarity of soil associations, and particular soils of the nature region in 2010		Performance of natural soil and archival functions/sum of the five analysed soil functions above in 2010		Soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance, as well as soil sealing degree in 2010		Naturalness (contrary: hemeroby) in 2010	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	Low for 97% of the area	Low for 71% of the area, medium for 21% of the area	Low for 76% of the area, medium for 21% of the area	High for 24% of the area, medium for 26% of the area	Very high for 2% of the area, high for 21% of the area	Very high for 17% of the area, high for 16% of the area	Low for 54% of the area, medium for 25% of the area	Low for 45% of the area, medium for 39% of the area
Public accessible managed green areas/parks (2010)	Low for 96% of the area	Low for 73% of the area, medium for 23% of the area	Low for 85% of the area, medium for 11% of the area	High for 23% of the area, medium for 26% of the area	Very high for 3% of the area, high for 12% of the area	Very high for 21% of the area, high for 15% of the area	Low for 76% of the area, medium for 19% of the area	Low for 63% of the area, medium for 34% of the area
Allotments (2015)	Low for 48% of the area, medium for 52% of the area	Low for 46% of the area, medium for 53% of the area,	High for 80% of the area	High for 78% of the area	Very high for 74% of the area, high for 8% of the area	Very high for 54% of the area, high for 28% of the area	Low for 54% of the area, medium for 36% of the area	Low for 15% of the area, medium for 82% of the area
Cemeteries (2010)	Low for 82% of the area, medium for 18% of the area	Low for 65% of the area, medium for 35% of the area,	High for 64% of the area, medium for 32% of the area	High for 38% of the area, medium for 42% of the area	Very high for 82% of the area	Very high for 72% of the area	Medium for 96% of the area	Medium for 97% of the area

Green space land use type in Berlin	**Exchange frequency of groundwater (contrary: water storage capacity) in 2010**		**Water supply/effective field capacity in 2010**		**Filtration capacity (contrary: permeability) in 2010**		**Occurrence of soil associations within the area of Berlin in 2010**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	Very low for 23% of the area, low for 27% of the area, medium for 41% of the area	Very low for 44% of the area, low for 28% of the area, medium for 21% of the area	Medium for 71% of the area, bad for 28% of the area	Medium for 71% of the area, bad for 19% of the area	Low for 98% of the area	Low for 76% of the area, medium for 23% of the area	Frequent for 53% of the area, very frequent for 39% of the area	Frequent for 49% of the area, very frequent for 34% of the area
Public accessible managed green areas/parks (2010)	Very low for 15% of the area, low for 59% of the area, medium for 26% of the area	Very low for 47% of the area, low for 18% of the area, medium for 35% of the area	Medium for 50% of the area, bad for 49% of the area	Medium for 70% of the area, bad for 23% of the area	Low for 97% of the area	Low for 77% of the area, medium for 23% of the area	Frequent for 69% of the area, very frequent for 17% of the area	Frequent for 45% of the area, very frequent for 30% of the area
Allotments (2015)	Very low for 85% of the area	Very low for 73% of the area	Medium for 80% of the area	Medium for 76% of the area	Low for 71% of the area, medium for 29% of the area	Low for 58% of the area, medium for 42% of the area	Frequent for 67% of the area, very frequent for 29% of the area	Frequent for 40% of the area, very frequent for 47% of the area
Cemeteries (2010)	Very low for 80% of the area	Very low for 97% of the area	Medium for 99% of the area	Medium for 100% of the area	Low for 36% of the area, medium for 64% of the area	Low for 62% of the area, medium for 38% of the area	Frequent for 1% of the area, medium for 78% of the area	Frequent for 49% of the area, very frequent for 34% of the area

Green space land use type in Berlin	Binding capacity of heavy metals in 2010		Nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity in 2010		Soil moisture in 2010 (dry: not groundwater influenced soil types, moist/wet: groundwater influenced soil types)		Filtration capacity of the subsoil (contrary: permeability) in 2010		Filtration capacity of the topsoil (contrary: permeability) in 2010	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	Very high for 35% of the area, high for 58% of the area	Very high for 24% of the area, high for 61% of the area	Low for 97% of the area, medium for 2% of the area	Low for 76% of the area, medium for 18% of the area	Dry for 99%, but not particularly dry location for 87% of the area	Dry for 86%, but not particularly dry location for 85% of the area	Low for 68% of the area, medium for 30% of the area, high for 1% of the area	Low for 64% of the area, medium for 18% of the area, high for 16% of the area	Low for 97% of the area, medium for 2% of the area	Low for 72% of the area, medium for 27% of the area
Public accessible managed green areas/parks (2010)	Very high for 13% of the area, high for 73% of the area	Very high for 21% of the area, high for 65% of the area	Low for 97% of the area, medium for 3% of the area	Low for 79% of the area, medium for 19% of the area	Dry for 99%, but not particularly dry location for 73% of the area	Dry for 89%, but not particularly dry location for 84% of the area	Low for 91% of the area, medium for 6% of the area, high for 3% of the area	Low for 69% of the area, medium for 14% of the area, high for 17% of the area	Low for 96% of the area, medium for 4% of the area	Low for 72% of the area, medium for 28% of the area
Allotments (2015)	Very high for 36% of the area, high for 64% of the area	Very high for 43% of the area, high for 53% of the area	High for 51% of the area, medium for 38% of the area	High for 45% of the area, medium for 48% of the area	Dry for 68%, but not particularly dry location for 99% of the area	Dry for 77%, but not particularly dry location for 100% of the area	Low for 70% of the area, medium for 10% of the area, high for 21% of the area	Low for 55% of the area, medium for 16% of the area, high for 29% of the area	Low for 49% of the area, medium for 51% of the area	Low for 48% of the area, medium for 52% of the area
Cemeteries (2010)	Very high	Very high	Low for	Low for	Dry for	Dry for	Low for	Low for	Low for	Low for

	for 65% of the area, high for 35% of the area	for 39% of the area, high for 60% of the area	36% of the area, medium for 64% of the area	62% of the area, medium for 38% of the area	91%, but not particularly dry location for 100% of the area	78%, but not particularly dry location for 99% of the area	35% of the area, high for 64% of the area,	61% of the area, high for 38% of the area,	36% of the area, medium for 64% of the area,	72% of the area, medium for 27% of the area,

Green space land use type in Berlin	**Average ground water recharge per m² per annum in 2012**	
	Inner city	Whole city
Public parks (2015)	131.82 l	113.04 l
Public accessible managed green areas/parks (2010)	179.07 l	123.91 l
Allotments (2015)	140.24 l	136.20 l
Cemeteries (2010)	82.81 l	85.29 l

2.5.2.3. Vegetation volume

The vegetation volume can be used as indirect indicator of different biophysical ecosystem services such as the production of oxygen, the filtration of dust and other particles in the air, the reduction of wind speed and noise, and as habitat for species (Chapter 3.3. Proposal of a first set of 10 alternative indicators for evaluations of urban biodiversity on page 169). However, it hardly can be used as indicator for cultural ecosystem services, particularly when use and non-use interests (values) differ. For example, grasslands need to be kept open, regularly mown and often fertilized to serve for playgrounds or picnics which does not allow growing higher vegetation that is generally sensitive to trampling pressure.

As a result of the analysis, the vegetation volume in public parks is quite similar in the inner city compared to the whole city of Berlin in 2009-2010. About 44.78% of the area had a vegetation volume of less than 4 m³/m² in the inner city in comparison to around 42.03% in the whole city of Berlin (Fig. 59) (Table 12).

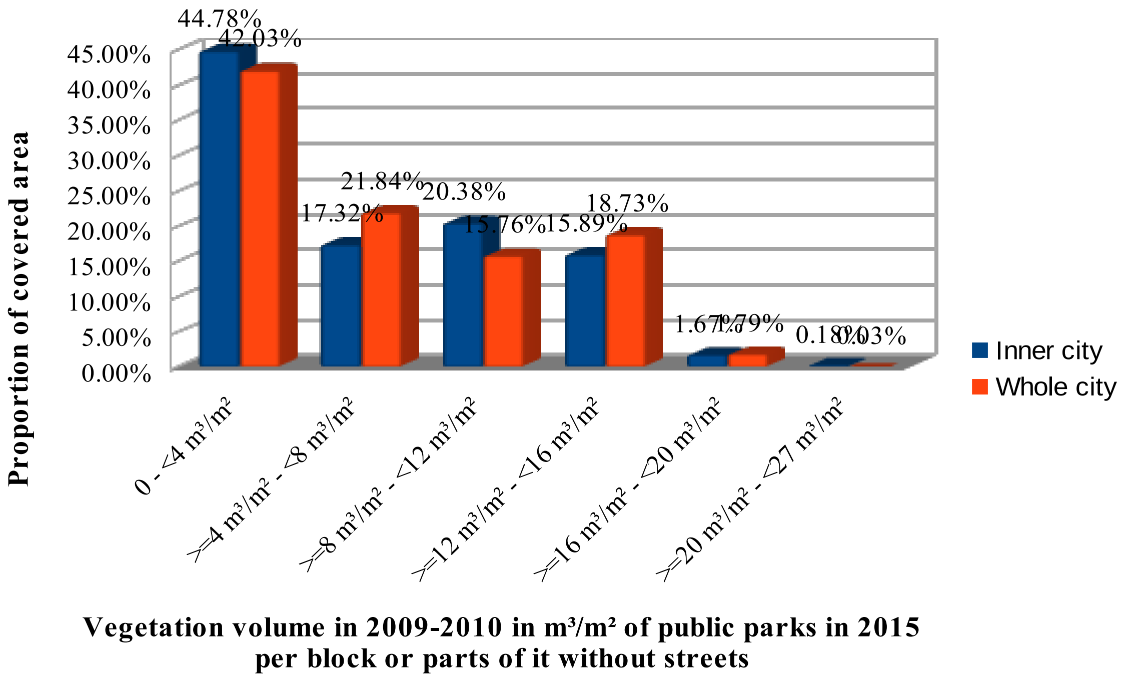


Fig. 59 - Vegetation volume in 2009-2010 in m³/m² of public parks in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

The situation is worse within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2010 with an area of approximately 82.24% of a vegetation volume of less than 4 m³/m² in the inner city and around 74.85% in the whole city of Berlin in 2009-2010 (Fig. 60).

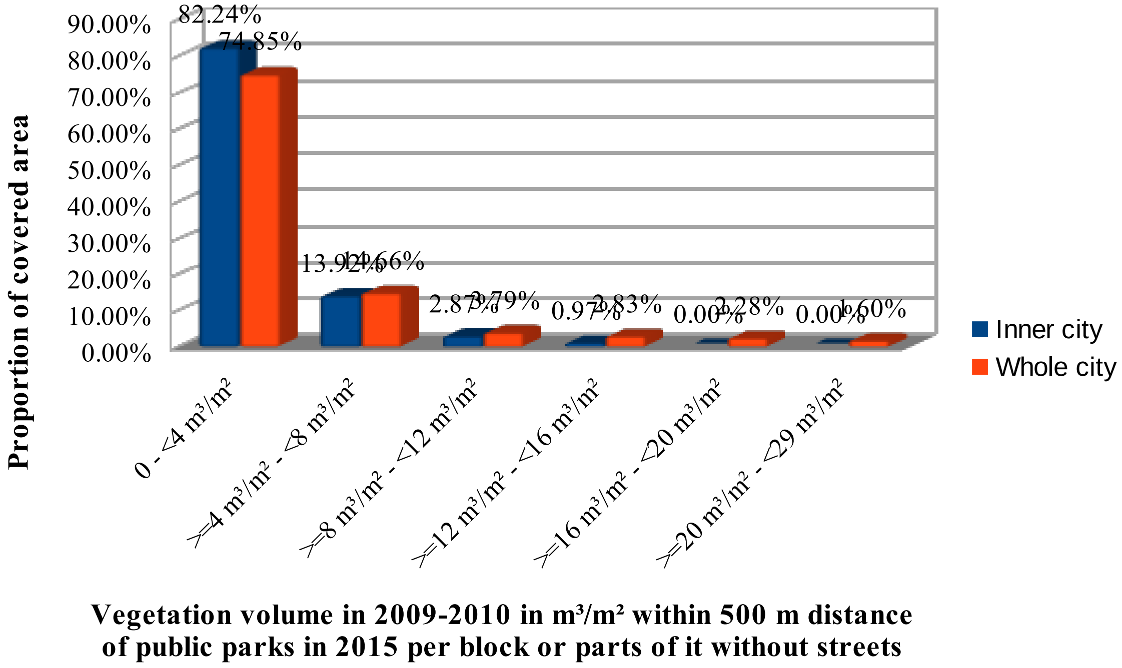


Fig. 60 - Vegetation volume in 2009-2010 in m^3/m^2 within 500 m distance of public parks of a minimum size of 0.5 ha in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

Regarding the streets within public parks, the vegetation volume is for about 79.79% of the area less than 4 m^3/m^2 in the inner city compared to around 57.47% in the whole city of Berlin (Fig. 61).

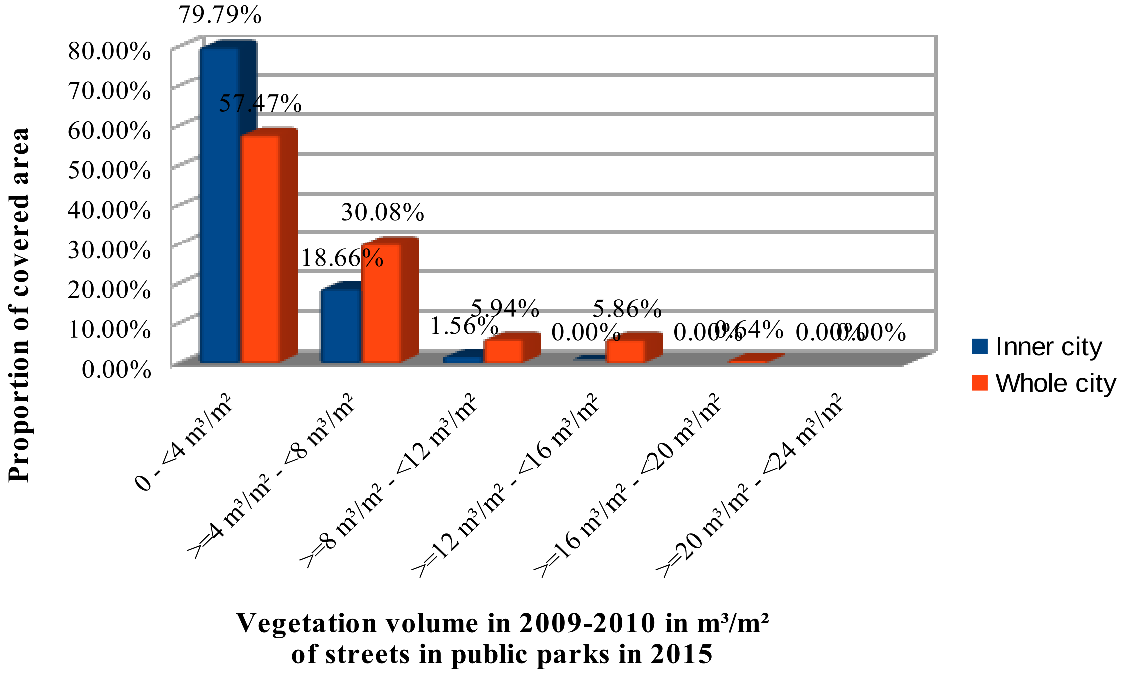


Fig. 61 - Vegetation volume in 2009-2010 in m³/m² of streets in public parks in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

This vegetation volume in streets is similar within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin with an area of approximately 78.97% of a vegetation volume of less than 4 m³/m² in the inner city, but higher in the whole city of Berlin of around 72.47% from 2009-2010 (Fig. 62).

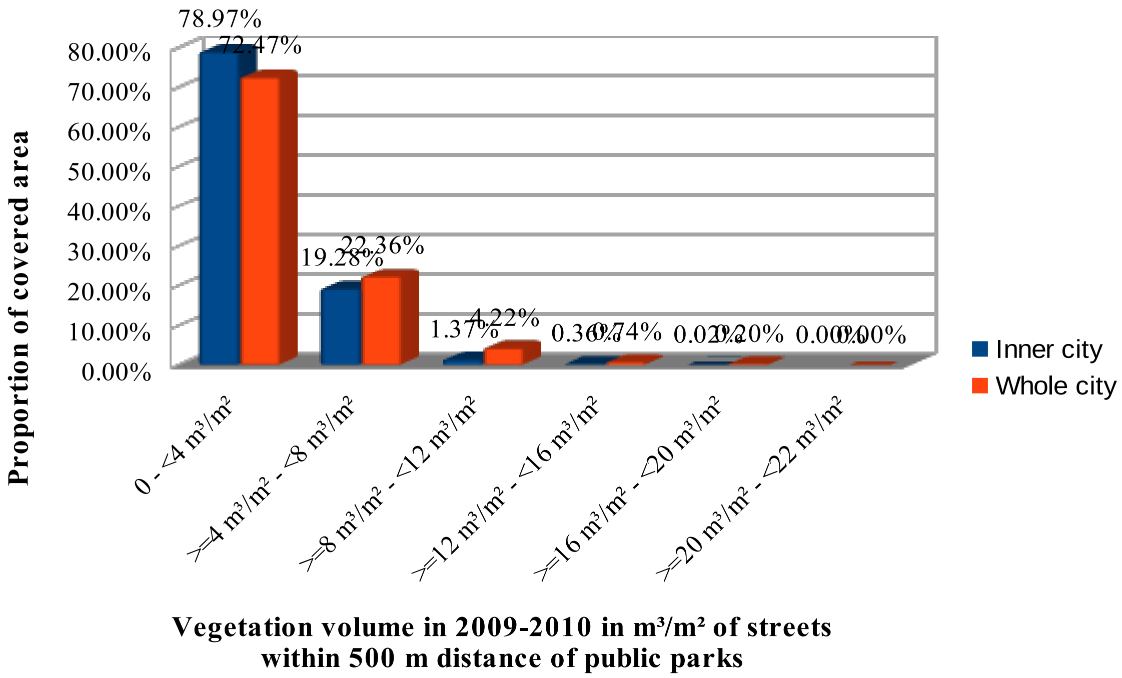


Fig. 62 - Vegetation volume in 2009-2010 in m^3/m^2 of streets within 500 m distance of public parks of a minimum size of 0.5 ha in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

Table 12 - Overview of the results of the vegetation volume analysis for public parks, public accessible managed green areas/parks, allotments, and cemeteries (own calculation based on data of the Senate of Berlin, 2017a).

Green space land use type in Berlin	**Vegetation volume in 2009-2010**							
	Inner city				Whole city			
	Inner parts without streets	Inner streets	Within 500 m distance of a minimum size of 0.5 ha without streets of the green land use type	Streets within 500 m distance of a minimum size of 0.5 ha of the green land use type	Inner parts without streets	Inner streets	Within 500 m distance of a minimum size of 0.5 ha without streets of the green land use type	Streets within 500 m distance of a minimum size of 0.5 ha of the green land use type
Public parks (2015)	45% of the area: <4 m^3/m^2; 17% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 20% of the area: >=8 m^3/m^2 - <12 m^3/m^2	80% of the area: <4 m^3/m^2; 19% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 2% of the area: >=4 m^3/m^2 - <8 m^3/m^2	82% of the area: <4 m^3/m^2; 14% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 3% of the area: >=8 m^3/m^2 - <12 m^3/m^2	79% of the area: <4 m^3/m^2; 19% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 1% of the area: >=8 m^3/m^2 - <12 m^3/m^2	42% of the area: <4 m^3/m^2; 22% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 16% of the area: >=8 m^3/m^2 - <12 m^3/m^2	57% of the area: <4 m^3/m^2; 30% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 6% of the area: >=8 m^3/m^2 - <12 m^3/m^2	75% of the area: <4 m^3/m^2; 15% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 4% of the area: >=8 m^3/m^2 - <12 m^3/m^2	72% of the area: <4 m^3/m^2; 22% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 4% of the area: >=8 m^3/m^2 - <12 m^3/m^2
Public accessible managed green areas/parks (2010)	21% of the area: <4 m^3/m^2; 30% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 39% of the area: >=8 m^3/m^2 - <12 m^3/m^2	89% of the area: <4 m^3/m^2; 10% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 0% of the area: >=8 m^3/m^2 - <12 m^3/m^2	81% of the area: <4 m^3/m^2; 14% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 3% of the area: >=8 m^3/m^2 - <12 m^3/m^2	79% of the area: <4 m^3/m^2; 19% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 2% of the area: >=8 m^3/m^2 - <12 m^3/m^2	37% of the area: <4 m^3/m^2; 26% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 25% of the area: >=8 m^3/m^2 - <12 m^3/m^2	80% of the area: <4 m^3/m^2; 15% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 3% of the area: >=8 m^3/m^2 - <12 m^3/m^2	75% of the area: <4 m^3/m^2; 16% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 4% of the area: >=8 m^3/m^2 - <12 m^3/m^2	73% of the area: <4 m^3/m^2; 22% of the area: >=4 m^3/m^2 - <8 m^3/m^2; 4% of the area: >=8 m^3/m^2 - <12 m^3/m^2
Allotments (2015)	93% of the area: <4 m^3/m^2; 7% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	65% of the area: <4 m^3/m^2; 30% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	81% of the area: <4 m^3/m^2; 12% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	68% of the area: <4 m^3/m^2; 27% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	96% of the area: <4 m^3/m^2; 3% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	77% of the area: <4 m^3/m^2; 21% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	72% of the area: <4 m^3/m^2; 14% of the area: >=4 m^3/m^2 - <8 m^3/m^2;	74% of the area: <4 m^3/m^2; 22% of the area: >=4 m^3/m^2 - <8 m^3/m^2;

	2% of the area: >=8 m³/m² - <12 m³/m²	5% of the area: >=8 m³/m² - <12 m³/m²	6% of the area: >=8 m³/m² - <12 m³/m²	3% of the area: >=8 m³/m² - <12 m³/m²	1% of the area: >=8 m³/m² - <12 m³/m²	2% of the area: >=8 m³/m² - <12 m³/m²	6% of the area: >=8 m³/m² - <12 m³/m²	3% of the area: >=8 m³/m² - <12 m³/m²
Cemeteries (2010)	5% of the area: <4 m³/m²; 56% of the area: >=4 m³/m² - <8 m³/m²; 37% of the area: >=8 m³/m² - <12 m³/m²	55% of the area: <4 m³/m²; 38% of the area: >=4 m³/m² - <8 m³/m²; 7% of the area: >=8 m³/m² - <12 m³/m²	79% of the area: <4 m³/m²; 12% of the area: >=4 m³/m² - <8 m³/m²; 6% of the area: >=8 m³/m² - <12 m³/m²	81% of the area: <4 m³/m²; 18% of the area: >=4 m³/m² - <8 m³/m²; 1% of the area: >=8 m³/m² - <12 m³/m²	4% of the area: <4 m³/m²; 31% of the area: >=4 m³/m² - <8 m³/m²; 40% of the area: >=8 m³/m² - <12 m³/m²	61% of the area: <4 m³/m²; 35% of the area: >=4 m³/m² - <8 m³/m²; 2% of the area: >=8 m³/m² - <12 m³/m²	73% of the area: <4 m³/m²; 14% of the area: >=4 m³/m² - <8 m³/m²; 6% of the area: >=8 m³/m² - <12 m³/m²	72% of the area: <4 m³/m²; 22% of the area: >=4 m³/m² - <8 m³/m²; 4% of the area: >=8 m³/m² - <12 m³/m²

2.5.2.4. Hemeroby of biotope types

I analysed the classified degree of hemeroby of the database of biotope types of Berlin's Environmental Atlas within the covered area of the selected urban green space land use types, because urban ecosystems are formed and influenced by man and historically unnatural (see Section 3.2.1. Native biodiversity on page 161).

As a result, the biotope types indicate for about 68.70% of the area of public parks a high degree of human influence (hemeroby) in the inner city of Berlin in 2009 to 2010. This is more than the double proportional area than in public parks of a high degree of hemeroby in the whole city of Berlin, while approximately 53.28% of the latter area shows a low hemeroby in 2009 to 2010 (Fig. 63) (Table 13).

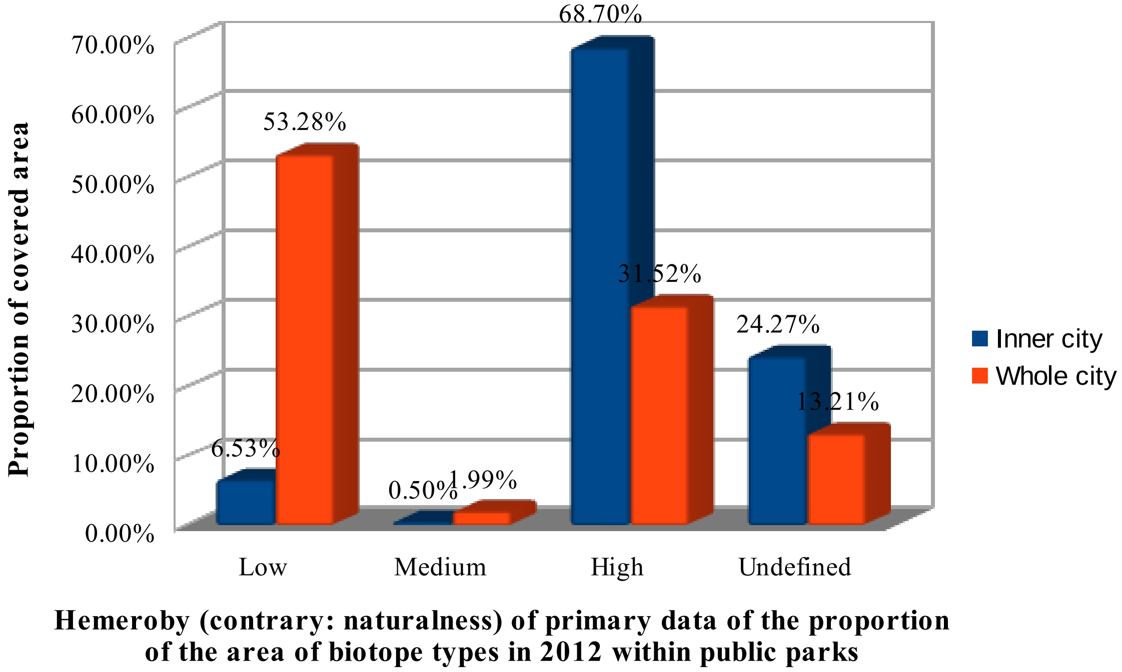


Fig. 63 - Hemeroby (contrary: naturalness) of primary data of the proportion of the area of biotope types in 2012 within public parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2012d; Köstler et al., 2005).

Table 13 - Overview of the results of the hemeroby (contrary: naturalness) analysis of primary data of the proportion of the area of biotope types in 2012 for public parks, public accessible managed green areas/parks, allotments, and cemeteries (own calculation based on data of the Senate of Berlin, 2017a).

Green space land use type in Berlin	**Hemeroby (contrary: naturalness) in 2012**	
	Inner city	Whole city

Public parks (2015)	High for 69% of the area; 1% of the area medium; 7% of the area low; 24% of the area unknown	High for 32% of the area; 2% of the area medium; 53% of the area low; 13% of the area unknown
Public accessible managed green areas/parks (2010)	High for 39% of the area; 2% of the area medium; 28% of the area low; 30% of the area unknown	High for 32% of the area; 1% of the area medium; 46% of the area low; 21% of the area unknown
Allotments (2015)	High for 2% of the area; 0% of the area medium; 73% of the area low; 25% of the area unknown	High for 5% of the area; 0% of the area medium; 49% of the area low; 46% of the area unknown
Cemeteries (2010)	High for 18% of the area; 0% of the area medium; 58% of the area low; 24% of the area unknown	High for 32% of the area; 1% of the area medium; 30% of the area low; 37% of the area unknown

2.5.3. Social and economic data of inhabitants

Public accessible green space within a reachable distance needs to take into account the individual social circumstances of inhabitants. The schematic figure is arbitrary of the minimum need of 6 m² public green space per inhabitant within a maximum distance of 500 m of a minimum size of 5,000 m² (0.5 ha) in the near neighbourhood according to Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a, 1994a). It does neither take into account the individual mobility of inhabitants nor the individual socio-economic situation to reach alternative public green spaces within longer distance. Only recently, Berlin's Environmental Atlas has started to take over the concept of environmental justice in relating social and further environmental factors to the quality of the neighbourhood for living. However, the indicators of environmental justice are still rather restricted in scope by Berlin's Environmental Atlas (Section 2.4.4. Social and further environmental factors on page 53).

Furthermore, it is important to know which socio-economic conditions have inhabitants within a neighbourhood distance to public urban green space. Therefore, I analysed them within a distance of 500 m from the boundaries of public urban green space of a minimum size of 5,000 m² (0.5 ha) according to Berlin's Landscape and Species Protection Programme as it was adopted and intended as urban planning guideline by Berlin's parliament (Senate of Berlin, 2016a, 1994a) (Fig. 64 to Fig. 88; Table 14).

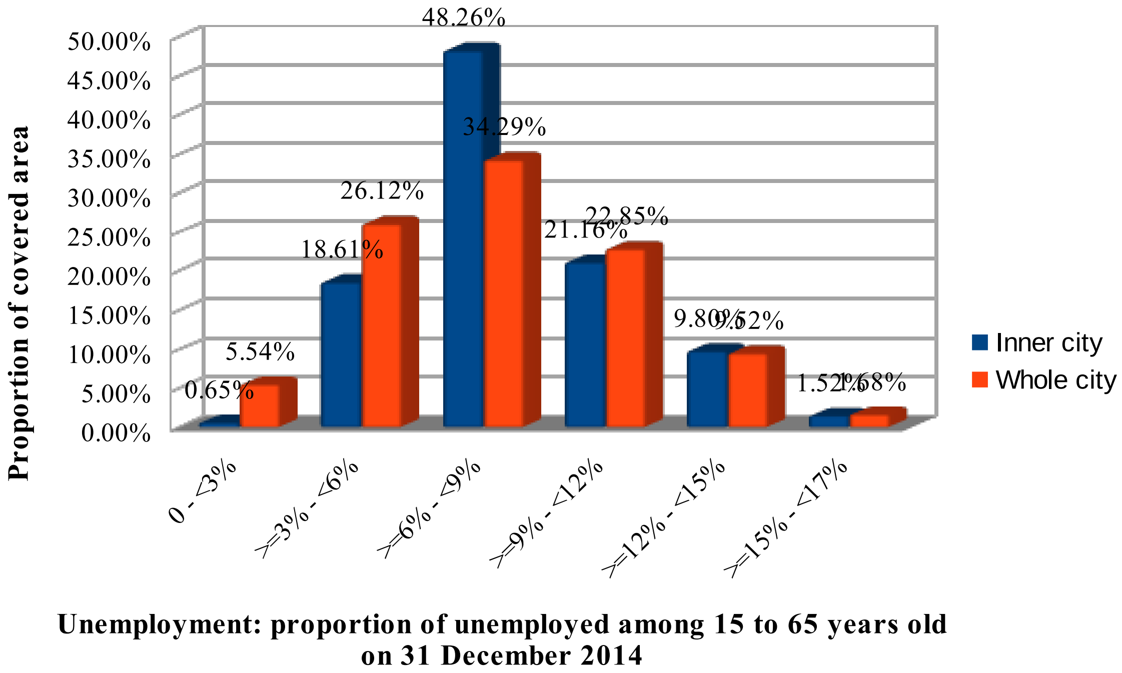


Fig. 64 - Unemployment: proportion of unemployed among 15 to 65 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

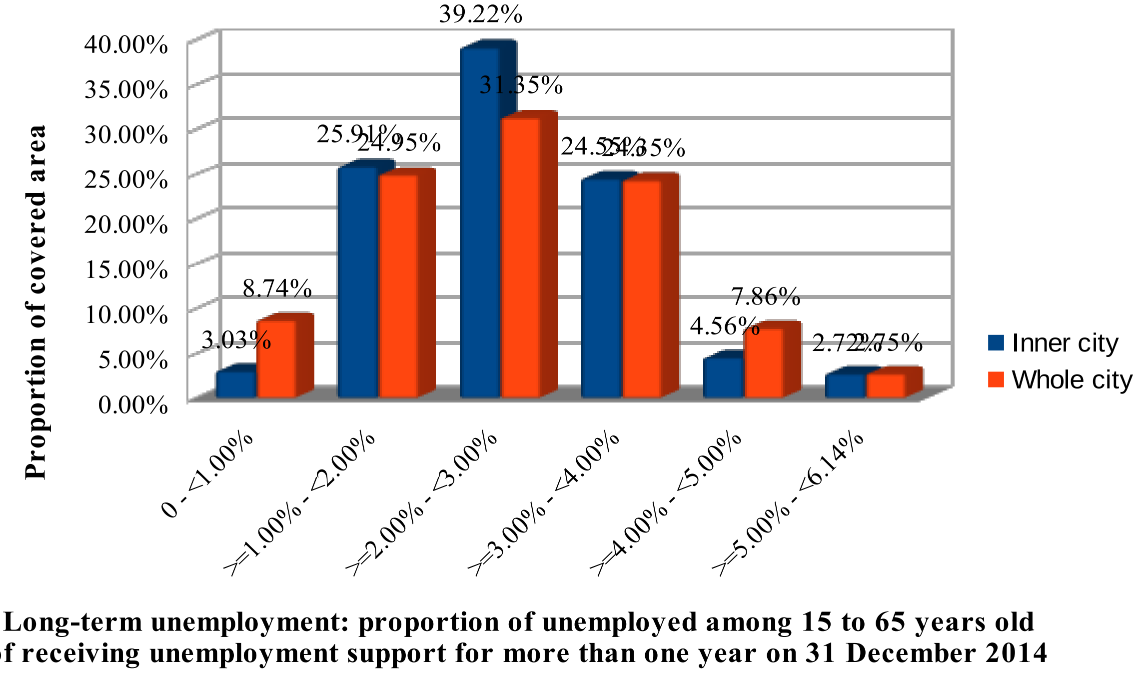


Fig. 65 - Long-term unemployment: proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

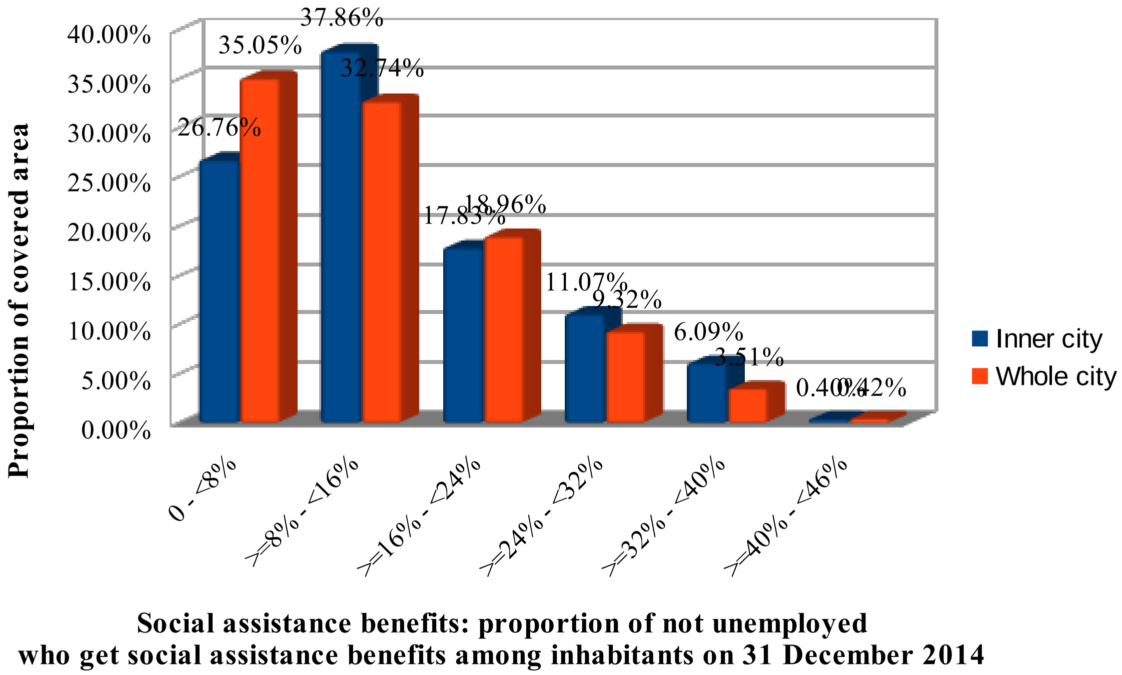
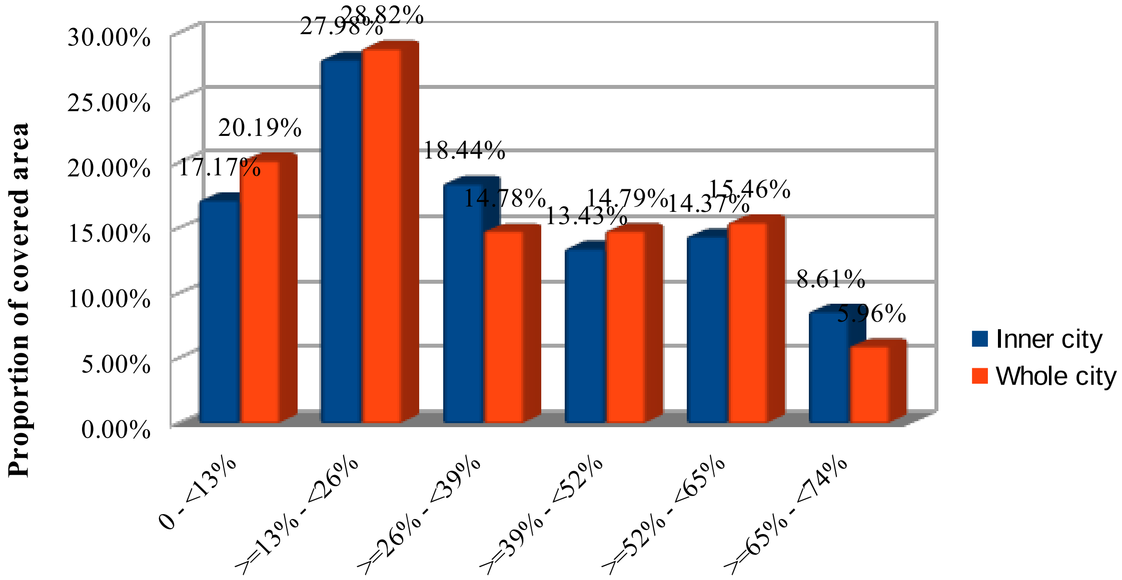
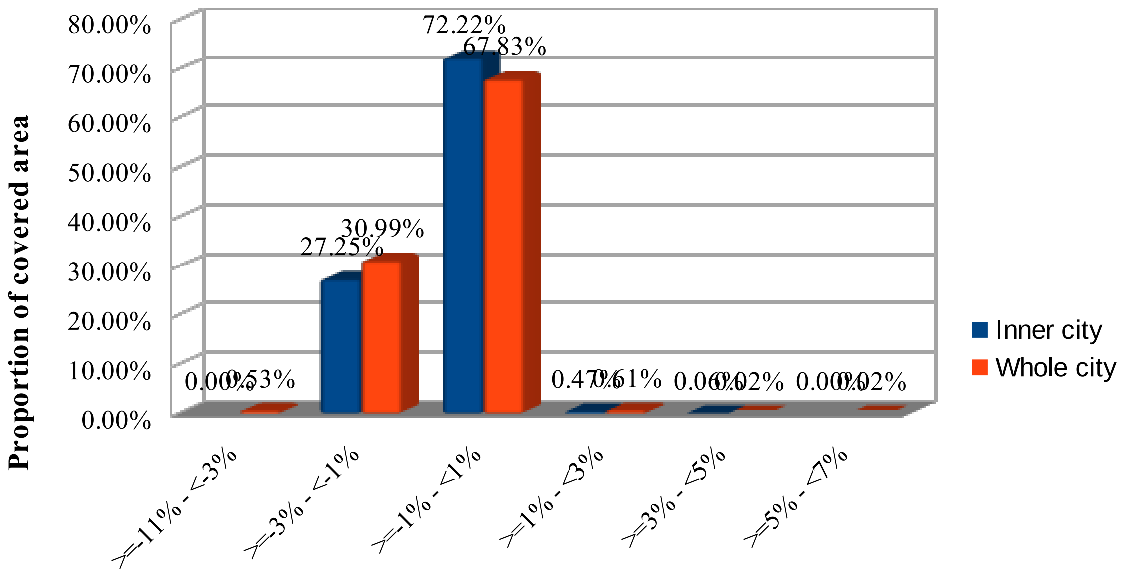


Fig. 66 - Social assistance benefits: proportion of not unemployed who get social assistance benefits among inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



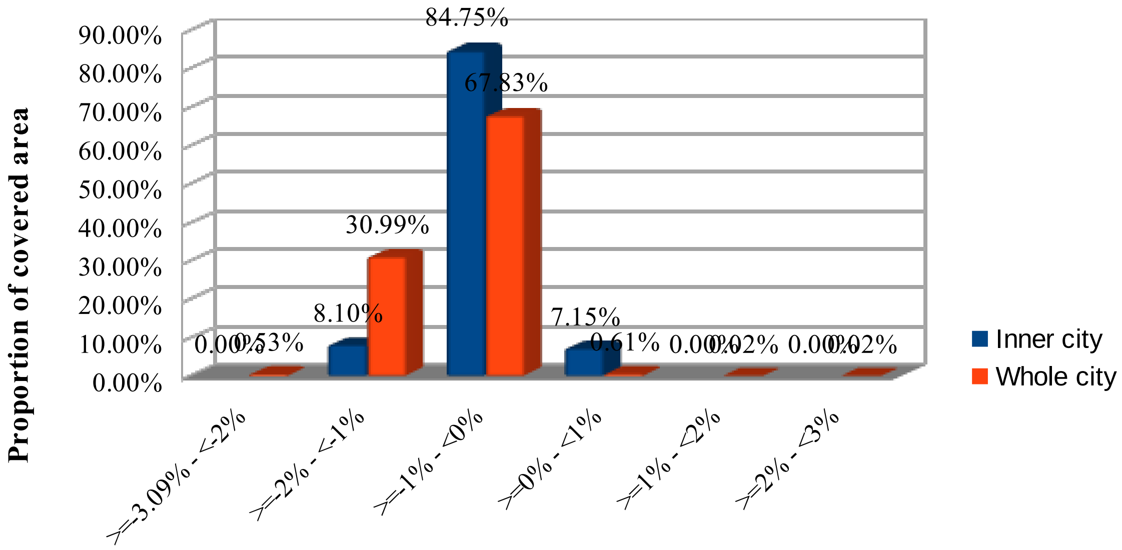
Children poverty: proportion of children and teenagers under 15 years old in households who depend on social welfare among all 15 years old on 31 December 2014

Fig. 67 - Children poverty: proportion of children and teenagers under 15 years old in households who depend on social welfare among all 15 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



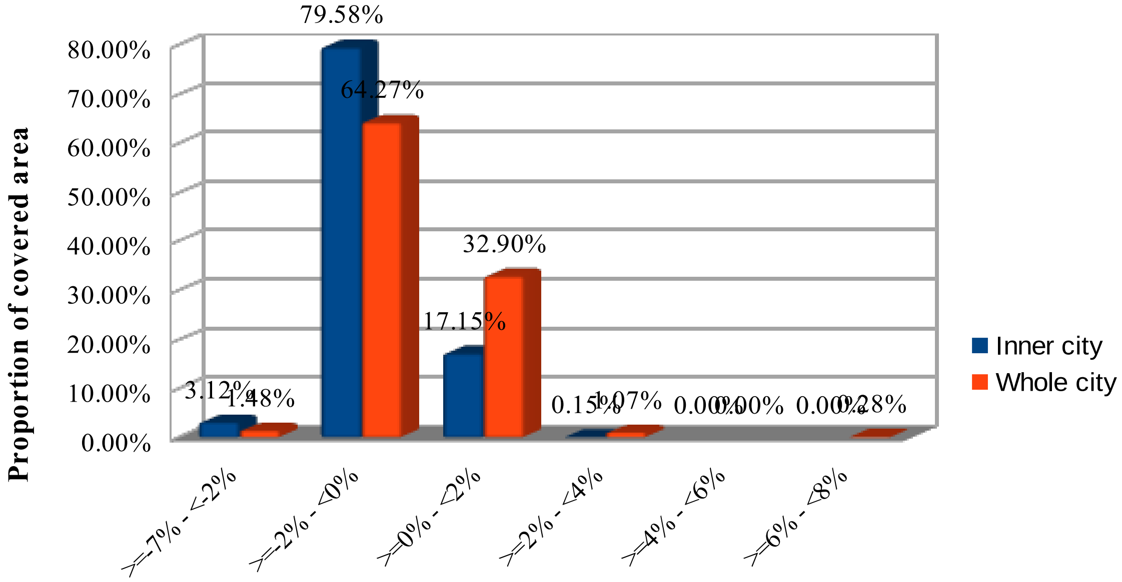
Unemployment change: change of the proportion of unemployed among 15 to 65 years old from 31 December 2012 to 31 December 2014

Fig. 68 - Unemployment change: change of the proportion of unemployed among 15 to 65 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



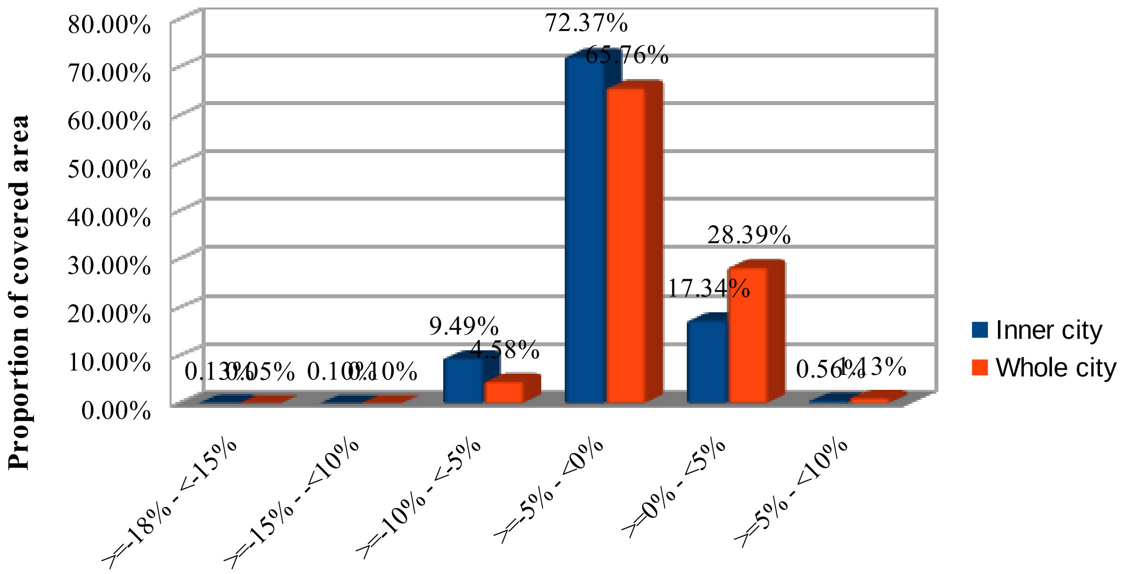
Change of long-term unemployment: change of the proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year from 31 December 2012 to 31 December 2014

Fig. 69 - Change of long-term unemployment: change of the proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



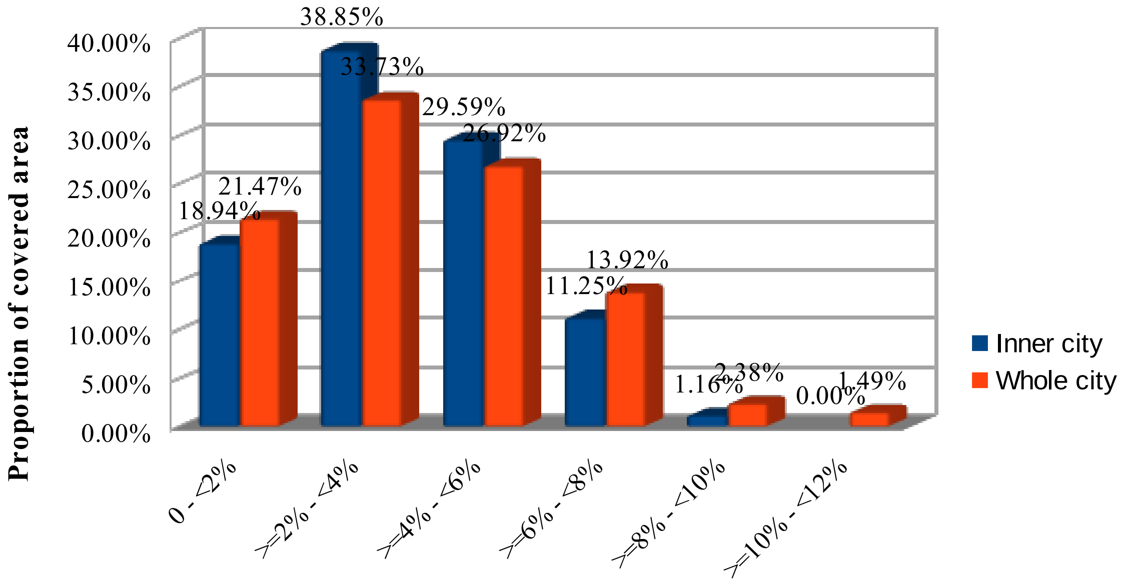
Change of social assistance benefits: change of the proportion of not unemployed getting social assistance benefits from 31 December 2012 to 31 December 2014

Fig. 70 - Change of social assistance benefits: change of the proportion of not unemployed who get social assistance benefits among inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Change of children poverty: change of the proportion of children and teenagers of less than 15 years old in households who depend on social welfare among all 15 years old

Fig. 71 - Change of children poverty: change of the proportion of children and teenagers of less than 15 years old in households who depend on social welfare among all 15 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of unemployed, aged under 25, among 15 to 25 years old on 31 December 2014

Fig. 72 - Proportion of unemployed, aged under 25, among 15 to 25 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

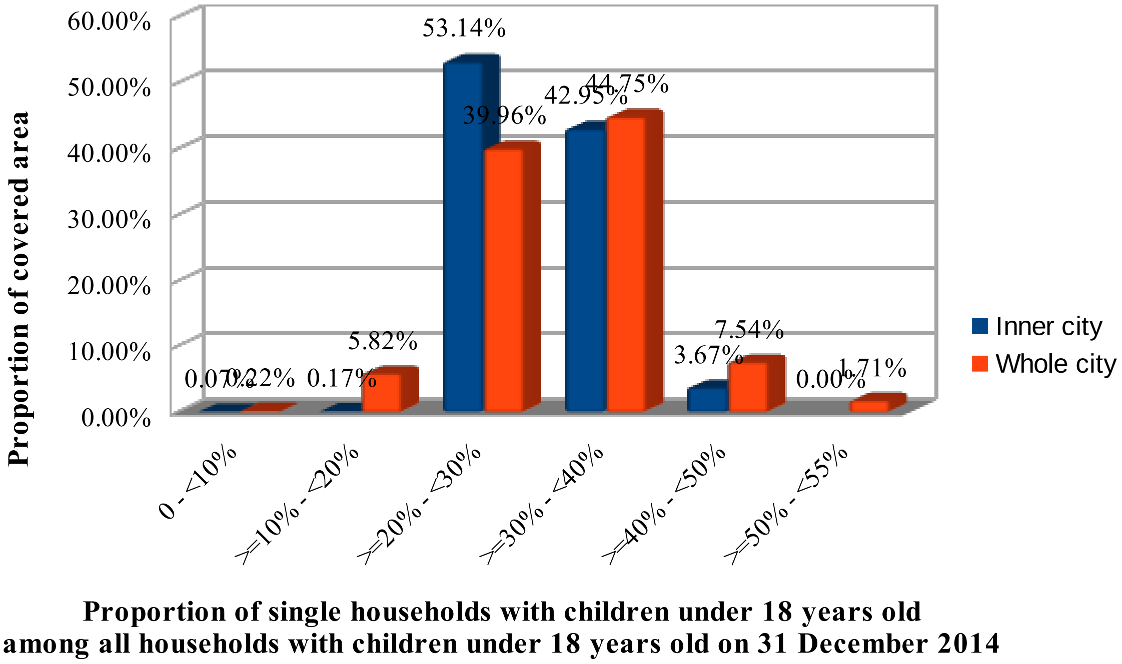
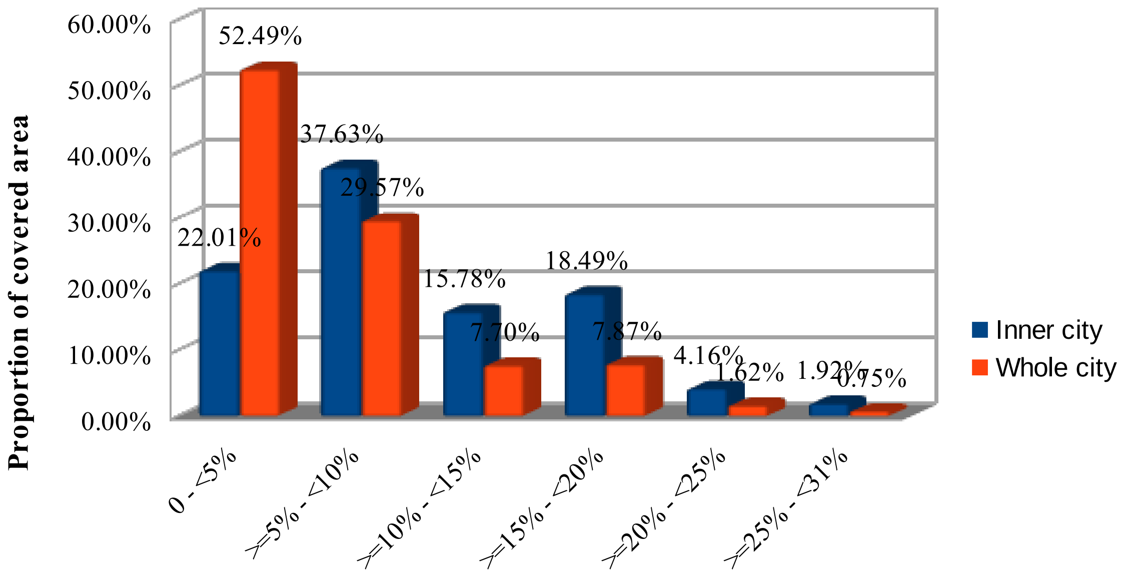


Fig. 73 - Proportion of single households with children under 18 years old among all households with children under 18 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of inhabitants who depend on social welfare (not living in institutions) of 65 years and older among all inhabitants of this age class on 31 December 2014

Fig. 74 - Proportion of inhabitants who depend on social welfare (not living in institutions) of 65 years and older among all inhabitants of this age class on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

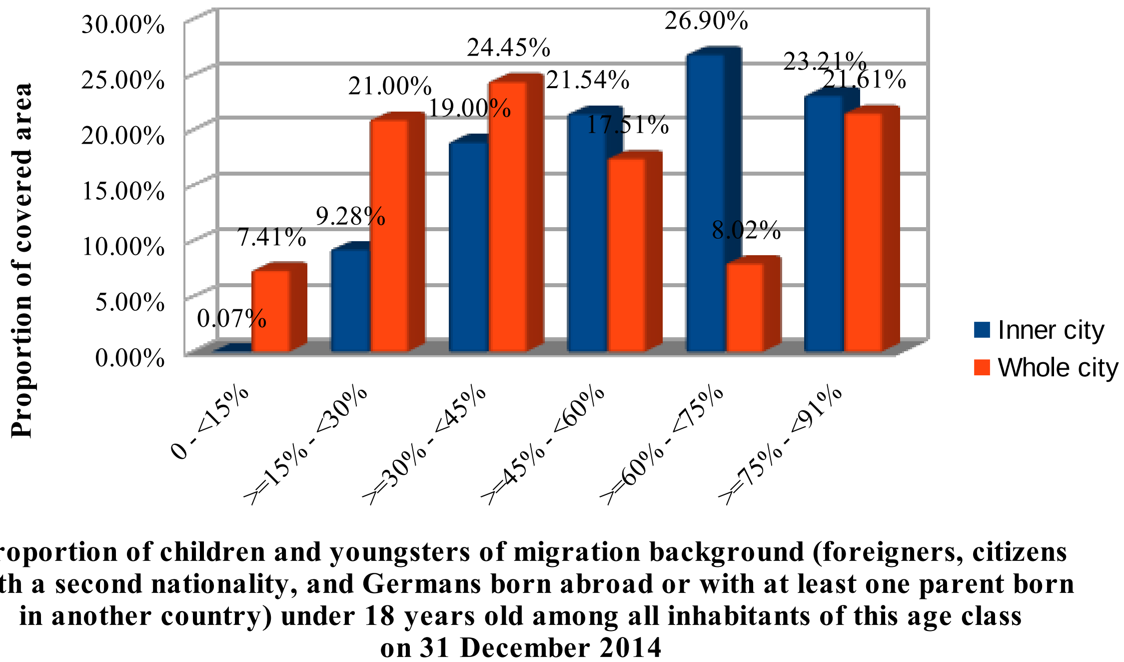


Fig. 75 - Proportion of children and youngsters of migration background (foreigners, citizens with a second nationality, and Germans born abroad or with at least one parent born in another country) under 18 years old among all inhabitants of this age class on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

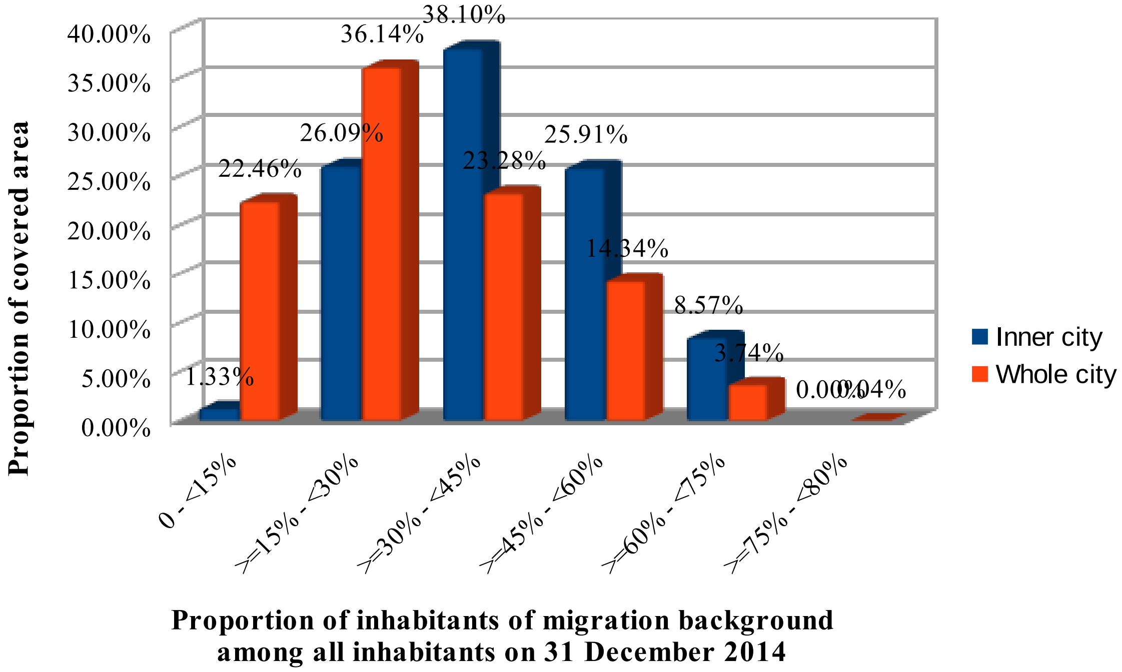


Fig. 76 - Proportion of inhabitants of migration background among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

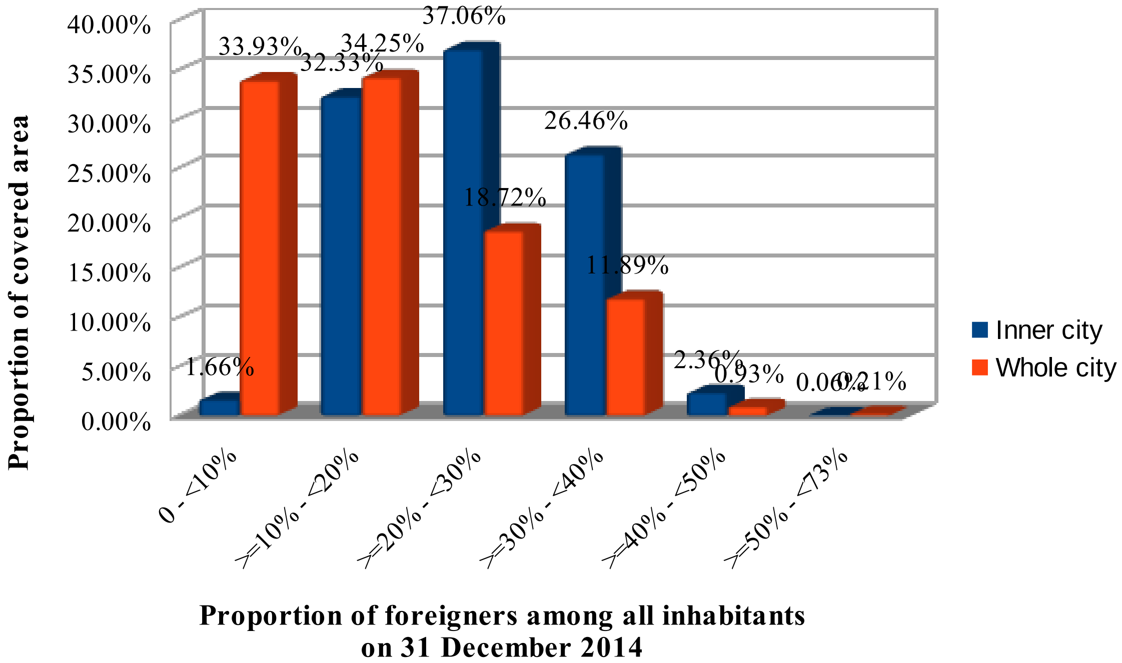


Fig. 77 - Proportion of foreigners among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

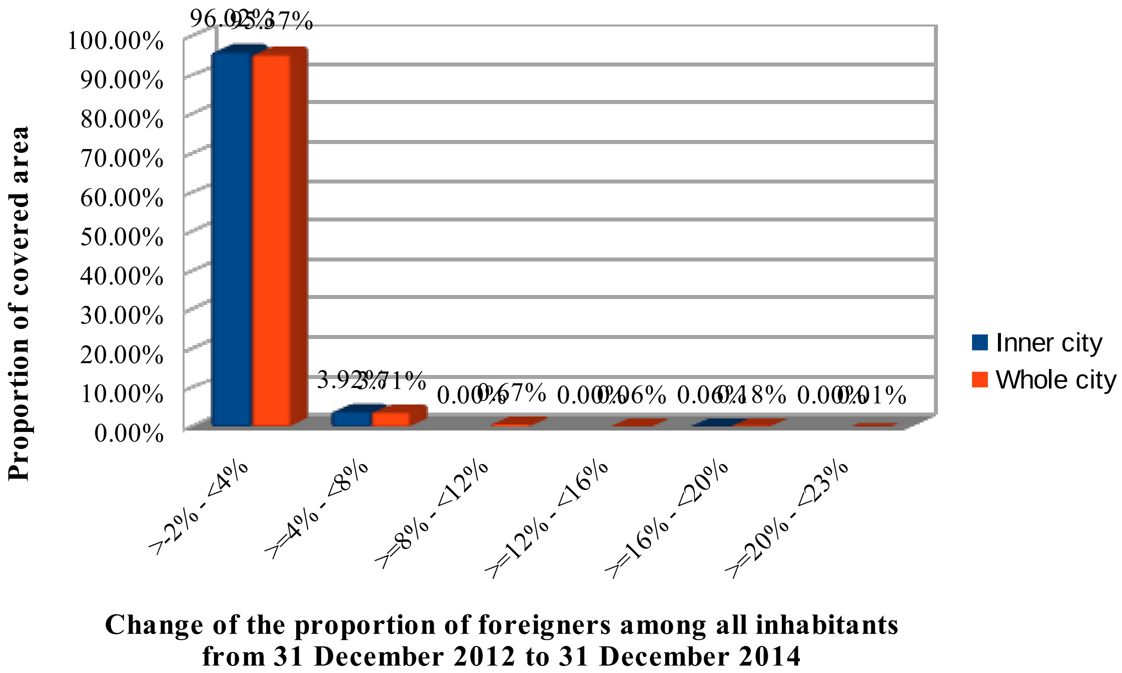


Fig. 78 - Change of the proportion of foreigners among all inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

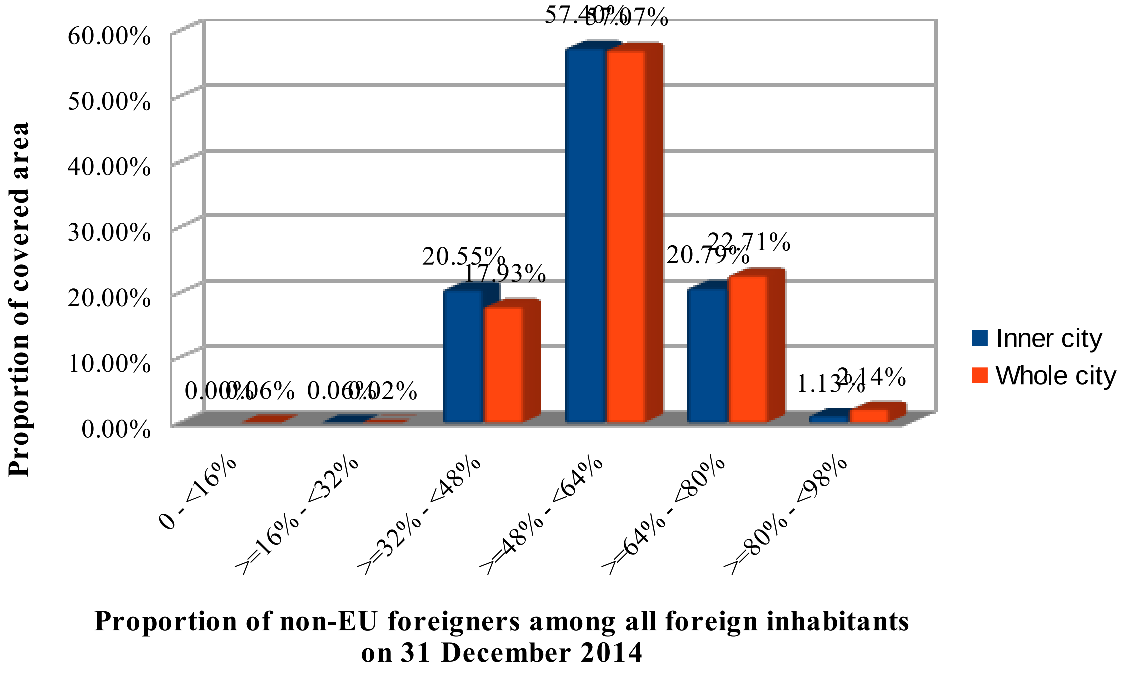
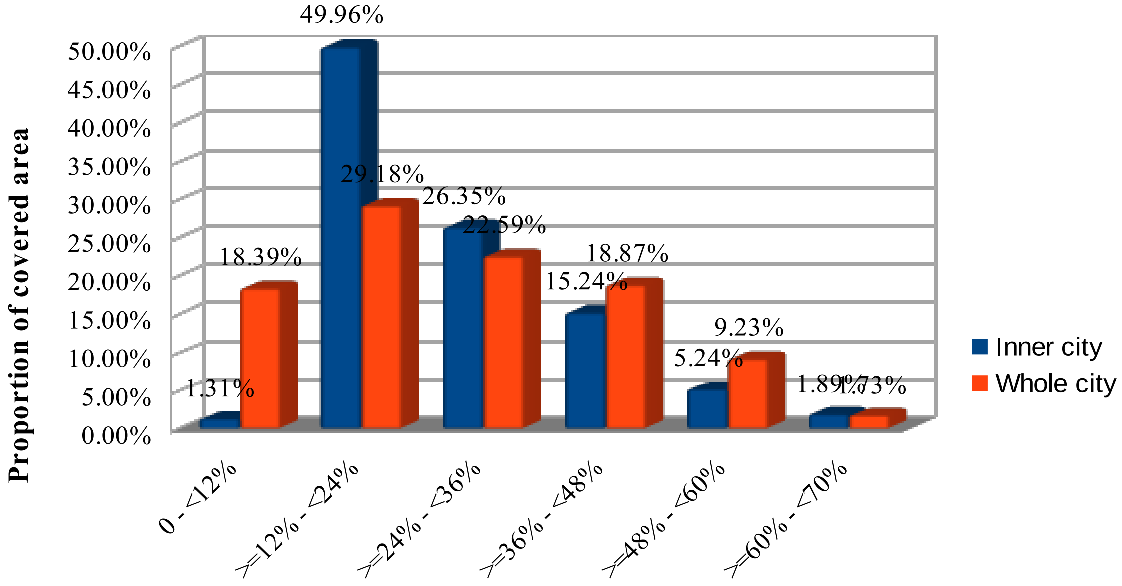
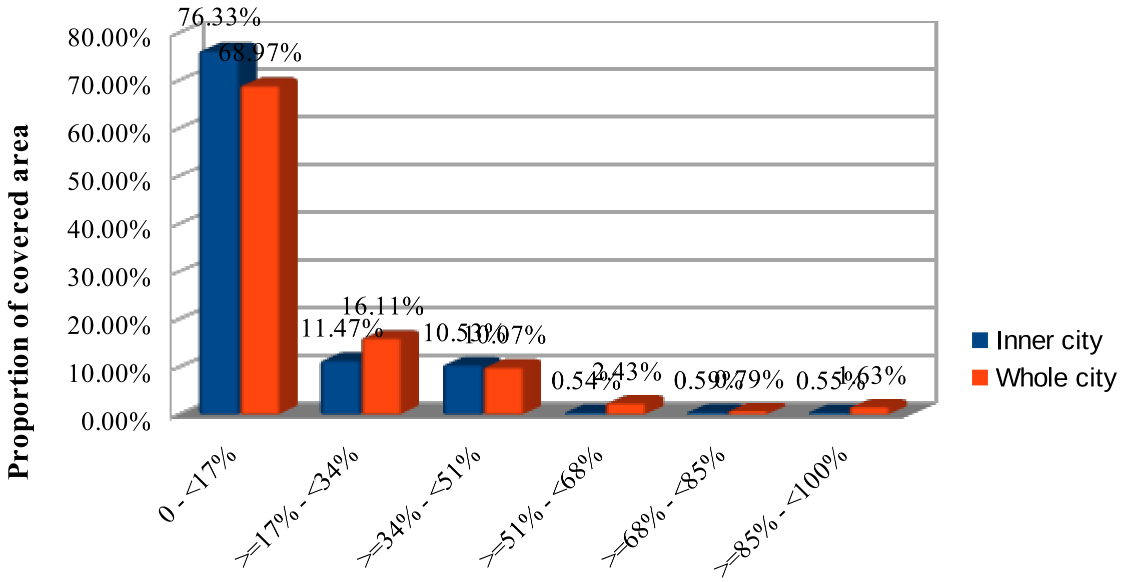


Fig. 79 - Proportion of non-EU foreigners among all foreign inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of foreigners in households who depend on social welfare among all foreign inhabitants under 65 years old on 31 December 2014

Fig. 80 - Proportion of foreigners in households who depend on social welfare among all foreign inhabitants under 65 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of flats owned by Berlin's state housing associations among all flats on 31 December 2014

Fig. 81 - Proportion of flats owned by Berlin's state housing associations among all flats on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

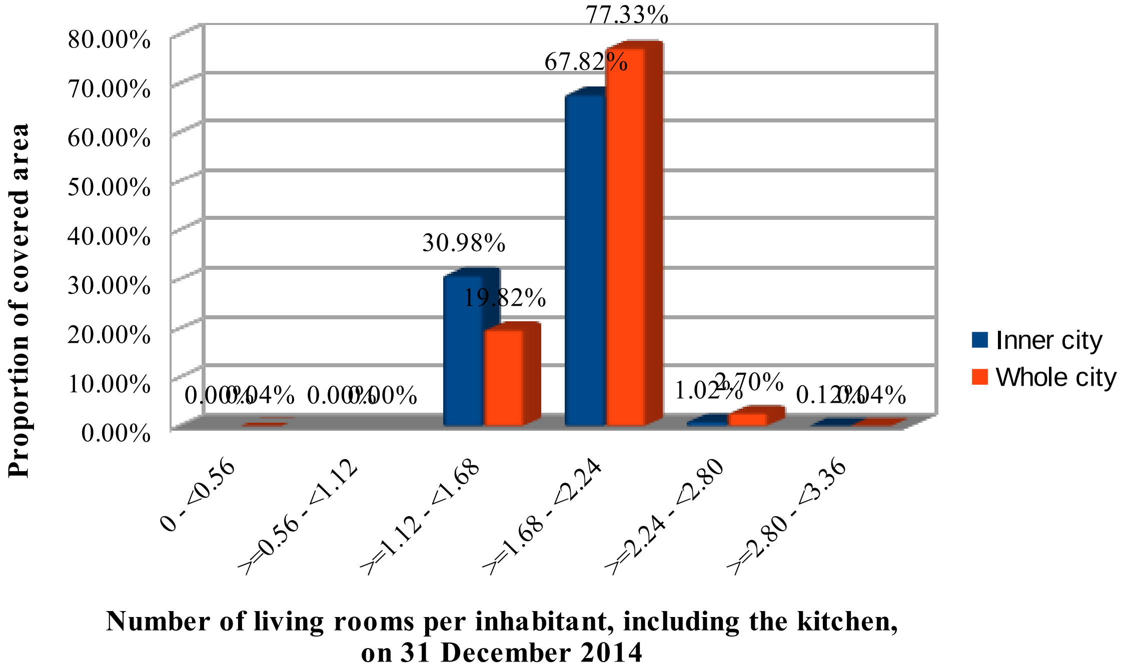


Fig. 82 - Number of living rooms per inhabitant, including the kitchen, on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

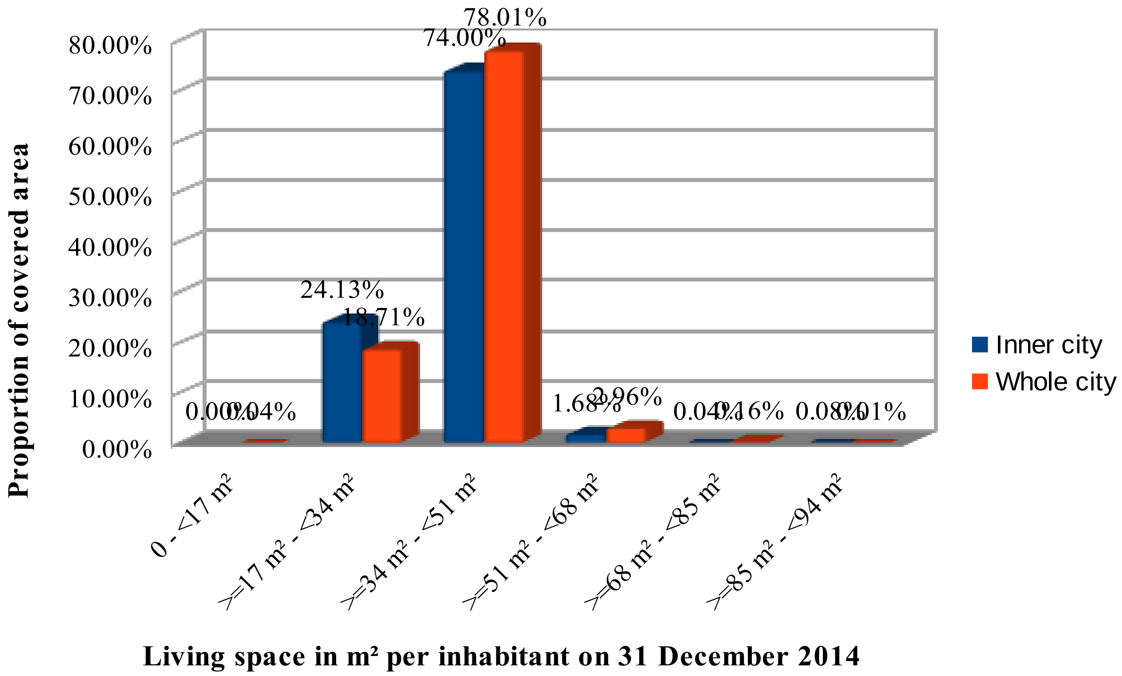
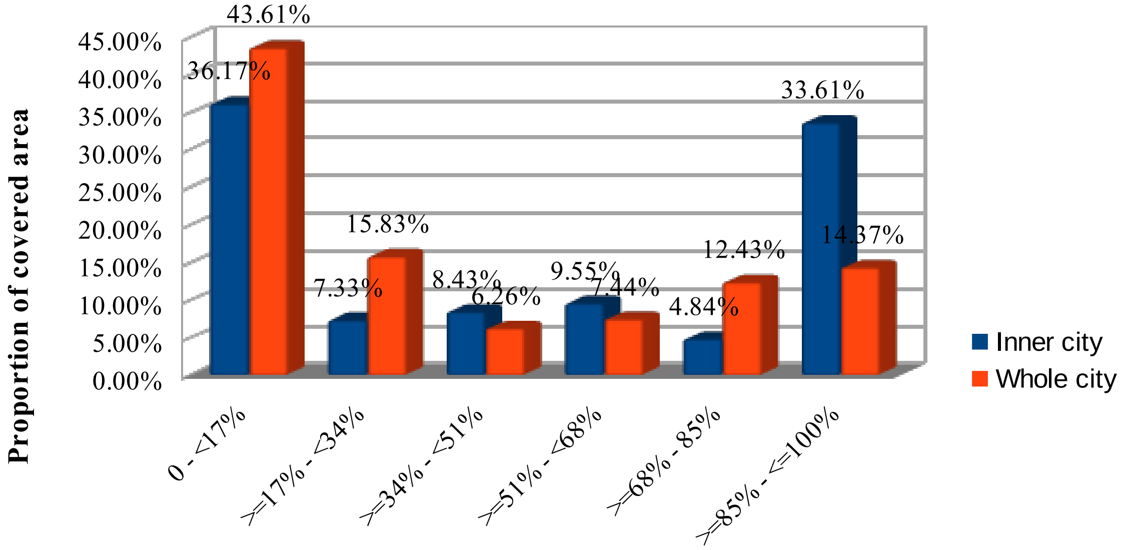
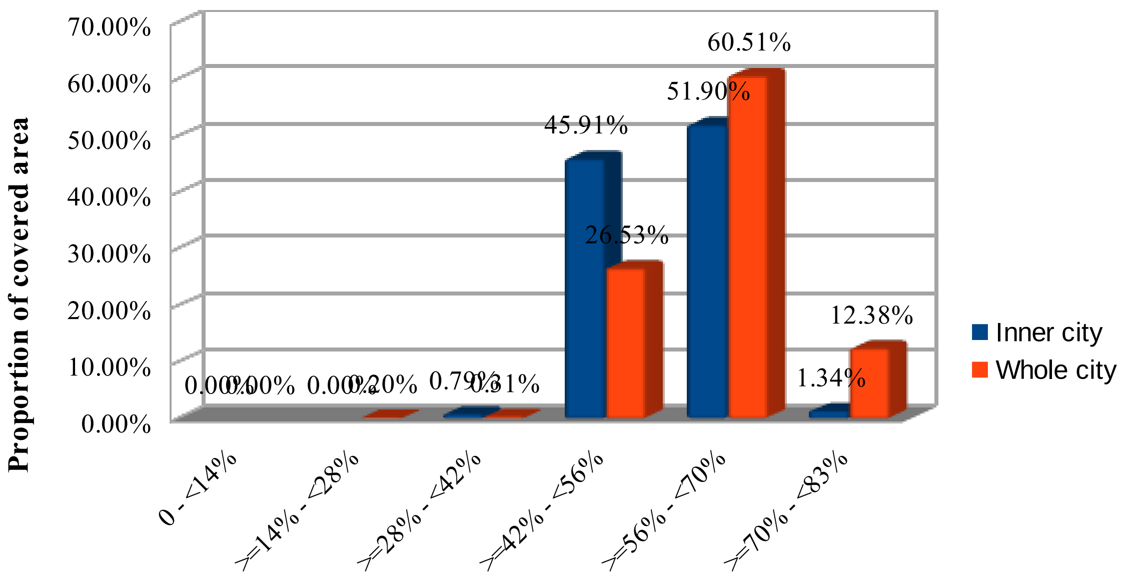


Fig. 83 - Living space in m² per inhabitant on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



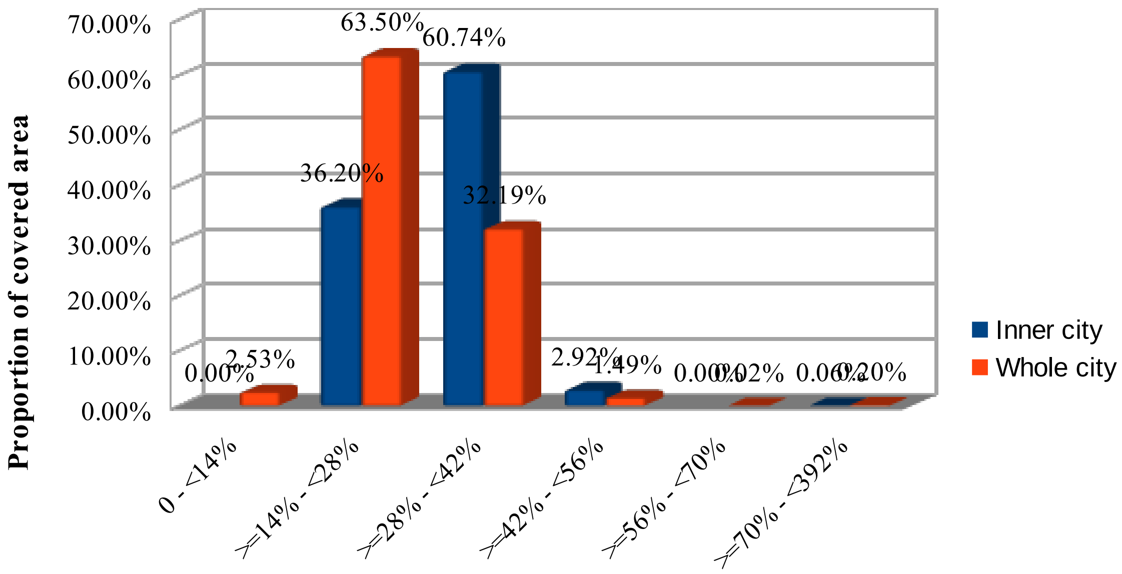
Proportion of inhabitants of simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) among all inhabitants on 31 December 2014

Fig. 84 - Proportion of inhabitants of simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of inhabitants with an occupancy of at least five years at their current address among all inhabitants on 31 December 2014

Fig. 85 - Proportion of inhabitants with an occupancy of at least five years at their current address among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Migration volume: proportion per annum of the sum of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014

Fig. 86 - Migration volume: proportion per annum of the sum of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

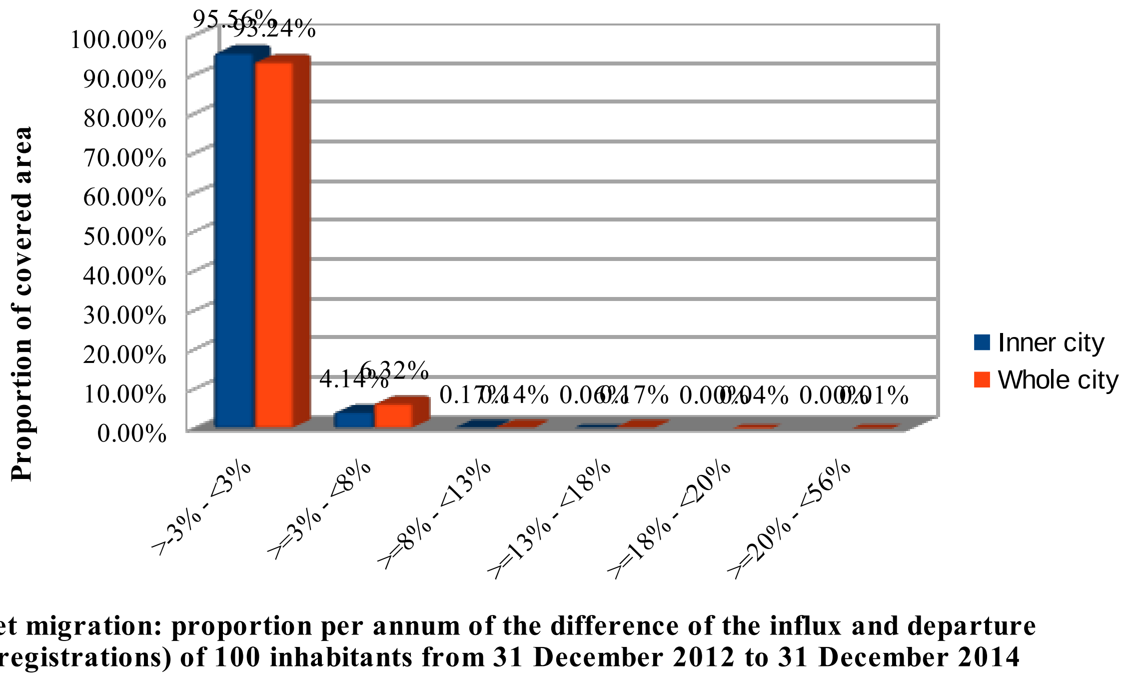
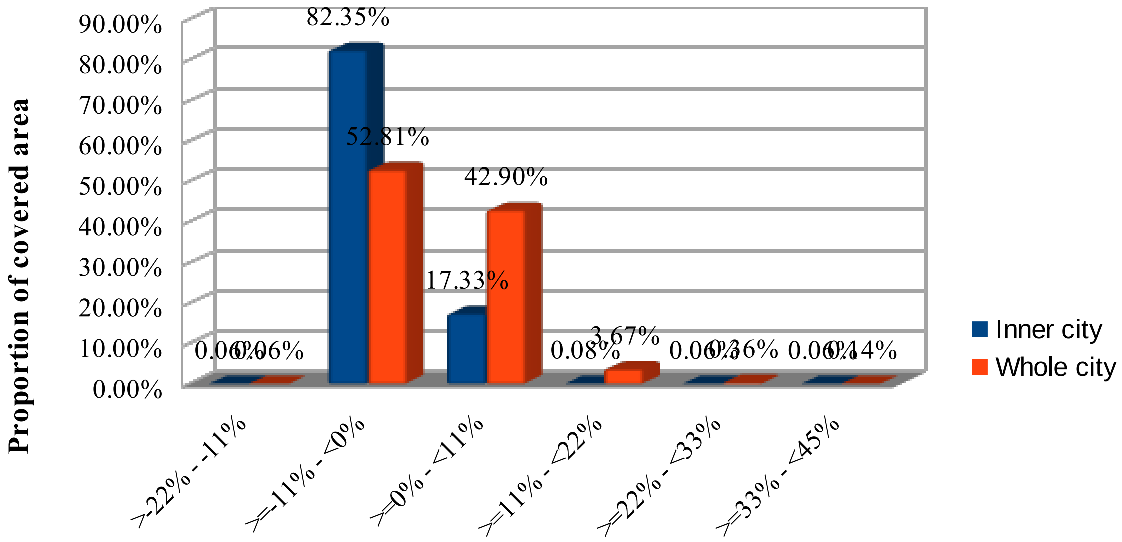


Fig. 87 - Net migration: proportion per annum of the difference of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Net migration of children of an age less than six years: proportion per annum of the difference of the influx and departure (registrations) of children less than six years old of 100 children of this age class from 31 December 2012 to 31 December 2014

Fig. 88 - Net migration of children of an age less than six years: proportion per annum of the difference of the influx and departure (registrations) of children less than six years old of 100 children of this age class from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

Table 14 - Overview of the results of the analysis of socio-economic data of inhabitants within 500 m distance of public parks, and public accessible managed green areas/parks of a minimum size of 0.5 ha in Berlin (own calculation based on data of the Senate of Berlin, 2017a).

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Unemployment: proportion of unemployed among 15 to 65 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Long-term unemployment: proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Social assistance benefits: proportion of not unemployed who get social assistance benefits among inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Children poverty: proportion of children and teenagers under 15 years old in households who depend on social welfare among all 15 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	19% of the area: >=3% - <6%; 48% of the area: >=6% - <9%; 21% of the area: >=9% - <12%	26% of the area: >=3% - <6%; 34% of the area: >=6% - <9%; 23% of the area: >=9% - <12%	26% of the area: >=1.00% - <2.00%; 39% of the area: >=2.00% - <3.00%; 25% of the area: >=3.00% - <4.00%	25% of the area: >=1.00% - <2.00%; 31% of the area: >=2.00% - <3.00%; 24% of the area: >=3.00% - <4.00%	27% of the area: >=8% - <16%; 38% of the area: >=16% - <24%; 18% of the area: >=24% - <32%	35% of the area: >=8% - <16%; 33% of the area: >=16% - <24%; 19% of the area: >=24% - <32%	17% of the area: <13%; 28% of the area: >=13% - <26%; 18% of the area: >=26% - <39%; 13% of the area: >=39% - <52%; 14% of the area: >=52% - <65%	20% of the area: <13%; 29% of the area: >=13% - <26%; 15% of the area: >=26% - <39%; 15% of the area: >=39% - <52%; 15% of the area: >=52% - <65%
Public accessible managed green areas/parks (2010)	22% of the area: >=3% - <6%; 46% of the area: >=6% - <9%; 22% of the area: >=9% - <12%	26% of the area: >=3% - <6%; 34% of the area: >=6% - <9%; 23% of the area: >=9% - <12%	28% of the area: >=1.00% - <2.00%; 40% of the area: >=2.00% - <3.00%; 22% of the area: >=3.00% - <4.00%	26% of the area: >=1.00% - <2.00%; 29% of the area: >=2.00% - <3.00%; 24% of the area: >=3.00% - <4.00%	28% of the area: >=8% - <16%; 37% of the area: >=16% - <24%; 18% of the area: >=24% - <32%	35% of the area: >=8% - <16%; 33% of the area: >=16% - <24%; 19% of the area: >=24% - <32%	18% of the area: <13%; 30% of the area: >=13% - <26%; 18% of the area: >=26% - <39%; 13% of the area: >=39% - <52%; 14% of the area: >=52%	23% of the area: <13%; 26% of the area: >=13% - <26%; 15% of the area: >=26% - <39%; 15% of the area: >=39% - <52%; 16% of the area: >=52%

							- <65%	- <65%

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	Unemployment change: change of the proportion of unemployed among 15 to 65 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016		Change of long-term unemployment: change of the proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016		Change of social assistance benefits: change of the proportion of not unemployed getting social assistance benefits from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016		Change of children poverty: change of the proportion of children and teenagers under 15 years old in households who depend on social welfare among all 15 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	27% of the area: >=-11% - <-3%; 72% of the area: >=-3% - <-1%	31% of the area: >=-11% - <-3%; 68% of the area: >=-3% - <-1%	8% of the area: >=-2% - <-1%; 85% of the area: >=-1% - <0%; 7% of the area: >=0% - <1%	8% of the area: >=-2% - <-1%; 75% of the area: >=-1% - <0%; 17% of the area: >=0% - <1%	80% of the area: >=-2% - <0%; 17% of the area: >=0% - <2%	64% of the area: >=-2% - <0%; 33% of the area: >=0% - <2%	9% of the area: >=-10% - <-5%; 72% of the area: >=-5% - <0%; 17% of the area: >=0% - <5%	5% of the area: >=-10% - <-5%; 66% of the area: >=-5% - <0%; 28% of the area: >=0% - <5%
Public accessible managed green areas/parks (2010)	26% of the area: >=-11% - <-3%; 73% of the area: >=-3% - <-1%	30% of the area: >=-11% - <-3%; 69% of the area: >=-3% - <-1%	7% of the area: >=-2% - <-1%; 86% of the area: >=-1% - <0%; 7% of the area: >=0% - <1%	8% of the area: >=-2% - <-1%; 75% of the area: >=-1% - <0%; 17% of the area: >=0% - <1%	81% of the area: >=-2% - <0%; 16% of the area: >=0% - <2%	61% of the area: >=-2% - <0%; 36% of the area: >=0% - <2%	10% of the area: >=-10% - <-5%; 74% of the area: >=-5% - <0%; 16% of the area: >=0% - <5%	5% of the area: >=-10% - <-5%; 66% of the area: >=-5% - <0%; 28% of the area: >=0% - <5%

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Proportion of unemployed, aged under 25, among 15 to 25 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of single households with children under 18 years old among all households with children under 18 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of inhabitants who depend on social welfare (not living in institutions) of 65 years and older among all inhabitants of this age class on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of children and youngsters of migration background (foreigners, citizens with a second nationality, and Germans born abroad or with at least one parent born in another country) under 18 years old among all inhabitants of this age class on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	19% of the area: <2%; 39% of the area: >=2% - <4%; 30% of the area: >=4% - <6%; 11% of the area: >=6% - <8%	21% of the area: <2%; 34% of the area: >=2% - <4%; 27% of the area: >=4% - <6%; 14% of the area: >=6% - <8%	53% of the area: >=20% - <30%; 43% of the area: >=30% - <40%	40% of the area: >=20% - <30%; 45% of the area: >=30% - <40%	22% of the area: <5%; 38% of the area: >=5% - <10%; 16% of the area: >=10% - <15%; 18% of the area: >=15% - <20%	52% of the area: <5%; 30% of the area: >=5% - <10%; 8% of the area: >=10% - <15%; 8% of the area: >=15% - <20%	0% of the area: <15%; 9% of the area: >=15% - <30%; 19% of the area: >=30% - <45%; 22% of the area: >=45% - <60%; 27% of the area: >=60% - <75%; 23% of the area: >=75% - <91%	7% of the area: <15%; 21% of the area: >=15% - <30%; 24% of the area: >=30% - <45%; 18% of the area: >=45% - <60%; 8% of the area: >=60% - <75%; 22% of the area: >=75% - <91%
Public accessible managed green areas/parks (2010)	20% of the area: <2%; 41% of the area: >=2% - <4%; 28% of the area: >=4% - <6%; 10% of the area: >=6% - <8%	21% of the area: <2%; 34% of the area: >=2% - <4%; 27% of the area: >=4% - <6%; 14% of the area: >=6% - <8%	54% of the area: >=20% - <30%; 42% of the area: >=30% - <40%	40% of the area: >=20% - <30%; 45% of the area: >=30% - <40%	22% of the area: <5%; 37% of the area: >=5% - <10%; 17% of the area: >=10% - <15%; 17% of the area: >=15% - <20%	52% of the area: <5%; 30% of the area: >=5% - <10%; 8% of the area: >=10% - <15%; 8% of the area: >=15% - <20%	0% of the area: <15%; 10% of the area: >=15% - <30%; 20% of the area: >=30% - <45%; 21% of the area: >=45% - <60%; 27% of the area: >=60%	7% of the area: <15%; 21% of the area: >=15% - <30%; 24% of the area: >=30% - <45%; 17% of the area: >=45% - <60%; 17% of the area: >=60%

							- <75%; 22% of the area: >=75% - <91%	- <75%; 12% of the area: >=75% - <91%

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Proportion of inhabitants of migration background among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of foreigners among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Change of the proportion of foreigners among all inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of non-EU foreigners among all foreign inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	1% of the area: <15%; 26% of the area: >=15% - <30%; 38% of the area: >=30% - <45%; 26% of the area: >=45% - <60%; 9% of the area: >=60% - <69%	22% of the area: <15%; 36% of the area: >=15% - <30%; 23% of the area: >=30% - <45%; 14% of the area: >=45% - <60%; 4% of the area: >=60% - <75%	2% of the area: <10%; 32% of the area: >=10% - <20%; 37% of the area: >=20% - <30%; 26% of the area: >=30% - <40%	34% of the area: <10%; 34% of the area: >=10% - <20%; 19% of the area: >=20% - <30%; 12% of the area: >=30% - <40%	96% of the area: >-2% - <4%; 4% of the area: >=4% - <8%	95% of the area: >-2% - <4%; 4% of the area: >=4% - <8%	21% of the area: >=32% - <48%; 57% of the area: >=48% - <64%; 21% of the area: >=64% - <80%	18% of the area: >=32% - <48%; 57% of the area: >=48% - <64%; 23% of the area: >=64% - <80%
Public accessible managed green areas/parks (2010)	2% of the area: <15%; 27% of the area: >=15% - <30%; 37% of the area: >=30% - <45%; 27% of the area: >=45% - <60%; 7% of the area: >=60% - <69%	22% of the area: <15%; 36% of the area: >=15% - <30%; 23% of the area: >=30% - <45%; 14% of the area: >=45% - <60%; 4% of the area: >=60% - <75%	2% of the area: <10%; 31% of the area: >=10% - <20%; 39% of the area: >=20% - <30%; 28% of the area: >=30% - <40%	34% of the area: <10%; 34% of the area: >=10% - <20%; 31% of the area: >=20% - <30%; 1% of the area: >=30% - <40%	96% of the area: >-2% - <4%; 4% of the area: >=4% - <8%	95% of the area: >-2% - <4%; 4% of the area: >=4% - <8%	21% of the area: >=32% - <48%; 57% of the area: >=48% - <64%; 20% of the area: >=64% - <80%	18% of the area: >=32% - <48%; 57% of the area: >=48% - <64%; 23% of the area: >=64% - <80%

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Proportion of foreigners in households who depend on social welfare among all foreign inhabitants under 65 years old on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of flats owned by Berlin's state housing associations among all flats on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Number of living rooms per inhabitant, including the kitchen, on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Living space in m^2 per inhabitant on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	1% of the area: <12%; 50% of the area: >=12% - <24%; 26% of the area: >=24% - <36%; 15% of the area: >=36% - <48%; 5% of the area: >=48% - <60%	18% of the area: <12%; 29% of the area: >=12% - <24%; 23% of the area: >=24% - <36%; 19% of the area: >=36% - <48%; 9% of the area: >=48% - <60%	76% of the area: <17%; 11% of the area: >=17% - <34%; 11% of the area: >=34% - <51%	69% of the area: <17%; 16% of the area: >=17% - <34%; 10% of the area: >=34% - <51%	31% of the area: >=1.12 - <1.68; 68% of the area: >=1.68 - <2.24	20% of the area: >=1.12 - <1.68; 77% of the area: >=1.68 - <2.24	24% of the area: >=17 m^2 - <34 m^2; 74% of the area: >=34 m^2 - <51 m^2	19% of the area: >=17 m^2 - <34 m^2; 78% of the area: >=34 m^2 - <51 m^2
Public accessible managed green areas/parks (2010)	20% of the area: <12%; 34% of the area: >=12% - <24%; 26% of the area: >=24% - <36%; 14% of the area: >=36% - <48%; 4% of the area: >=48% - <60%	18% of the area: <12%; 29% of the area: >=12% - <24%; 22% of the area: >=24% - <36%; 19% of the area: >=36% - <48%; 9% of the area: >=48% - <60%	76% of the area: <17%; 11% of the area: >=17% - <34%; 11% of the area: >=34% - <51%	69% of the area: <17%; 16% of the area: >=17% - <34%; 10% of the area: >=34% - <51%	29% of the area: >=1.12 - <1.68; 70% of the area: >=1.68 - <2.24	20% of the area: >=1.12 - <1.68; 77% of the area: >=1.68 - <2.24	23% of the area: >=17 m^2 - <34 m^2; 75% of the area: >=34 m^2 - <51 m^2	19% of the area: >=17 m^2 - <34 m^2; 78% of the area: >=34 m^2 - <51 m^2

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Proportion of inhabitants of simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Proportion of inhabitants with an occupancy of at least five years at their current address among all inhabitants on 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Migration volume: proportion per annum of the sum of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**		**Net migration: proportion per annum of the difference of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city	Inner city	Whole city
Public parks (2015)	36% of the area: <17%; 7% of the area: >=17% - <34%; 8% of the area: >=34% - <51%; 10% of the area: >=51% - <68%; 5% of the area: >=68% - 85%; 34% of the area: >=85% - <=100%	44% of the area: <17%; 16% of the area: >=17% - <34%; 6% of the area: >=34% - <51%; 7% of the area: >=51% - <68%; 12% of the area: >=68% - 85%; 14% of the area: >=85% - <=100%	46% of the area: >=42% - <56%; 52% of the area: >=56% - <70%; 1% of the area: >=70% - <83%	27% of the area: >=42% - <56%; 61% of the area: >=56% - <70%; 12% of the area: >=70% - <83%	36% of the area: >=14% - <28%; 61% of the area: >=28% - <42%	63% of the area: >=14% - <28%; 32% of the area: >=28% - <42%	96% of the area: >-3% - <3%; 4% of the area: >=3% - <8%	93% of the area: >-3% - <3%; 6% of the area: >=3% - <8%

Public accessible managed green areas/parks (2010)	36% of the area: <17%; 8% of the area: >=17% - <34%; 8% of the area: >=34% - <51%; 10% of the area: >=51% - <68%; 5% of the area: >=68% - 85%; 33% of the area: >=85% - <=100%	44% of the area: <17%; 9% of the area: >=17% - <34%; 7% of the area: >=34% - <51%; 6% of the area: >=51% - <68%; 7% of the area: >=68% - 85%; 27% of the area: >=85% - <=100%	46% of the area: >=42% - <56%; 52% of the area: >=56% - <70%; 1% of the area: >=70% - <83%	27% of the area: >=42% - <56%; 61% of the area: >=56% - <70%; 12% of the area: >=70% - <83%	18% of the area: >=14% - <28%; 79% of the area: >=28% - <42%	66% of the area: >=14% - <28%; 32% of the area: >=28% - <42%	96% of the area: >-3% - <3%; 4% of the area: >=3% - <8%	93% of the area: >-3% - <3%; 6% of the area: >=3% - <8%

Within 500 m distance of the green space land use type of a minimum size of 0.5 ha in Berlin	**Net migration of children of an age under six years: proportion per annum of the difference of the influx and departure (registrations) of children under six years old of 100 children of this age class from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016**	
	Inner city	Whole city
Public parks (2015)	82% of the area: >=-11% - <0%; 17% of the area: >=0% - <11%	53% of the area: >=-11% - <0%; 43% of the area: >=0% - <11%
Public accessible managed green areas/parks (2010)	81% of the area: >=-11% - <0%; 18% of the area: >=0% - <11%	53% of the area: >=-11% - <0%; 43% of the area: >=0% - <11%

2.5.4. Discussion

2.5.4.1. Biophysical data

2.5.4.1.1. Microclimate

There is a clear distinction visible between the provided ecosystem services of public urban green space in the inner city boundaries of the S-Bahn circle in comparison to the whole city of Berlin. 66% of the area in the inner city and 62% of whole Berlin have a degree of soil sealing ranging from 60% to 100% which surrounds public parks within a walking distance of 500 m of a minimum size of 0.5 ha (Fig. 28).

The degree of soil sealing is also reflected in the cities' heat island effect which increases towards the inner city area. Berlin's inhabitants depend on a cooling down effect by public parks of a minimum size of 0.5 ha within a distance of 500 m which is at average one class less strong of minus 20 K per hour for the great majority of this distance area from 10:00 in the evening to 4:00 in the morning in the inner city than in the whole city (Fig. 29). Both show at 10:00 pm a medium to strong pressure of more than 24°C of less favourable to unfavourable bioclimatic heat conditions within this distance area (Fig. 30 and Fig. 31) (Senate of Berlin, 2015g). However, the bioclimatic heat situation relaxes much faster until 4:00 am for most of this distance area in the whole city than in the inner city area of Berlin (Fig. 32). It worsens again at average within this distance equally in the inner city to the whole city of Berlin from warm to hot conditions of up to almost 36°C by 2:00 pm in the afternoon (Fig. 33). However, the average cold air volume flow is much higher within this distance area in the whole city than in the inner city at 4:00 am at night (Fig. 34), but the difference becomes less evident at 10:00 pm (Fig. 35).

As consequence, Berlin's inhabitants have to suffer from more tropical nights within a distance of 500 m of public parks of a minimum size of 0.5 ha in the inner city than in the whole city (Fig. 36). The inner city island heat effect increases also the number of summer days of 25°C or more within this distance area more than in the whole city (Fig. 37). Also the average number of heat days of a minimum temperature of 30 °C or more per year is higher in the inner city in comparison to the whole city of Berlin within this distance area (Fig. 38). Overall, the thermal situation is equally mainly unfavourable within this walking distance of 500 m of a minimum size of 0.5 ha of public parks in the inner city and the whole city of Berlin in comparison (Fig. 39). The thermal situation is similar in the inner city and the whole city within this distance area at 2:00 pm (Fig. 41). Unfortunately, the cooling down night effect within this distance area can hardly be assessed until 4:00 am in the morning due to unknown data of about 31% to 40% of this area (Fig. 40).

Beneficiary for the bioclimatic conditions is within the walking distance of 500 m of a minimum size of 0.5 ha that the soil sealing degree is equally just 0% to <20% to about 71% to 72% of the area within public parks in the inner and whole city of Berlin (Fig. 42) which is main reason for the high value public parks for the bioclimatic heat conditions within this distance area. Overall, there is the highest worthiness of the protection of the green and open space of public parks in the inner city as well as in the whole city of Berlin according to the microclimatic analysis (own calculation based on data of the Senate of Berlin, 2017a).

The analysis of public accessible managed green areas/parks of a minimum size of 0.5 ha show a lower degree of soil sealing within a distance of 500 m compared to public parks, but similar differences of bioclimatic conditions within the inner city compared to the whole city apart from the average number of summer days of 25°C or more (Table 10).

Allotments of a minimum size of 0.5 ha have also a less high degree of soil sealing within a distance of 500 m of them in comparison to public parks. The average bioclimatic pressure (PET) is comparably higher within this distance area during the day until 10:00 pm, but it cools down better at average in the whole city than the inner city combined with a similar average cold air volume flow to public parks within this distance area. The thermal situation of allotments of a minimum size of 0.5 ha is better at 4:00 am within this distance area than of public parks.

The degree of soil sealing is relatively low within all investigated land use types of public parks, allotments, and cemeteries in the inner city and the whole city of Berlin. Just public accessible managed green areas/parks show a higher degree of soil sealing within a range from >=20% to <40%. Allotments show a higher degree of soil sealing in the inner city than in the entire city of Berlin. It is the other way around for cemeteries. The other analysis results of cemeteries are also similar to public parks (Table 10).

2.5.4.1.2. Soil functions

The soils of public parks are to about two third of the area of medium regulation function for the water balance in the inner city of Berlin, but almost half in the whole city of a high exchange frequency of the soil water per annum (Fig. 43). Also the buffering and filtration functions of soils are stronger in the whole city, i.e. high or medium for about two thirds. Whereas about half of the area of public parks in the inner city is medium and around one third low of this sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity, and binding capacity of heavy metals (Fig. 44). The yield function of public parks is low for cultivated plants/sum of water and nutrient supply indicators of the proportion of the area in the inner city, as well as the whole city of Berlin (Fig. 46).

Rare natural vegetation can just find habitats of natural soils to a low extent in the inner city as well as in the whole city (Fig. 45). This is a consequence from the analysed sum of indicators by the method of the Environmental Atlas Berlin (Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015) of public parks to a majority of the area of low or very low naturalness (high hemeroby) (Fig. 50), frequently or very frequently occurring soils of the nature region of Berlin (Fig. 54), widely dry soil moisture (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015), and low nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) (Fig. 58), as well as of the subsoil (Fig. 57). Correspondingly, the archival function of natural history/rarity of soil associations, and particular soils of the nature region of public parks is low in the inner city and the whole city of Berlin (Fig. 47).

About half of the area of the soils of public parks perform medium and high of natural soil and archival functions for the whole city in comparison to a low performance in the inner city when all five soil functions mentioned above are analysed together (Fig. 48). However, in total the soil protection values of public parks are high or very high to one third of the soil areas in the whole city, but less in the inner city of Berlin (Fig. 49).

The exchange frequency of groundwater (contrary: water storage capacity) is low or very low for about half of the soil area within public parks in the inner city compared to more than two-thirds in the whole city of Berlin (Fig. 51), the water supply/effective field capacity for more than two thirds medium for both (Fig. 52). Soils are widely not particularly dry in public parks in the inner city and in whole Berlin. Nevertheless, some areas of public parks have particularly dry soil locations in the inner city of around 12% as well as in the whole city of about 14% in Berlin (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013). The annual groundwater recharge per m² is about 17% higher in public parks in the inner city than in the whole city (Table 11).

The soils of public accessible managed green areas/parks show similar analysis results to public parks within the inner city as well in the entire city of Berlin. Their naturalness is even lower (higher hemeroby). The water supply/effective field capacity is better in the whole city than in the inner city, and the filtration capacity of the subsoil is lower in the inner city than in the whole city of Berlin of public accessible managed green areas/parks compared to public parks. Soil associations of public accessible managed green areas/parks occur more frequently in the inner city of Berlin in comparison to whole city, but also to public parks. Public accessible managed green areas/parks have to a larger extent particularly dry locations at around 27% of the area in the inner city, but similar to public parks just 16% in the whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013). However, the annual groundwater recharge is the highest per m² in the inner city area of public accessible managed green areas/parks of all investigated land use types, which is about 45% higher than of public accessible managed green areas/parks in the whole city of Berlin (Table 11).

The analysis results are similar for allotments, and cemeteries, but contrary for their high regulation function for the water balance, i.e. high exchange frequency of the soil water per year. Also the yield function for cultivated plants of allotments is high in contrast in the inner city and the whole city of Berlin, medium for cemeteries. The performance of natural soil and archival functions of allotments are higher in comparison to public parks, and public accessible managed green areas/parks in the inner city as well as in the whole city of Berlin. However, the performance of natural soil and archival functions is lower of cemeteries to allotments, i.e. just high for about two thirds of the soil area of cemeteries in the inner city and around one third in the whole city, but still higher in the inner city of Berlin compared to public parks, and public accessible managed green areas/parks. In addition, the overall soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance are very high for the soil area of allotments, and cemeteries (Table 11).

The naturalness of soils is low in public parks, public accessible managed green areas/parks, and of allotments in the inner city, but medium for allotments in the entire city as well as for cemeteries medium both the inner city and the whole city of Berlin. The exchange frequency of groundwater (contrary: water storage capacity) is in contrast very low for allotments, and cemeteries.

Exceptionally for allotments in comparison to the other analysed land use types of urban green space, the nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity is medium or high to about half of the area in the inner city as well as the whole city of Berlin. About one third in the inner city and around one fourth of allotments in the whole city have groundwater influenced soil types of moist to wet conditions.

Another difference is the filtration capacity of the subsoil which is high for around two thirds in the inner city of cemeteries and still high for about one third in the whole city of Berlin. The topsoil has a medium filtration capacity of two thirds of the area on cemeteries in the inner city in contrast to a low one for more than two thirds in the whole city and medium for less than one-third in the inner city of Berlin. The filtration capacity of the topsoil of cemeteries is also better as medium for the great majority of the area in the inner city of Berlin compared to public parks, and public accessible managed green areas/parks. However, the average ground water recharge per m² per annum is the lowest on cemeteries in the inner city as well as the whole city of Berlin in comparison to the analysed other urban green space land use types such as about 70% higher on allotments (Table 11).

2.5.4.1.3. Vegetation volume

Table 12 on page 105 provides an overview of the results of the vegetation volume analysis of public parks, public accessible managed green areas/parks, allotments, and cemeteries. The vegetation volume of public accessible managed green areas/parks (Fig. 202) was much higher than in public parks in the inner city (Fig. 59), but also in the whole city of Berlin. However, inner streets did interrupt the volume of the vegetation cover even stronger within public accessible managed green areas/parks (Fig. 204) than within public parks (Fig. 61) both in the inner city and the entire city of Berlin. The vegetation volume was comparably higher in inner streets of allotments (Fig. 208) and cemeteries (Fig. 212) in the inner city of Berlin. In the whole city of Berlin, the vegetation volume of inner streets was similarly higher in public parks (Fig. 61) and cemeteries (Fig. 212), and comparably lower in public accessible managed green areas/parks (Fig. 204) and allotments (Fig. 208).

The vegetation volume was similar of the surrounding area within 500 m distance to public parks of a minimum size of 0.5 ha (Fig. 60) to public accessible managed green areas/parks (Fig. 203) in the inner city, as well as in the whole city of Berlin. This refers also in comparison to allotments (Fig. 207) and cemeteries (Fig. 211). Similar vegetation volume occurred in the streets within this surrounding distance of all investigated green space land use types in the inner city and the whole city of Berlin (Fig. 62, Fig. 205, Fig. 209, Fig. 213).

The lowest vegetation volume could be found within allotments in the inner city and the whole city of Berlin (Fig. 206), within cemeteries the highest (Fig. 210). The vegetation volume of streets was higher within allotments (Fig. 208) and cemeteries (Fig. 212) than in public parks and public accessible managed green areas/parks in the inner city as well as in the whole city of Berlin.

2.5.4.1.4. Hemeroby (contrary: naturalness) of biotope types

Table 13 on page 107 provides an overview of the results of the hemeroby analysis of public parks, public accessible managed green areas/parks, allotments, and cemeteries of primary data. The degree of human impacts (hemeroby) is high for about 69% of the area of biotope types within public parks of primary data. In contrast, about 53% of the area biotope types of public parks have a low hemeroby in the whole city of Berlin, just 32% of the area a high one (Fig. 63). The area of biotope types with a high hemeroby was much lower for public managed green areas/parks of approximately 39% and around 28% of a low hemeroby in the inner city of Berlin. For the whole city of Berlin, the hemeroby was even low for about 46% of the area of biotope types of public managed green areas/parks also of primary data (Fig. 214).

Allotments showed a low degree of human impacts (hemeroby) of biotope types for about 73% of the area in the inner city of Berlin (Fig. 215). The area of low hemeroby of biotope types within allotments was 49% of the whole city, but uncertain due to the high proportion of 46% of the area of unknowns. For cemeteries, the hemeroby of biotope types was low for approximately 58% of the area, but high for about 18% of the area in the inner city of Berlin. The figures were of about 30% low hemeroby and approximately 32% high hemeroby of the area of biotope types of cemeteries in the whole city of Berlin. However, about 37% of the area of biotope types of cemeteries had an unknown hemeroby (Fig. 216).

2.5.4.2. Social and economic data of inhabitants

The availability of public accessible green space in walking distance is closely related not only to the number of inhabitants and other people passing by, but to the social conditions of their life. Unemployment hinders the opportunities to reach public green space for relaxation and inspiration on your own or in social contact with others, i.e. for direct and indirect benefits of psychological values (including the physical and mental health), and social values (Chapter 3. The international context of measuring urban biodiversity through a City Biodiversity Index (CBI) on page 158). Table 14 on page 126 provides an overview of the analysis of the socio-economic data of inhabitants within 500 m distance of public parks, and public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner city and the entire city of Berlin on 31 December 2014.

The proportion of unemployed among 15 to 65 years old ranged from >=6% to <9% for about half of the area within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin on 31 December 2014 in comparison to about one third within the same range in the whole city at the same time (Fig. 64). Long-term unemployment among this age group was similar in the inner city and the whole city of Berlin (Fig. 65). Also the proportion of inhabitant is an indicator of their financial resources within this distance area from public parks who are not registered as being unemployed, but receive social assistance benefits. It is higher in the inner city than in the whole city of Berlin (Fig. 66). About one-third of this distance area had a proportion from >=10% to <20% and approximately 60% of a range from 0% to <10% of inhabitants of 65 years and older among all inhabitants of this age class who depended on social assistance benefits while not living in institutions in the inner city on 31 December 2014, but just about 16% of this distance area from >=10% to <20% and around 82% of a range from 0% to <10% in the whole city of Berlin within this range (Fig. 74). Partially, the children poverty is also higher in the inner city of Berlin, but in general it was similar within this distance area from public parks in the inner city and whole city of Berlin on 31 December 2014 (Fig. 67).

Unemployment stayed relatively stable by more than two thirds of the area which changed just from >=-1% to <1% of the proportion of unemployed among 15 to 65 years old from 31 December 2012 to 31 December 2014. This means it did not worsen, but also did not improve much within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city and the whole city of Berlin (Fig. 68). This refers also to the change classes from >=-1% - <1% of long-term unemployment (Fig. 69). The proportion of not unemployed getting social assistance benefits was reduced at 80% of the distance area to public parks by >=-2% to <0% in the inner city of Berlin, but only 64% in the whole city within this range from 31 December 2012 to 31 December 2014 (Fig. 70). Children poverty decreased in the inner city at 72% of this distance area from public parks of a range from >=-5% to <0%, i.e. stronger than in the whole city within 66% of the distance area of the same range from 31 December 2012 to 31 December 2014. Furthermore, children poverty increased at 28% of the distance area of a range of >=0% - <5% in the whole city in comparison to 17% of the distance area in the inner city of Berlin (Fig. 71). For about 41% of the area within 500 m distance of public parks of a minimum size of 0.5 ha, young unemployment ranged among 15 to 25 years old from >=4% to <8% in the inner city as well as in the whole city of Berlin on 31 December 2014 (Fig. 72). About 96% of the respective distance area of public parks contained >=20% to <40% of single households with children under 18 years old among all households with children under 18 years old within the inner city and approximately 85% of the whole city of Berlin on 31 December 2014 (Fig. 73).

Unemployment of adults is therefore still stronger within walking distance of public parks of a minimum size of 0.5 ha in the inner city of Berlin than in the city in total. Also the elder depend to a larger extent within this distance area on social benefits in the inner city than in whole Berlin. This situation did not change very much for unemployed within two years from 2012 to 2014 neither in the inner city nor in the whole city of Berlin. The reduction of unemployed getting social assistance benefits was a little bit better in the inner city than in the whole city, but still neglectable in comparison to the total figures. Children poverty is a comparably continuous problem in the inner city and the whole city of Berlin. Thus, the most vulnerable social groups of limited financial resources are more affected by the deficit of public accessible green space (Section 2.4.1. Deficits of public green space on page 32) in the inner city of Berlin than in whole Berlin in comparison. Also the large number of affected single households with children under 18 years old is higher in the inner city than in Berlin in total.

In addition, the social and cultural development of inhabitants plays also an important role of the different approaches to green space such as Berlin's inhabitants of Turkish roots who like to barbecue and socialize in groups in public parks (Prahl, 2013; Stoetzer, 2014). About half of the area which surrounds public parks of a minimum size of 0.5 ha within 500 m distance consisted from >=60% to <91% children and youngsters of migration background (foreigners, citizens with a second nationality, and Germans born abroad or with at least one parent born in another country) under 18 years old among all inhabitants of this age class in the inner city of Berlin on 31 December 2014. The respective figure was just 30% of this distance area and range for the whole city of Berlin

(Fig. 75). The range was from >=30% to <60% for around two-thirds of this distance area of the proportion of inhabitants of migration background among all inhabitants in the inner city on 31 December 2014, around one-third within this range and about 58% of this distance area within a range from <15% to <30% in the whole city of Berlin (Fig. 76). The proportion of foreigners among all inhabitants ranged from >=20% to <40% for about two-thirds of the area within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city on 31 December 2014, but for around one-third within this range in the whole city of Berlin (Fig. 77). The change of the proportion of foreigners among all inhabitants ranged from equally or more than -2% to less than 4% in almost all of this surrounding distance area of public parks in the inner city and the whole city of Berlin within two years from 31 December 2012 to 31 December 2014 (Fig. 78).

The proportion of non EU-foreigners ranged from >=48% to <80% of all foreign inhabitants within about four-fifths of this distance area to public parks equally in the inner city and the whole city of Berlin on 31 December 2014 (Fig. 79). About half of this surrounding distance area of public parks in the inner city ranged from >=12% to <24% of foreigners of an age under 65 years who lived in households which depended on social welfare on 31 December 2014. The same figure referred to just 29% of this surrounding distance area within the same range of public parks in the whole city of Berlin, but 18% of this distance area below 12% in comparison to just 1% in the inner city of Berlin on 31 December 2014 (Fig. 80).

These results of a high proportion of inhabitants with migration and those of non-EU background have practical consequences for the use and planning of public parks particularly in their higher occurrence in the inner city of Berlin. First, there is a need to investigate further the different values of public parks for foreigners in Berlin for their individual practical use, but also for the management and further development of public parks. Subjective use and non-use (e.g. ethical bequest and existence values) depend on the socialization and culture-historical background of people as a social community or group like families, and individual perceptions and needs (Botzat et al., 2016). This cannot be carried out solely statistically, but it depends on the results of behavioural surveying and individual participation methods in decision-making of the neighbourhood of each public park (Grün Berlin GmbH, 2015). For instance, larger public parks are used at weekends for picnics even in longer distance in Berlin (Bertram et al., 2017), which is likely of different user groups, age, social and health status when some citizens have more free time than during the week which needed to be investigated in more detail.

In this respect, urban and landscape planning can just provide guidelines of best scientific and practical knowledge by planners and park managers, but the decisive management decision of public parks should be done in moderated public decision-making. For example, there is Berlin's Neighbourhood Management Programme as a social program "…to help disadvantaged inner city neighbourhoods and suburban neighbourhoods." (Senate of Berlin, 2017d). Neighbours can apply for funding for carrying out individual projects to improve their neighbourhood. The EU co-funded projects had a volume of €387 million in total from 1999 to 2015. About 3000 projects were funded within 35 Neighbourhood Management Areas of around 390,000 inhabitants with about 29% immigrants and approximately 36% recipients of transfer income in 2009 (Senate of Berlin, 2017d).

There is an active management tool available and urgently needed for halting the steep increase of rents in Berlin after the break through of the wall in 1989 (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24). About three-fourths of the area within 500 m distance of public parks of a minimum size of 0.5 ha had flats which were equally less than 17% publicly owned by state housing associations in the inner city of Berlin on 31 December 2014, about 69% for this distance area within the same range class in the whole city of Berlin (Fig. 81). More than two-thirds of this surrounding distance area of public parks in the inner city and about three-fourths in the whole city of Berlin had equally or more than 1.68 to less than 2.24 living rooms (including the kitchen) per inhabitant on 31 December 2014 (Fig. 82). This means that the available rooms and living space were a little bit less for inhabitants within the inner city in comparison to the entire city of Berlin which can be a signal of the increased rents and housing prices (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24). Approximately three-fourths of inhabitants within this surrounding distance area of public parks had 34 m² to less than 51 m² living space per inhabitant available in the inner city as well as in the whole city of Berlin on 31 December 2014 (Fig. 83). About one-third of this surrounding distance area of public parks had a range of >=85% to <=100% of inhabitants living in simple housing areas with a recognized noise exposure to road traffic in the inner city, but just around 14% within this range in the whole city of Berlin (Fig. 84). Traffic noise is a major issue for Berlin's inhabitants (Senate of Berlin, 2013c) which adds to the low housing standard. Adversely, public parks become more valuable as refuge for relaxation and health issues for stressed and less mobile inhabitants with little financial resources to leave the inner city.

Also fluctuation of inhabitants is higher in the inner city of Berlin than in the whole city of Berlin within the area which surrounds public parks of a minimum size of 0.5 ha within 500 m distance. There were about three-fourths of inhabitants of this surrounding distance area of public parks who lived at their current address more than five years of a range from 56% to less than 83% in the whole city of Berlin in comparison to just about more than half of the area within this range in the inner city of Berlin (Fig. 85). One reason was the net rent increase particularly in the inner city area, which causes gentrification (Smith, 2002; Colomb, 2012), i.e. the exchange of the residential population by newcomers of higher income (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24). As a consequence, the social relations among inhabitants can decrease as much the fluctuation increases. People are pushed out of gentrified neighbourhoods particularly in the inner city of Berlin (Holm, 2013; Balicka, 2013).

Consequently, the migration volume was much higher of about two-thirds of the area within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city within a range from 28% to less than 42% in comparison to around two-thirds within a range from 14% to less than 28% within this distance of public parks in the entire city of Berlin from 31 December 2012 to 31 December 2014 (Fig. 86).

However, the net migration per annum was relatively stable from more than -3% to less than 3% within 500 m distance of public parks of a minimum size of 0.5 ha in the inner city as well as the whole city of Berlin from 31 December 2012 to 31 December 2014 (Fig. 87). This means that the population density did not as much change in the inner city of Berlin as the exchange of inhabitants occurred due to the major effect of gentrification by net rent increases (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24).

Nevertheless, a clear loss of children under an age of six years could be notified for about 82% of this surrounding distance area of public parks in the inner city within a range among all children of inhabitants of less than 0% to -11% from 31 December 2012 to 31 December 2014 in comparison to more than half in the whole city of Berlin within the same range (Fig. 88).

The results of the analysis of the socio-economic data of Berlin's Environmental Atlas were quite similar to public parks for public accessible managed green areas/parks in the inner city and the entire city of Berlin (Table 14 on page 126; Fig. 217 to Fig. 241).

2.5.4.3. Ecosystem services of Berlin's urban green space based on Berlin's Environmental Atlas

Berlin's Environmental Atlas (Senate of Berlin, 2017a) provides spatial biophysical as well as social and economic data, but lacks of biological information on distribution, range and (meta-) population size of fauna & flora and their particular habitats. Unfortunately, the legal and practical requirements are not fulfilled of gathering sufficient monitoring data on the conservation status of species and habitat types of Community interest according to the EU Habitats Directive (European Commission, 1992) and birds of the EU Birds Directive (European Commission, 2009) and their national monitoring implementation requirements in § 6 (3) 2 German Federal Nature Conservation Act (BNatSchG, 2017), as well as § 6 Berlin's Nature Conservation Act (NatSchGBln, 2013).

Further analysis of Berlin's GIS data on biotopes was unfortunately not useful than hemeroby (degree of human impacts) (Senate of Berlin, 2012d, 2017a; Köstler et al., 2005). The classification of biotope types was too generic to allow deeper analysis of the different ecosystem services (values of biodiversity) related to them. Second, only primary data of biotope types could be analysed which was based on aerial surveys and mapping on the ground. The secondary data described mainly structural land use types of no empirical data on occurring fauna and flora in practice.

Moreover, Berlin's biotope mapping was widely based on plant sociological mapping of vegetation on different land use types, but not on occurring fauna (Senate of Berlin, 2012d, 2017a; Köstler et al., 2005). There was no coherent comprehensive evaluation system applied of common criteria which are related to certain indicators to assess the different ecosystem services (values of green space) of each biotope type and their abiotic and biotic components (Zisenis, 2006, 2008, 2009). In addition, the human related values were not considered which are related to certain biotope types. A representative monitoring programme of fauna and flora was planned for Western Berlin in the 1980s, but never implemented (Janotta et al., 1987), despite legal obligations to monitor species and habitat types of Community interest and birds (European Commission, 1992, 2009).

In addition, non-use values are hardly considered in Berlin's Environmental Atlas such as the bequest value for future generations or individual non-use values of inhabitants according to surveys or other data collection methods. Moreover, a comprehensive evaluation of the different values of urban green space is missing in Berlin's Environmental Atlas as basis for the implementation of Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a) and other major urban and landscape planning tools and strategies in Berlin (Section 2.2. Major planning tools and strategies to integrate the different values of biodiversity on page 10).

Nevertheless, Berlin's Environmental Atlas provides a very valuable though limited source for investigating the different ecosystem services (biodiversity values) of public parks and other analysed public urban green space types (public accessible managed green areas/parks, allotments, and cemeteries) and their integration into urban and landscape planning in Berlin of this research. In particular, the analysis results of the soil functions as well as the microclimate, social and economic data within 500 m distance of of public parks and other researched public urban green space types of a minimum size of 0.5 ha in Berlin showed their high value for Berlin's inhabitants and on their own. A clear distinction became visible between the provided ecosystem services (use values) by them in the inner city in comparison to the whole city of Berlin.

Within the inner S-Bahn circle of Berlin, the particular density of soil sealing had direct and indirect impacts on the microclimate for inhabitants due to the heat island effect of concrete that storages heat and cools down much slower than open green space. This could be clearly detected within 500 m distance of public parks and the other investigated public urban green space types (public accessible managed green areas/parks, cemeteries, and allotments) of a minimum size of 0.5 ha. The situation was clearly more severe in the inner city than in the whole city of Berlin. The degree of soil sealing is a relatively easy quantifiable and comparable indicator for urban and landscape planning (Section 3.3.1. Sealed urban area on page 10). Berlin had to suffer several extreme heat events in the past (Schubert and Grossmann-Clarke, 2013).

However, the buffering and filtration functions of soils, and the exchange frequency of the soil water per annum (regulation function) of public parks were much lower in the inner city. One reason was likely in the inner city of Berlin the low naturalness of frequently or very frequently occurring soils of the nature region, which was caused by human influences and human use over the years (high hemeroby). The degree of human impact (hemeroby) was much higher on public parks in the inner city of Berlin than in the whole city according to their classified biotope types as an indicator. Natural soils were consequently rare and not preserved after centuries of human activities neither in the inner city nor the whole city of Berlin. This situation provided rarely habitats for rare natural vegetation in public parks in the inner city and the whole city of Berlin.

Theoretically, the dry soil moisture and low nutrient supply of the topsoil of public parks, and public accessible managed green areas/parks could have provided extreme environmental conditions for rare natural vegetation, but likely the not particularly dry location and high hemeroby did allow just temporarily or not at all rare natural vegetation to establish such as trampling sensitive dry grasslands. In addition, particularly dry locations were also rare according to the results, but the water supply/effective field capacity (for plants) was medium of public parks in the inner city and the whole city of Berlin. This is an indicator for common medium, more or less dry soil moisture conditions which do not support rare plant associations. Consequently, the habitat function for rare natural vegetation as indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) was low for all investigated four green space land use types even though the hemeroby was lower of the area of biotope types within allotments, and cemeteries of also higher water supply/effective field capacity.

On the contrary, the annual groundwater recharge per m² is much higher in public parks in the inner city than in the whole city of Berlin. One reason can be found in the higher rainfall in the inner city due to increased emissions of fine particles by industry, motor vehicles, and households in cities (Kuttler, 1993; Sukopp, 1990). The yield function of public parks was low for cultivated plants in the inner city and the whole city of Berlin, which is not the main use purpose according to Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a). Nevertheless, Berlin's Environmental Atlas concluded that public parks are highly valuable for protection in the inner city and the whole city of Berlin.

The vegetation volume was quite similar as indicator for different connected biophysical ecosystem services in public parks in the inner city as well as the whole city of Berlin. The vegetation cover in the streets, particularly of trees, did not compensate in comparison for the loss green space and consequently isolation barrier of all investigated green space types. Of course, there is an expected much higher deficit of vegetation volume, i.e. green space, of the area within 500 m distance to public parks of a minimum size of 0.5 ha in the inner city as well as similar in the whole city of Berlin, which is comparable in all four investigated green space types within this surrounding distance. The deficit also of the vegetation volume in separating streets is similar within 500 m distance to public parks of a minimum size of 0.5 ha to public accessible managed green areas/parks, allotments, and cemeteries irrespectively if in the inner city or the whole city of Berlin. The absolute values of the vegetation volume, however, were likely overestimated, because of the methodological approach of Berlin's Environmental Atlas to calculate the whole cube in m³ according to the average vegetation height per block area, parts of it or street sections (Senate of Berlin, 2017a).

The similarity of the much lower vegetation volume is no surprise within 500 m distance to all these four investigated green space types of a minimum size of 0.5 ha as they are located in similar concreted environments (Table 10). Public parks generally do not include brownfields such as public accessible managed green areas/parks, which increases vegetation volume during succession towards woodlands. Cemeteries obviously had a higher amount of vegetation volume than public parks and public accessible managed green areas/parks, and the lowest of all vegetation volumes within allotments. Inner streets of cemeteries and allotments had a higher vegetation volume than public parks and public accessible managed green areas/parks.

The hemeroby of the area of biotope types was lower within public accessible managed green areas/parks than in public parks in the inner city of Berlin as they were not generally actively managed for recreational purposes, but similar in the whole city of Berlin. Water supply and buffering and filtration functions of public accessible managed green areas/parks were lower in the inner city than in whole Berlin. Particularly dry locations of public accessible managed green areas/parks could be found in one fourth of the area in the inner city of Berlin. However, the annual groundwater recharge was the highest per m² in the inner city area of public accessible managed green areas/parks of all four investigated urban green space types also in comparison to the whole city of Berlin. Other soil functions were similar to public parks regarding the comparison of the inner city to the whole city of Berlin. This refers widely also to allotments, and cemeteries with the exception of their high regulation function for the water balance, i.e. high exchange frequency of the soil water per year in the inner city, and the high water storage capacity also in the whole city of Berlin. Also the buffering and filtration functions were higher for allotments and cemeteries in comparison to public parks, and public accessible managed green areas/parks. Not surprisingly, the yield function for cultivated plants of allotments was high in the inner city and the whole city of Berlin as it is one main management purpose to gather fresh fruits and vegetables from own gardens. It was still medium for cemeteries, likely due to their undisturbed soils of higher biological activity.

Obviously, the relatively stable grounds in comparison to building grounds allowed a higher performance of natural soil and archival functions of allotments in the inner city as well as in whole Berlin. For cemeteries this was just the case in the inner city. Allotments showed a higher nutrient storage and binding capacity of pollutants than the other three urban green space types. Soils of allotments and cemeteries had a high naturalness of less human impacts (hemeroby) compared to the high hemeroby of public parks, and public accessible managed green areas/parks in the inner city of Berlin. Few areas of biotope types within allotments showed a high hemeroby compared to the other three investigated green space land use types in the whole city. The soil associations were generally frequent with the exception of those areas on cemeteries in the inner city of Berlin. The soil protection values or of allotments and cemeteries were mainly or widely very high in the inner city and the whole city of Berlin as sum of the habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance. Allotments had less dry soil moisture areas than the other three investigated green land use types in the inner city of Berlin; irrigation by citizens might play a role for this result. On the contrary, the average ground water recharge per m² per annum is the lowest on cemeteries in the inner city as well as the whole city of Berlin, possibly because they are less artificially irrigated, but have a higher humus content and thereby water storage capacity like allotments than public parks, and public accessible managed green areas/parks. Exceptionally, the degree of soil sealing of allotments was lower in the inner city than of the other three investigated green space land use types in the inner city as well as the entire city of Berlin.

On the other hand, allotments and cemeteries as well as specifically brownfields have been under high conversion pressure in Berlin since the breakthrough of the wall in 1989. They were continuously lost, particularly in the already highly concreted inner city of Berlin for new constructions (Section 2.4.2. Development of green space over time after the breaking down of the wall in 1989 on page 41). About 60% of the area of allotments in the inner city and approximately 45% in the whole city was publicly owned by the city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

Regarding the results of the socio-economic analysis of inhabitants of spatial data of Berlin's

Environmental Atlas who live within 500 m distance of public parks, and public accessible managed green areas/parks of a minimum size of 0.5 ha (Table 14): one could argue that there is no need for children in the inner city of Berlin or for inhabitants of lower income in favour of business and wealthy employees as inhabitants. Other metropolises have made similar urban developments like Paris (Cohen et al., 2012) and its "banlieue" suburbs, but social segregation and tension have been the consequence in Berlin as well (Häussermann and Kapphan, 2013; Eksner, 2013). This has consequences for the need and use of public accessible green space which is left after densification, particularly within the inner city of Berlin (Section 2.4.2. Development of green space over time after the breaking down of the wall in 1989 on page 41, Section 2.4.3. Degree of soil sealing on page 46).

The social demands on accessible public green space were particularly high and specific in the inner city of Berlin due to the high deficit of public green space and the socio-economic structure within walking distance of public parks, and equally public accessible managed green areas/parks (Table 14). There could be specifically vulnerable user groups detected of unemployed, inhabitants who depend on social benefit transfer, elderly, single households with children, and poor children additionally with a high proportion of migration background within a distance of 500 m in the inner city of public parks, and public accessible managed green areas/parks of a minimum size of 0.5 ha on 31 December 2014 more than in entire Berlin. This socio-economic situation is aggravated by a higher proportion of the area of inhabitants who live in simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) in the inner city compared to the whole city of Berlin. On the other hand, the higher proportion of inhabitants with an occupancy of at least five years at their current address among all inhabitants in the whole city indicates a gentrification loss of these socio-economic groups in the inner city. The high turnover of inhabitants of simultaneously increasing rent and estate prices in particular in the inner city of Berlin needs to be altered as being main drivers (Section 2.3.3. Prices of real estates and rents as main drivers with an impact on green space on page 24) also of the high deficit of public green space and low share of private or semi-public open space, as well as a corresponding high degree of soil sealing particularly in the inner city of Berlin (Section 2.4.1. Deficits of public green space on page 32).

Thereby, social connections get lost among inhabitants in their neighbourhood which affects mostly the analysed vulnerable groups of our society particularly in the inner city of Berlin. As a result, the democratic bottom-up movements are weakened when the social interconnections are lost which can hinder the participation and optimization in decision-making of planning and project decisions in urban development in Berlin to integrate the different values of green space by the public directly and indirectly concerned (Section 2.4.5. Participation tools with an influence on planning decisions on page 56). The use and particular demands on public green space are expected to change with the demographic exchange of its population as much as they depend on the socio-cultural and income related circumstances of its inhabitants within the investigated walking distance as urban development goal of 500 m in the inner city of public parks, and public accessible managed green areas/parks of a minimum size of 0.5 ha (Section 2.2.1 Berlin's Landscape and Species Protection Programme on page 16).

This research did not intend to comprehensively evaluate the different ecosystem services (biodiversity values) of (all) public green space types in Berlin. It aims at providing examples to distinguish between the demands and situation in the inner circle of Berlin in comparison to the whole city, based on the available limited spatial data of Berlin's Environmental Atlas (Chapter 2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin on page 57).

2.6. Available public green urban areas in the inner city parts of other European metropolises

The Urban Atlas of the European Environment Agency provides land use spatial data with a geometric resolution of 0.25 ha (1:10.000) of Urban Morphological Zones of European cities with more than 100,000 inhabitants (European Environment Agency, 2014). I selected metropolises of more than 1 million inhabitants for the spatial analysis while using GIS software (gvSIG Association, 2015; QGIS, 2015) for the geometric analysis. From the "core city" database of the Urban Audit 2011-2014 (Eurostat, 2015), i.e. the city without the surrounding city region, I carried out a fixed distance geometrical buffer inside of 2/3 of the (core) city area of each metropolis while using the GIS software to get a corresponding border line of the inner city area to the borders of each European metropolis. As a result, each metropolis had an individual proportional inner city area depending on the shape of the corresponding border line of the core city. I used each inner city template to clip the Urban Atlas spatial land use data of each European metropolis of more than 1 million inhabitants within the database for comparison of this individual inner city (downtown) area to the second template of the area of each whole "core" city.

As a result, I could gather detailed land use comparisons of the downtown area of each European metropolis of more than 1 million inhabitants in Europe (see Appendix ranked by the number of inhabitants: Fig. 92, Fig. 93, Fig. 94, Fig. 95, Fig. 96, Fig. 97, Fig. 98, Fig. 99, Fig. 100, Fig. 101, Fig. 102, Fig. 103, Fig. 104, Fig. 105, Fig. 106, Fig. 107, and Fig. 108).

Furthermore, as the share of available public green space depends also on the number of inhabitants. I calculated the public green urban areas by the same GIS spatial analysis while using the same downtown template as well as each second template for the whole "core city" area. I clipped these templates of each metropolis with the population data of inhabitants for 2006 and 2011 respectively (Eurostat 2006, 2011). "Green urban areas" of the Urban Atlas cover within a minimum mapping unit of 0.25 ha of 10 m minimum width:

> "Public green areas for predominantly recreational use such as gardens, zoos, parks, castle parks. Suburban natural areas that have become and are managed as urban parks. Forests or green areas extending from the surroundings into urban areas are mapped as green urban areas when at least two sides are bordered by urban areas and structures, and traces of recreational use are visible.
>
> Not included are: Private gardens within housing areas → class 1.1; Cemeteries → class 1.2.1; Buildings within parks, such as castles or museums → class 1.2.1; Patches of natural vegetation or agricultural areas enclosed by built-up areas without being managed as green urban areas → class 1." (European Commission, 2011).

As a result, Fig. 89 shows the difference of public green urban areas per inhabitant of the inner city areas in comparison to the respective public green urban areas of the whole metropolis for the year 2011.

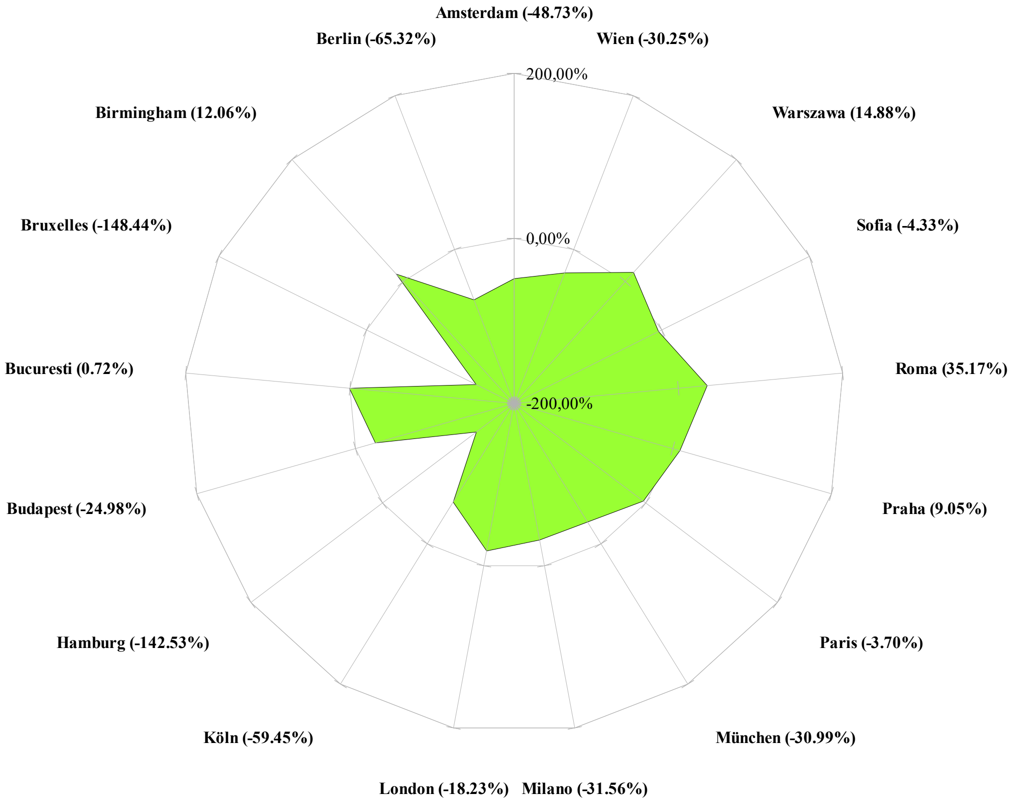


Fig. 89 - Proportion of the difference of inner city public green urban areas in m² per inhabitant to those of the total area of each European metropolis of more than 1 million inhabitants in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2011, 2015; © EuroGeographics for the administrative EU city boundaries).

Despite the one sample Kolmogorov Smirnov test showed a normal distribution of the inner city green urban areas (K-S z: 0.66, max d: 0.16, n: 17) while using the PSPP statistical analysis software (GNU, 2015). There was no significant correlation detectable on either side (two-sided) between the total area of each metropolis and the public green urban areas of the inner city in 2011 (Pearson's correlation coefficient r: 0.11, p: 0.663, n: 17). This means that an increase or decrease respectively of the total area of European metropolises of more than 1 million inhabitants is not correlated to the amount of public green urban areas in the respective inner city area. Fig. 90 and Fig. 91 show the available public green urban areas per inhabitant of each European metropolis for the years 2006 and 2011.

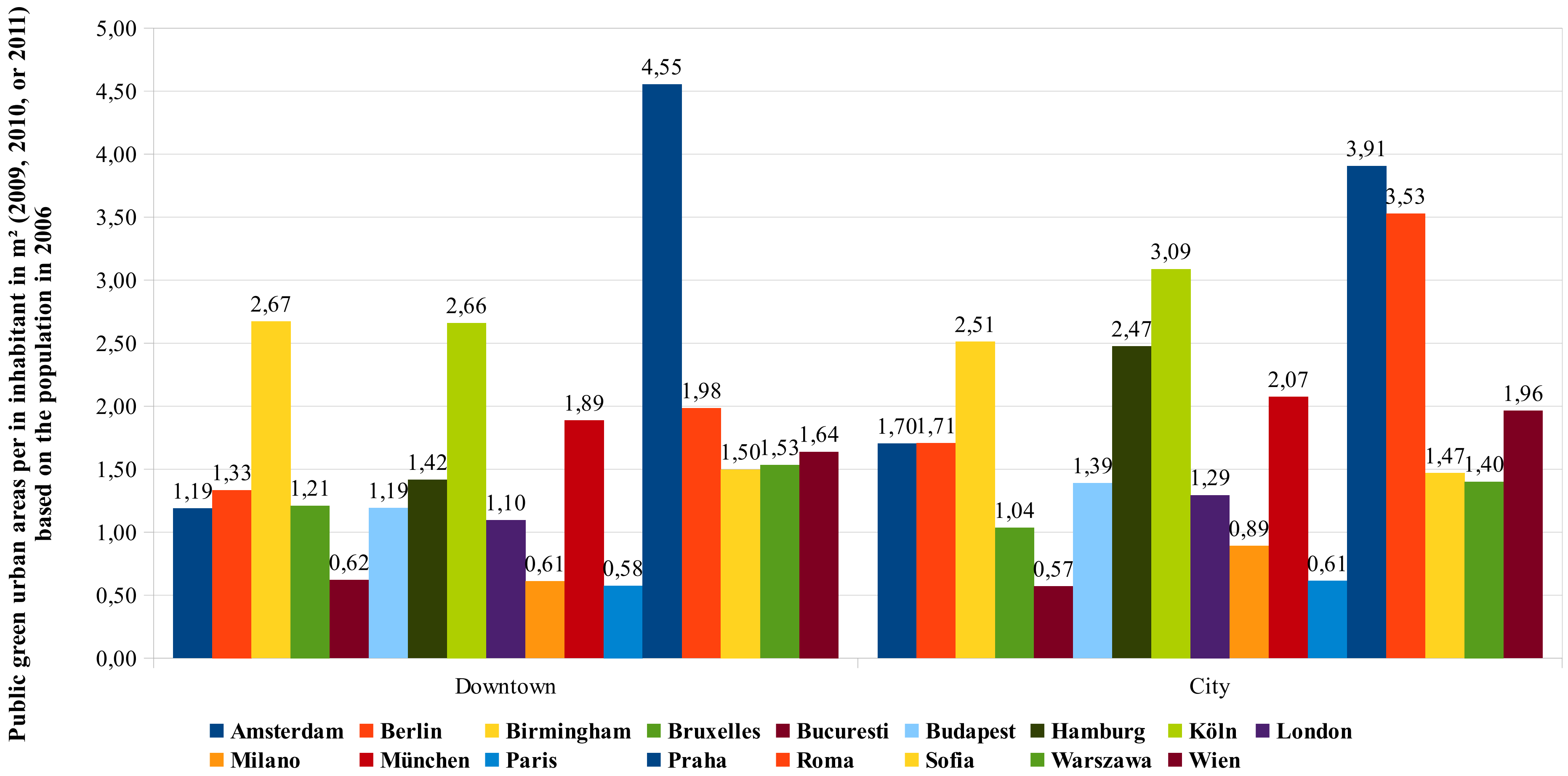


Fig. 90 - Public green urban areas per capita of European metropolises of more than 1 million inhabitants in 2006 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2006, 2011; © EuroGeographics for the administrative EU city boundaries).

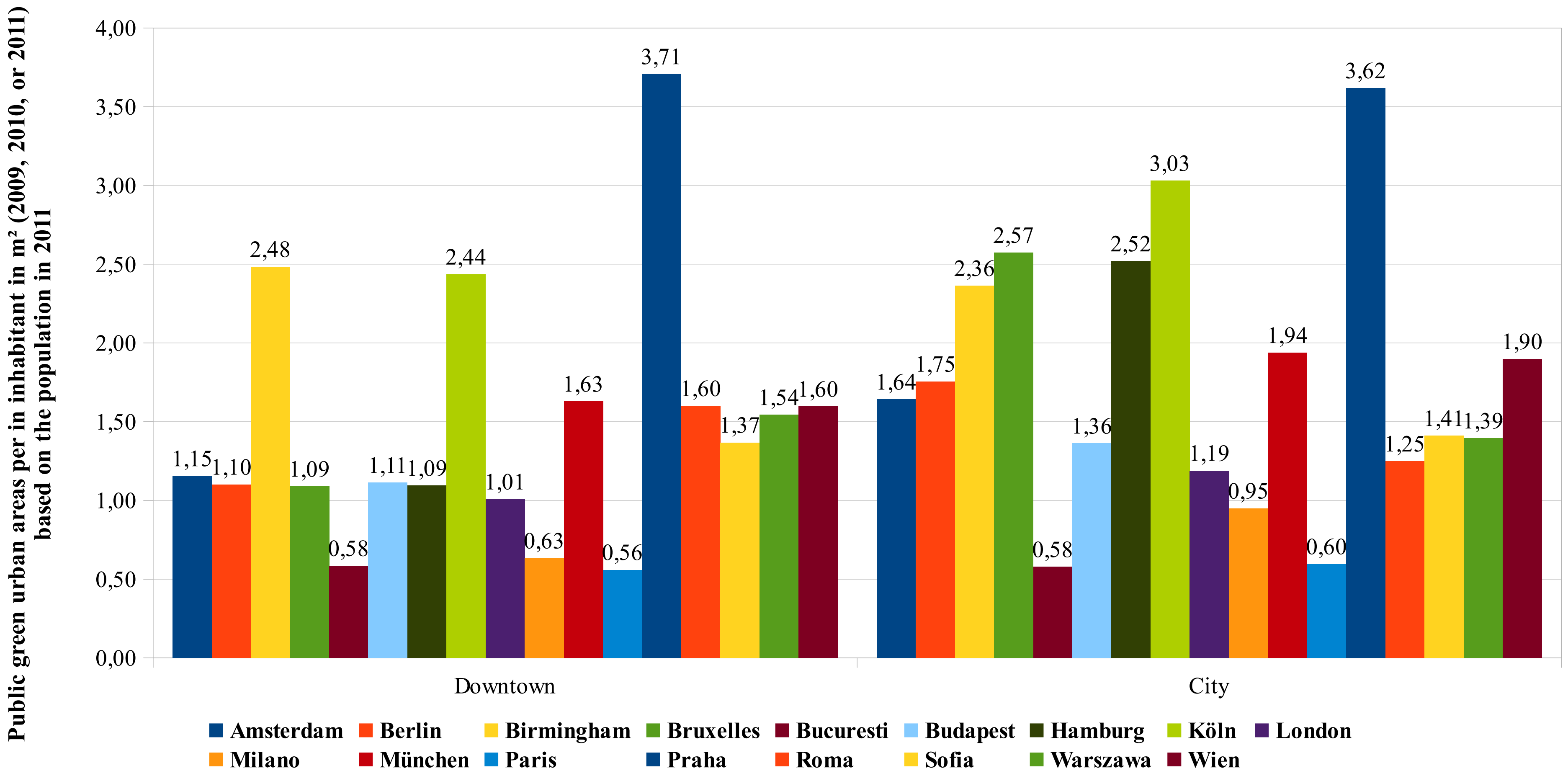


Fig. 91 - Public green urban areas per capita of European metropolises of more than 1 million inhabitants in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2006, 2011; © EuroGeographics for the administrative EU city boundaries).

2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin

With a population of estimated 3,574.8 million inhabitants in 2016 (Amt für Statistik Berlin-Brandenburg, 2017a) and about 1,139,011 people living in the inner city area of the study template in 2011 (Fig. 93). Berlin has a severe unaltered deficit of public accessible green space. Although Berlin's net population has not increased more than 128,800 (3.60%) from 3,446.0 million in 1991 to estimated 3,574.8 million in 2016 (Amt für Statistik Berlin-Brandenburg, 2017a) (Fig. 2). The results show that Berlin's inhabitants of the inner city area had with just 1.10 m²/person about 65.32% less public green urban areas available than within the whole metropolis of 1.75 m²/inhabitant in 2011 (Fig. 91). This was a decrease by 20.9% from 1.33 m²/capita in downtown Berlin in 2006 (Fig. 90). In comparison, other European metropolises had at average 1.45 m²/inhabitant public green urban areas (median: 1.15 m²/capita) available in the inner city area, and at average 1.77 m²/inhabitant (median: 1.64 m²/capita) of the city in total in 2011 (Fig. 91).

However, these compared results should be interpreted with care, because the spatial land use and population structure as well as the individual size and border line of each European metropolis are different. Moreover, the transition area to the countryside differs individually due to the historical development of each European metropolis. For instance, Berlin’s wall around Western Berlin prevented suburbanisation until the break through of the wall in 1989 (Reif, 2003) which is also reflected in the size and border line (borders) of the core city area of Berlin. Therefore, I did not analyse schematically the same inner fixed distance area from the outer border line or from a centroid for each (core) metropolis to gather the inner city (downtown) area, but a proportional individual total downtown area of 2/3 of the inner fixed distance area from the respective outer border line of each European metropolis (Chapter 2.6. Available public green urban areas in the inner city parts of other European metropolises on page 149).

The reason of the unaltered deficit of public green space particularly in the inner city area of Berlin can be mainly found in real estate speculation and profitable rent increases for houses since the break through to Berlin's separating wall in 1989 which opened also huge open space for replanning. The average net cold rent[8] increased in the meantime by 30.25% from EUR 4.00 to EUR 5.21 from October 1999 to October 2010 (Fig. 3), i.e. about 14 times as much as the net increase of inhabitants of the city of Berlin within the same period of time by 74,000 (2.19%) from 3,386.7 million inhabitants in 1999 to 3,460.7 million inhabitants in 2010 (Amt für Statistik Berlin-Brandenburg, 2017a) (Fig. 2). Families and lower income classes are driven out by increasing rents that cannot be compensated by their income anymore in Berlin and other cities in Germany (Kollenbroich et al., 2016; Lembke, 2016) as well as beyond during the process of gentrification (Smith, 2002).

Meanwhile, the standard land value of Berlin's estates increased in particular within the central

[8] Without running costs such as heating and electricity.

district “Mitte“ of Berlin from 2002-2018 (Fig. 7 and Fig. 8). At median, the standard land value rose in the central district “Mitte” with an emphasis on housing from 530€/m² to 2350€/m² (343.40%), for mixed (building) areas from 1300€/m² to 5000€/m² (284.62%), and for core (building) areas from 3400€/m² to 7000€/m² (105.88%) from 2002-2018 (Fig. 7). The dominant political arguments were rapid population growth and economic prosperity of the city of Berlin after the break through of the wall in 1989 for a “gold rush” expecting urban development of Berlin towards the 21th century in particular in the city centre (Strom, 1996).

By the year 2012, public property was already sold out to an amount of €2 billion and there were still about 5,000 real estates in the portfolio of the real estate fund of Berlin (Senate of Berlin, 2013a). Non-constructable open green space was converted into valuable real estates through master plans and other development plans over the existing planning schemes (Fig. 1; Section 2.3.1. Planning strategies after the breaking down of Berlin's wall by the public in 1989 on page 18) for constructions of a short term orientated monetary win-win situation for the investors and the state of Berlin. Brownfields were severely lost by about nine-tenths for new constructions within the inner city planning areas of the inner S-Bahn circle railway line of Berlin from 7.31% in 1990 (Fig. 15) to 0.77% in 2015 (Fig. 20). The increasing real estate prices have severe consequences for urban development as planning opportunities for communal use are limited by the available public budget such as the reduction of the deficits of accessible public green space (Section 2.4.1. Deficits of public green space on page 32). Also social and cultural private initiatives are affected to find affordable room, particularly in the inner city area in the process of gentrification (Holm, 2013; Balicka, 2013).

However, the long-term economic and other values of biodiversity were undervalued in Berlin's planning policy and strategy (Section 2.3. Historical development of the integration of the different values of green space into planning decisions on page 18). Berlin's government has several planning tools and strategies to integrate the different values of green space as part of biodiversity into planning decisions (Section 2.2. Major planning tools and strategies to integrate the different values of biodiversity on page 15) as mentioned in the preamble of the Convention on Biodiversity (CBD, 1992; Zisenis, 2006, 2009). To these belongs Berlin's Landscape and Species Protection Programme (Table 5) which was adopted by Berlin's parliament (Senate of Berlin, 1994a, 2016a). The preparatory work for the species protection programme of “West-Berlin” includes detailed protection, re-establishment and management recommendations for each biotope type of the different land use types of Berlin (Sukopp et al., 1984). It covers 100% of non-building and building grounds, but it needs to be still effectively applied in practice.

The reality of Berlin's urban planning and development is different from theory. Berlin's deficit of public green space per inhabitant has been well calculated in this study, also in relative comparison of public green urban areas of the inner city of Berlin to other European metropolises (Section 2.6. Available public green urban areas in the inner city parts of other European metropolises on page 149). Berlin's parliament subjectively determined to provide each citizen in walking distance with a minimum of 6 m² accessible public green space within a maximum distance of 500 m and a minimum size of 5,000 m² (0.5 ha) in the near neighbourhood (Senate of Berlin, 1994a, 2013b, 2016a) (Fig. 9, Fig. 10, Fig. 11, Fig. 12, Fig. 13, Table 5, Table 6, Table 7, Table 8).

Theoretically, these measurements are binding for the public administration as they were adopted by Berlin's parliament, as well as other measures of Berlin's Landscape and Species Protection Programme (Fig. 1). Further densification in particular of the inner city area and consequently persisting deficits of public green space per inhabitant should not be allowed. However, the need to protect and to restore green space does not refer exclusively to the highly concreted central districts “Mitte” and “Friedrichshain-Kreuzberg” (Fig. 21) where 63.5% and 69.9% respectively of the soils were sealed, but to the city of Berlin in total of already 36.1 % concreted soils (excluding waterbodies) in 2016 (Fig. 24; Senate of Berlin, 2017a). Similar deficits of public green urban areas were revealed in this study for inner city areas of other European metropolises of more than 1 million inhabitants in comparison to the total city area of the recent population estimations in 2011 (Fig. 89, Fig. 91). In the long term, house prices for the whole neighbourhood are expected to be affected due to the loss of adjacent public green areas as many studies have shown the influence of green areas on the monetary value of real estates for housing (Gomez-Baggethun et al., 2013; Kolbe and Wüstemann, 2015).

Although the Senate of Berlin had to admit that its original prognosis failed of a net increase of 300,000 new inhabitants from 1994 to 3.7 million inhabitants by 2010 (Senate of Berlin, 2015a, 1994b) with all the consequences for the concluded necessary building pressure on existing green space for new estates of housing and commerce in particular in the inner city areas. The Senate of Berlin continued with the assumption of a population increase to 3.951 million inhabitants of Berlin at the most by 2030 mainly due to an assumed increasing number of refugees (Senate of Berlin, 2016i). In 2017, the Senate of Berlin assumed from a calculated baseline of 3,655 million inhabitants on 31 December 2016 an increase of about 181,000 new net inhabitants in total by 2030, including around 24,000 additional refugees by 2020 (Senate of Berlin, 2017e).

This obviously politically motivated justification for a further densification and loss of green space in Berlin was already outdated again in 2016 as the EU Member States fenced off the war refugees and introduced harsh border controls for those who were seeking humanitarian help in the European Union (Faigle et al., 2016). In fact, the immigration of refugees was reduced drastically since November 2015 from a solely peak of 79,304 in Berlin in the year 2015 in total (1,091,894 in total in Germany in 2015) to 13,330 refugees in Berlin by 10 May 2016 (134,393 in total in Germany by 10 May 2015) (Press and Information Office of the State of Berlin, 2016). The number of new refugees halved from 16,889 in 2016 (321,370 in whole Germany in 2016) to 8,285 in 2017 (164,013 in total in Germany in 2017), and decreased further to 2,568 from 1 January to 30 April 2018 (50,741 in Germany from 1 Januar to 30 April 2018) (State Agency for Refugee Matters of Berlin, 2018). Not surprising, the Senate of Berlin had to correct already his projection in 2017 to an increase of about 3.85 million inhabitants of Berlin by 2030 (Zawatka-Gerlach, 2017).

Berlin's Landscape and Species Protection Programme mainly focuses on use values, in particular as basis for urban life (natural balance and environmental protection), open green space and areas for sensory (landscape scenery), and recreational purposes (recreation and use of open space), as well as on flora & vegetation and to a limited extent on fauna and biogeographical features (target species, biotope types[9]) for ethical reasons (habitat and species protection) (Section 2.2.1 Berlin's Landscape and Species Protection Programme on page 16). Compensation for building on green space and other deteriorating impacts on nature and landscapes is mainly foreseen by upgrading existing green space and green corridors instead of compensating the quantitative loss of them and the different qualitative values of biodiversity related to them (Senate of Berlin, 2016a, 1994a) (Table 1). Compensation for the loss of green space is not secured nearby the impacted elements of urban biodiversity neither quantitatively nor qualitatively, in particular regarding the highly concreted inner city areas (Fig. 21, Fig. 24) of high building pressure in Berlin (Section 2.4.2. Development of green space over time after the breaking down of the wall in 1989 on page 41). Compensation measures can take place far away in the suburbs or even beyond according to Berlin's Nature Conservation Act (NatSchGBln, 2013) or not carried out at all according to Germany's building act (BauGB, 2017). An exception is the theoretical legal requirement of minimization measures, and compensation within the spatial proximity according to the higher overriding law to secure the theoretically long-term survival of species and habitat types of Community interest, among others, as "...contribution to the general objective of sustainable development;..." of the EU Habitats Directive (European Commission, 1992), as well as for birds of the EU Birds Directive for "...the improvement of living conditions and sustainable development." (European Commission, 2009).

Use values are also predominant in Berlin's Land Use Plan (Senate of Berlin, 2015a) (Table 2; (Section 2.2. Major planning tools and strategies to integrate the different values of biodiversity on page 15). In addition, the sectoral plan on green and open space of the central district of Berlin "Mitte" is limited to simply land use designations of green and open space with theoretical lines of green corridors between them (BA Mitte, 2008).

However, the quality of working and living in Berlin depends furthermore on overlapping social and other environmental factors such as mobility, income to reach public green space by public or private transport, population density and thereby the way and intensity of use by neighbours and other visitors. In addition, overlapping factors are air pollution, microclimate, and noise as well as the practical accessibility in the first place and use restrictions of public green spaces. Private and semi-public open and green space contribute as well to the different values of biodiversity in urban areas. However, their accessibility is practically restricted to those inhabitants who can afford to live in less densely built-up building grounds (Table 7, Table 8, Fig. 9, Fig. 21, Fig. 24) of better environmental protection conditions (Fig. 26, Fig. 27). These socio-economic, demographic, and further environmental factors have not yet been taken into account in Berlin's planning strategy for green urban areas. The different values of urban green space as part of biodiversity are just partly considered in Berlin's Environmental Atlas (Senate of Berlin, 2017a) (Section 2.5.4.3. Ecosystem services of Berlin's urban green space based on Berlin's Environmental Atlas on page 144).

There is a long-term orientated concept missing in Berlin's urban development which provides practical acting incentives for the conflicting needs of stakeholders while considering and integrating the different values of biodiversity. The public directly and indirectly concerned needs to

[9]"Biotope" types contain of a biocoenosis (Schulte et al., 1993, 2003). This German term "biotope" corresponds to the common use of the term "habitat" in English. Whereas a "habitat" describes the ecological niche of a single species in German.

participate in decision-making of urban development planning and projects to focus bottom-up the decisive planning power on the ground and to take into account the people's knowledge and support for the sustainable urban development of Berlin. “Wir sind das Volk!” (We are the people!) was the slogan on the streets of hundreds of thousands of protesters in Eastern German cities to abolish dictatorship in the former “German Democratic Republic” in 1989 (Schüddekopf, 1990).

Furthermore, a clear set of indicators is missing which covers the different values of biodiversity in urban areas, depending on available data, (Section 2.3.2. Overview of applied values and criteria of Berlin’s major green space planning tools and strategies to assess green space on page 21) and which allows deeper comparison with other European metropolises than just the accessible public green urban areas in m² per inhabitant. Current landscape planning approaches of Berlin do not fulfil the scientific criteria of transparency, reliability and validity. The evaluation levels are mixed vertically between values, criteria related to them and the measurement methods of social and natural sciences to assess them accordingly (Chapter 2.2. Major planning tools and strategies to integrate the different values of biodiversity on page 15). The four parts of Berlin's Landscape and Species Protection Programme “natural balance and environmental protection”, “habitat and species protection”, “landscape scenery”, and “recreation and use of open space” (Table 1) reflect mixed underlying values of biodiversity on horizontal level such as ethical or psychological values in a descriptive manner (Section 2.2.1 Berlin's Landscape and Species Protection Programme on page 16). However, Berlin's Landscape and Species Protection Programme does not provide sufficient indicators nor a concrete analysis of the actual needs of Berlin's inhabitants and urban biodiversity on its own (Section 2.4.5. Participation tools with an influence on planning decisions on page 56).

This is a strong weakness of scientific foundation for the integration of the different values of green space into urban development of Berlin, but also in other European metropolises (Niemelä, 2014) as the deficits of public green urban areas indicate after decades of urban densification in particular in inner city areas (Fig. 89, Fig. 90). The historical development of Berlin has shown that the long-term values of urban biodiversity have lost in competition with lobbying interests of short-time money after the break-through of the isolating wall in 1989 (Section 2.3.1. Planning strategies after the breaking down of Berlin's wall by the public in 1989 on page 18). There has been an undervaluation of urban green space as part of biodiversity and a lack of a comparable set of indicators of the different values of urban green space, as well as an urgent need of representative monitoring data accordingly (Section 2.5.4.3. Ecosystem services of Berlin’s urban green space based on Berlin’s Environmental Atlas on page 144).

Therefore, this study does not stop at this analytical stage of deficits in “The consideration of the different values of public green spacen urban development of Berlin after 1989” as the title suggests. It goes further in discussing the leading governmental set of indicators for evaluations of urban biodiversity on international level: the City Biodiversity Index (CBI) of the Convention on Biological Diversity (CBD). Furthermore, it results in an own suggestion of a first practical set of 10 structural, functional, and material indicators for evaluations of urban biodiversity for the integration into planning tools and strategies of the urban development of Berlin and other European metropolises.

3. The international context of measuring urban biodiversity through a City Biodiversity Index (CBI)

3.1. Biodiversity background of the Convention on Biological Diversity (CBD) of urban ecosystems

The Convention on Biological Diversity (CBD) emphasizes in Article 2 the different levels of biodiversity, in particular the "… diversity within species, between species and of ecosystems." including the genetic level as biological resource (CBD, 1992). Apart from the species composition as expression of the biodiversity between species, there is another (meta-)population level of the biodiversity of species implied (Noss, 1990). Furthermore, biodiversity does not stop at ecosystem level as scientific investigation unit. It can be distinguished in the diversity of landscapes and their mosaics which can be found in biomes on larger scale in forming the whole biosphere on earth (Angermeier and Karr, 1994).

Thus, biodiversity cannot be simplified to the diversity of species and their habitats in forming ecosystems which can be targeted by species and habitat protection schemes such as the EU's Habitats Directive (European Commission, 1992) in the traditional manner of managing protected areas. Instead, there is an integrated ecosystem approach of the whole landscape necessary (Zisenis, 2017). Discussions on the misuse of the term "biodiversity" in focusing on species conservation, instead of the relation between biodiversity and ecosystem function (Walker, 1992), came already up during the time of preparation of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992.

In urban ecosystems, the complexity of a mosaic of different land use patterns is even higher than at the countryside due to the varying high human influence on spatial scale (Sukopp and Werner, 1983; Sukopp and Starfinger, 1999; Sukopp and Wittig, 1998; Sukopp, 1990; Kelcey and Müller, 2011). This has consequences also for the biodiversity relations of urban nature itself (Müller et al., 2013) and the various interactions related to citizens. Therefore, biotope mapping of whole biocoenosis is a useful tool for urban landscape planning as first step to indicate biodiversity in urban areas (Schulte et al., 1993, 2006; Gao et al., 2010), which includes the human induced land-use patterns (Löfvenhaft et al., 2002).

Urban biodiversity action has recently become the subject of greater attention at global level within the Convention on Biological Diversity (CBD). As part of the UN International Year of Biodiversity 2010, more than 240 mayors, governors and high level government executives recognized the role of biodiversity in cities in the Aichi/Nagoya Declaration on Local Authorities and Biodiversity. They emphasized the need to value and to manage biodiversity in cities to be integrated in all aspects of local governance, including planning, finance, and infrastructure development (CBD, 2010a). A "Plan of Action on Subnational Governments, Cities and Other Local Authorities for Biodiversity" was endorsed under the Convention on Biological Diversity during their Conference of the Parties (COP) 10 for the period of 2011-2020 in Nagoya, Japan, in 2010

(CBD, 2010b). Within the Global Partnership on Cities and Biodiversity, a consultation process between Parties, cities and local authorities as well as other organizations took place in order to implement the CBD, among others, "…to manage biodiversity sustainably, provide ecosystem services to citizens and incorporate biodiversity concerns into urban planning and development" (CBD, 2010b). The Conference of the Parties of the CBD adopted the decision II/9 during its twelth meeting in Pyeongchang in 2014 (COP 12): "3. Calls on Parties to incorporate biodiversity considerations into their urban, peri-urban, land-use and infrastructure planning, such as "green infrastructure", among others, as appropriate, and to strengthen capacities of subnational and local governments to incorporate biodiversity into urban and other spatial planning processes;" (CBD, 2014). The CBD COP 11 in Hyderabad, India, in 2012 had encouraged: 1) the Biodiversity Indicators Partnership to develop indicators (e.g. based on the City Biodiversity Index), and 2) the Parties to monitor and to report on the contribution to reaching the Aichi Biodiversity Targets of the CBD (CBD, 2012b).

In the following chapter, I analysed the indicators of the City Biodiversity Index (CBI) as one major outcome of this process each by each for their reliability and validity.

3.2. Analysis results of the City Biodiversity Index (CBI)

From the 1970s onwards, there has been a range of initiatives to define urban indicators on global and European level which include environmental and biodiversity elements (Kohsaka, 2010; Mori and Christodoulou, 2012; Ahern et al., 2014; Alam et al., 2016; Maes et al., 2016a, 2018; Xing et al., 2017). An international expert group, supported by the CBD, developed the City Biodiversity Index (CBI) in three workshops in 2009, 2010, and 2011 as a leading global initiative (CBD, 2013; Kohsaka et al., 2013; Chan et al., 2014). The CBI shall "...enable cities to monitor and evaluate their urban biodiversity conservation efforts.". It "...serves as a self-assessment tool for cities to benchmark and monitor the progress of their biodiversity conservation efforts against their own individual baselines." (Chan et al., 2014). By 2016, the CBI was applied by 25 cities around the globe (Yap, 2016).

The CBI is structured in three main sectors: native biodiversity, ecosystem services, and governance and management (Table 15).

Table 15 - Indicators of the City Biodiversity Index (CBI) (adapted from Chan et al., 2014).

	Urban biodiversity values indicator	Measurement
Native biodiversity	1. Proportion of natural areas in cities	Percentage in relation to the total area of the city
	2. Connectivity measures or ecological networks of natural areas to counter fragmentation	Proportion of the sum of connected natural areas of a minimum distance of 100 m divided by the total area
	3. Native biodiversity in built-up areas (bird species)	Number of native bird species
	4.-8. Change in number of native species	Total number of 4. Vascular plants, 5. Birds, and 6. Butterflies
	9. Proportion of protected natural areas	Percentage with regard to the total area of the city
	10. Proportion of Invasive Alien Species	Percentage of the number of Invasive

	(as opposed to native species)	Alien Species versus the number of native species
Ecosystem services	11. Regulation of quantity of water	Proportion of the total permeable area versus the total terrestrial area of the city
	12. Climate regulation: carbon storage and cooling effect of vegetation	Percentage of the tree canopy cover of the total terrestrial area of the city
	13.-14. Recreational and educational services	13. Area of parks with natural areas and protected or secured natural areas (or accessible green spaces) per 1000 persons
		14. Number of formal educational visits per child under 16 years to parks with natural areas or protected or secured natural areas per year
Governance and management	15. Budget allocated to biodiversity	Proportion of the budget spent on biodiversity related administration to the total budget of the city
	16. Number of biodiversity projects implemented by the city annually	Total number of biodiversity programmes and projects per year
	17. Policy, rules and regulations – existence of Local Biodiversity Strategy and Action Plan	The status of the Local Biodiversity Strategy and Action Plan (or equivalent); number of associated CBD initiatives
	18.-19. Institutional capacity	18. Number of essential biodiversity-related institutions used by the city
		19. Number of city or local government agencies involved in inter-agency biodiversity cooperation
	20.-21. Participation and partnership	20. Existence and state of formal or informal public consultation on biodiversity-related matters
		21. Number of stakeholder organization partners in biodiversity activities, projects and programmes
	22.-23. Education and awareness	22. Inclusion of biodiversity or nature awareness in the school curriculum
		23. Number of outreach or public awareness events held in the city per year

For instance, the CBI was applied in Japanese cities (Uchiyama et al., 2015). Nevertheless, the CBI or as synonym "Singapore Index" is not supposed to be used to compare urban biodiversity and its management performance among different cities due to the different context of individual urban development (Chan et al., 2014). Furthermore, policy measures regarding urban biodiversity in cities shall be progressively updated from an original baseline which is individually set by each city (Chan et al., 2014).

3.2.1. Native biodiversity

Naturalness, instead of hemeroby, is a surprising criterion for selecting CBI indicators of urban ecosystems, because the human influence has modelled almost entirely urban areas by human constructions. Some relics of historically natural habitats of the wider countryside can be found in urban ecosystems such as bogs with the associated typical and natural fauna and flora. Nevertheless, nearly all habitat types in urban areas depend on the degree of human influence (hemeroby) (Sukopp and Werner, 1983; Sukopp et al., 1984; Sukopp and Starfinger, 1999; Sukopp and Wittig, 1998; Sukopp, 1990; Hill et al., 2002; Kelcey and Müller, 2011).

Native as non-native species have found as cultural followers ecological niches in urban areas which are similar to their origin such as the environmental conditions of generally higher temperatures in the concreted urban environment (Sukopp and Werner, 1983; Wittig, 2004; Williams et al., 2015; Zisenis, 2015a; Sukopp and Wurzel, 2003; Wittig, 2004). In urban areas, specific species compositions have developed which are adapted to the mosaic of urban habitats (Sukopp et al., 1984; Sukopp, 1990, 2011; Sukopp and Wittig, 1998; Rebele, 1994; Kelcey and Müller, 2011). They cannot be found in the surrounding wider countryside. Between 20-60% (40% at average) of the urban flora in 54 Central European cities consists of non-native species (Pyšek, 1998). Another study of 32 Central European cities shows that 49% of the 1180 plant taxa of the flora are non-native (Lososová et al., 2012). At global level, Aronson et al. (2014) modelled that at median most plant species are native to cities as well as widely bird species. The density of native and non-native plants correlates with intactness of vegetation and city age whereas bird density is negatively correlated to land cover in cities worldwide (Aronson et al., 2014).

Furthermore, even the same species at different places in the city has more or less isolated populations depending on the mobility of the taxon, because of the construction of buildings, roads, intensive open space management and other migration barriers. This supports the evolution of different isolated genotypes (Shochat et al., 2006). A particular ruderal flora and vegetation has developed spontaneously in urban habitats, created by man, such as railways, abandoned industrial areas and temporarily open grounds (Sukopp and Werner, 1983; Wittig, 1991). The evolved particular urban species and habitat types have become part of the urban biodiversity heritage (Müller and Werner, 2010) such as the Blackbird (*Turdus merula*) (Klausnitzer, 1993). Non-native as well as native species provide important ecosystem services such as fresh air, deposition of chemicals, reduction of noise, mitigation of climate change and global warming, inspiration and beauty. They enhance the quality of life of humans living and working in cities.

Thus, non-native species generally do not have lower values of biodiversity than native species (Zisenis, 2012). They have become typical and natural components in free or overlapping ecological niches with native species of urban biodiversity (Zisenis, 2015a). Consequently, endangered non-native species have entered also Red Lists of cities together with native species when they are successfully established and independently reproducing viable populations (Kowarik, 1991). As most habitats in urban areas are anyhow unnatural from the historical point of view due to the human influence as outlined above, it does not make sense to develop an indicator of the different values of urban biodiversity which is entirely focused on (originally) native biodiversity.

This refers to CBI indicators “1. Proportion of natural areas in cities”, “3. Native biodiversity in built-up areas (bird species)”, "4.-8. Change in number of native species - Total number of 4. Vascular plants, 5. Birds, and 6. Butterflies", "9. Proportion of protected natural areas", as well as "10. Proportion of Invasive Alien Species (as opposed to native species)" (Table 15).

Furthermore, CBI indicators 4.-8. show the tendency to focus on plants for biodiversity evaluations which cannot run away, as well as on pretty and relatively easily detectable birds and butterflies. However, these taxa form just a little part of ecosystems also in urban areas (Erz and Klausnitzer, 1998). For instance, springtails (Collemboles) occupy as microarthropods a wide range of ecological niches in soils and they are important indicators of vital ecological processes in soils (Fiera, 2008). Springtail biodiversity can be for example also used as pollution indicators of heavy metals in urban soils (Fiera, 2009).

The CBI indicator "2. Connectivity measures or ecological networks to counter fragmentation" (Table 15) is also referring to natural urban areas, but does neither take into account the permeability of the urban landscape nor the individual mobility of species taxa. The threshold of 100 m distance for connecting natural urban areas (Table 15) is arbitrary. Already roads can hinder invertebrates such as carabid beetles or lycosid spiders to cross over (Mader et al., 1990).

3.2.2. Ecosystem services

The concept of ecosystem services is widely used nowadays (Fisher et al., 2009; Schröter et al., 2016) and also recommended by certain authors for urban areas (Bastian et al., 2012; Mader et al., 2011; Rall et al., 2015; Kabisch, 2015; Hansen et al., 2015; Kain et al., 2016). However, it has been as well criticized for many years as being too anthropocentrically focused on direct and indirect use values (Gómez-Baggethun et al., 2010; Niemelä et al., 2010; Spangenberg and Settele, 2010). For instance, many local governments were interested in a quantitative and economic evaluation of urban ecosystem services according to a study on the application of the CBI in Nagoya though or because the importance of biodiversity was not well known (Kohsaka and Okumura, 2014). There is a reasonable fear that the non-monetary, non-use values are undervalued, in particular when ecosystem services are monetised such as aesthetic (psychological) values or the bequest values of biodiversity for future generations. Moreover, it is unclear what is new of the concept of ecosystem services to landscape planning as sustainable land-use planning (Niemelä et al., 2010).

There is a conceptional deficit of ecosystem services to the comprehensive evaluation of biodiversity which misses that biodiversity and “...the ecological complexes they are part of...” have an “intrinsic” (ethical) value on their own (CBD, 1992). This includes also the material and energy flows and the variability of changing structures which create ecological niches of life, as well as the corresponding species exchange and evolutionary development in space and time. Focusing on the material (biophysical) values of ecosystem services of biodiversity (Gómez-Baggethun and Barton, 2013) can serve as countable tool in a short-time purely market oriented system of urban development which undervalues other non-use, non-monetary values (Spangenberg and Settele, 2010).

Moreover, in the end nobody can foresee which parts and interactions of the different levels of biodiversity can be of use to humans in the near or long-term future. Therefore, even the Total Economic Value tries to cover non-use values of biodiversity as bequest and existence values (Pearce and Moran, 1994). From the practical point of view, it makes no difference in the long-term, if we preserve urban biodiversity for citizens or for the value on its own. Nobody can also foresee the interactions under changing environmental and human societal conditions of related values in a permanently changing urban society. For instance, there are the needs for climate change mitigation to heat waves (Wanka et al., 2014; Gómez-Baggethun et al., 2013; Arnberger, et al., 2017), or requirements to adapt the available public green space quantitatively and qualitatively in the near neighbourhood to the changing age structure of growing less mobile elderly people in the 28 Member States of the European Union (Eurostat, 2016b) as shown also in the case study example Berlin (Section 2.5.4.2. Social and economic data of inhabitants on page 140). Also the various impacts of growing and declining cities need to be considered in urban and landscape planning (Haase et al., 2013).

Furthermore, the purely description of provisioning and regulating ecosystem services, without common criteria to assess them according to the different values of biodiversity of the CBD (Zisenis, 2006, 2009), is a scientific conceptual deficit of transparency which turns into an urban planning one when it stays unclear who benefits to which extent from them. As a consequence, the different ecosystem services can hardly be weighed up against each other (Elmqvist et al., 2013) which was also a problem of Environmental Impact Studies in Germany in the 1990s with an emphasis on descriptions of occurring habitat types, species and abiotic conditions without comprehensively and transparently analysing the particular values related to them (Zisenis, 2008). Experience with the application of the CBI shows that there were resulting bundles of ecosystem services without concluding synergies and trade-offs for urban planning (Kohsaka et al., 2013). This is also a main problem of Berlin's major urban planning tools and strategies (Chapter 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin page on 153) and the spatial database Berlin's Environmental Atlas (Section 2.5.4.3. Ecosystem services of Berlin's urban green space based on Berlin's Environmental Atlas on page 144).

Cultural services shall reflect all other human related values together, but it stays unclear if they are based on social, psychological (including physical and mental health, and aesthetic beauty), educational, culture-historical, economic, ethical, or scientific values of biodiversity in urban and rural areas. There are common criteria missing for evaluations of biodiversity in urban and rural areas in the ecosystem services concept, as well as corresponding indicators which allow quantitative and qualitative evaluations of biodiversity in participatory ecosystem assessments (Zisenis et al., 2013; Langemeyer et al., 2016). In particular, non-use, non-monetary values of biodiversity cannot be assessed without asking and involving the people directly and indirectly concerned in decision-making such as for the beauty and the personal and societal needs of biodiversity that are affected by urban development decisions (Zisenis, 2006, 2009; Sagoff, 1997).

Furthermore, the concept of ecosystem services describes mainly basic sectoral functions (Gómez-Baggethun and Barton, 2013; Schröter et al., 2016; Gómez-Baggethun and Muradian,

2015) which are based on so called sustaining ecosystem services. This makes the ecosystem services concept vulnerable to manipulations of picking out arbitrarily certain ecological processes and intransparent cultural ecosystem services which ecologically depend on each other in reality. The selection of investigated ecosystem services and indicators chosen for them is often determined by the data available and policy objectives (Haase et al., 2014; Spangenberg and Settele, 2010; Chapter 2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin on page 57). The complex interrelations within and between ecosystems do not necessarily need to be considered anymore in urban development when it is enough to schematically describe biophysical components and general cultural services of them as done in Berlin's Landscape and Species Protection Programme (Senate of Berlin, 2016a, 1994a) and other major planning tools and strategies of Berlin (Chapter 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin on page 153).

As purely use values, they can be also artificially provided and substituted, for example green urban areas through television for psychological relaxation, or their production of clear drinking water through sewage plants. A particular species is not necessary anymore when its use can be provided also by another one. Personal relations to humans and their particular needs are not sufficiently taken into account in decision-making with an impact on biodiversity. Accounting of particular ecosystem services allows monetisation of biodiversity. It is no wonder that general sectoral ecosystem services cannot compete with construction and development interests which provide immediate tax revenue and create jobs, in particular in the inner city areas of European metropolises. The countable short-term profit expectations are stronger in a mainly market-driven society. This is reflected in Berlin' s urban development as a study example for other European metropolises of high deficits of green urban areas in inner city areas in comparison to the supply in more suburban districts (Chapter 2. The case study Berlin on page 13).

Also at EU level, ecosystems are schematically classified and mapped according to biophysical indicators (Maes et al., 2015, 2016a, 2016b, 2018; Burkhard and Maes, 2017) without taking into account the particularities in time and space, as well as the subjective value relations to the people concerned and the values of the different levels and interactions of biodiversity on its own (Zisenis et al., 2013; Zisenis, 2009). Nor ecosystems are considered as dynamic interactive discontinuously developing systems (Fisher et al., 2009; Zisenis, 2006; Rebele, 1994) in an open landscape. This refers also to the schematically overlaying of different subjectively selected ecosystem services with socio-economic indicators for social-ecological cluster analysis and mapping (McPhearson et al., 2013) or to studies of land use classes and their selected and generalized numerical ecosystem services in cities (Larondelle and Haase, 2013).

From the idea of raising public interest for biodiversity conservation through the concept of providing ecosystem services (CBD, 2012c; Breuste et al., 2013), it has more developed to an instrument to cash ecosystem services of biodiversity as commodities (Peterson et al., 2010; Gómez-Baggethun et al., 2010; Gómez-Baggethun and Ruiz-Pérez, 2011; Kosoy and Corbera, 2010; Neuteleers and Engelen, 2015; Spangenberg and Settele, 2010; Arias-Arévalo et al., 2018; Diaz et al., 2018). This can become counterproductive to biodiversity assessment based political decisions (Gómez-Baggethun et al., 2010) and supplant intrinsic values (Neuteleers and Engelen, 2015). It refers in particular to those ecosystem services which do not have a market value, but are inherent to biodiversity (Peterson et al., 2010; Neuteleers and Engelen, 2015; Spangenberg and Settele, 2010). For the EU European Ecosystem Assessment, (inherent) supporting ecosystem services are widely excluded (Maes et al., 2015, 2016a, 2016b, 2018; Burkhard and Maes, 2017).

Biodiversity becomes an exchangeable number like for building and other investment projects. Urban biodiversity is calculated as nothing more than a simplified cost factor of greenery of urban space without reflecting the quality of urban biodiversity and subjective values and relations to the public. Instead of participatory evaluation and decision-making processes of the different values of public green space in urban development of Berlin after 1989, there have been widely just simple hearings of the public (Section 2.4.5. Participation tools with an influence on planning decisions on page 56).

Such an example is the so called "Biotope Area Ratio (BAR)". It is practically a figure per m² of permeable open soil cover instead of an integrated biodiversity evaluation of urban biotopes[10] as the name suggests. The BAR can be easily mapped instead of a more complex biodiversity assessment which would involve the people and urban nature concerned. It substituted integrated landscape planning in biodiversity policy implementation in central parts of Berlin (Lakes and Kim, 2012). Those inner city districts of Berlin are affected which have already a large deficit of public accessible green space and low share of private or semi-public open space as well as a corresponding high degree of soil sealing (Section 2.4.1. Deficits of public green space on page 32). Obviously, the political intention has been to cash biodiversity particularly in the inner city of Berlin since the break through of the wall in 1989 which is supported by the simple BAR as an example. Instead of implementing consequently Berlin’s Landscape and Species Protection Programme through landscape and urban planning with detailed measures for the living and working quality of Berlin’s inhabitants and urban biodiversity on its own (Chapter 2.3. Historical development of the integration of the different values of green space into planning decisions on page 18).

Clearing habitats of urban wilderness (“brownfields”) has been strongly intensified after the wall was broken down between Eastern and Western Berlin to commercialise real estates and consequently the destruction of urban biodiversity through new speculative constructions and refurbishments (Section 2.4.2. Development of green space over time after the breaking down of the wall in 1989). This was carried out instead of making biodiversity an integral part of urban development as foreseen by Berlin's Landscape and Species Protection Programme, despite of its adoption by the regional parliament of Berlin as (theoretically) binding decision for Berlin’s administration (Senate of Berlin, 2016a, 1994a; Chapter 2.7. Discussion of the consideration of the different values of green space in major planning tools and strategies in Berlin).

CBI indicator "11. Regulation of quantity of water" covers this aspect of simplifying it to the ratio of permeable soil to the total terrestrial area of the city as sectoral ecosystem service (Table 15). CBI indicator "12. Climate regulation: carbon storage and cooling effect of vegetation" adds to

[10] Biotopes as habitats of a biocoenosis (Schulte et al., 1993, 2003).

it in being limited to tree canopy cover for microclimatic benefits in temperature and carbon storage (Table 15). However, vegetation in urban areas in general provides much more biophysical contributions to human health and well-being than in functioning as temperature buffer (Susca et al., 2011; Jennings et al., 2012; Gómez-Baggethun et al., 2013; Schubert and Grossmann-Clarke, 2013) or storing carbon (Davies et al., 2011), for example in cleaning air from pollutants (Nowak et al., 2006; Gómez-Baggethun et al., 2013), removing ozone (Manes et al., 2012), reducing noise (Gómez-Baggethun et al., 2013), lowering wind speed, enriching the air with moisture and oxygen, and limiting water runoff (Bolund and Hunhammer, 1999; Gómez-Baggethun et al., 2013). These positive microclimatic effects of urban vegetation are not limited to trees, but refer also to the opportunities of wall and roof greening (Oberndorfer et al., 2007) as well as to open currently sealed urban space for vegetation and horticulture (Mok et al., 2014).

CBI indicator "13.-14. Recreational and educational services" refers to 13. natural areas within parks per 1000 persons or more precisely the accessible green space (Table 15) which is a common general indicator in short or longer distance to inhabitants of cities (Singh et al., 2010). However, the values of green space in urban areas are multifunctional and not limited to recreational or educational purposes (Handley et al., 2003). They include social and psychological (aesthetic and recreational) values for citizens apart from others (Tzoulas et al., 2007; Lee and Maheswaran, 2011; Gómez-Baggethun et al., 2013). Green urban areas contribute as ecosystems to perceived mental health (van den Berg et al., 2015, 2016; Grahn and Stigsdotter, 2010; Gruebner et al., 2017) and social interactions (Völker and Kistemann, 2015; Jennings et al., 2016) within a complexity of biodiversity related values (Madureira et al., 2015). Opportunities and needs of education of urban biodiversity are not limited to "formal educational visits" of children under an age of 16 (Table 15), but they are a life-long opportunity and challenge of human curiosity of the complex structures, functions and components of urban ecosystem (Dearborn and Kark, 2010).

Furthermore, the ecosystem services approach is often a description of partly overlapping ecological processes, also applied to urban areas (Baró et al., 2015; Ahern et al., 2014), instead of a participatory weighing up of different transparent and comprehensive values of (urban) biodiversity according to the preamble of the CBD (Zisenis, 2006, 2009; Zisenis et al., 2013). For instance, ground water recharge is classified as provisioning ecosystem service as an economic value for irrigation, as well as psychological (health) regulating (filtering) ecosystem service of clean drinking water. However, it can be equally classified as sustaining ecosystem service, because otherwise the ground water dependent waters and vegetation might suffer and the associated flora & fauna in urban areas as ethical value with them. Moreover, healthy clean drinking water or water for irrigation can be also provided through technical purification plants at certain costs as purely monetary (economic use) value or it can be transported from long distances such as the mountains as purely monetary factor in the calculation. There is no need to keep the self-filtration ecosystem functions of green space when the water is drained into the canal system and evaluated as pure commodity through the sectoral accounting concept of ecosystem services. Other non-monetary, non-use values are systemically undervalued.

This makes the ecosystem services concept intransparent which particular value is preferred by whom (Jax et al., 2013) depending on which evaluation criteria and which reliable and validate measurement methods are used in the particular case. Ecosystems are artificially cut into pieces of certain ecological functions, so called ecosystem services. Systemically, the different partly overlapping ecosystem services become disconnected from the conditions and development of biodiversity as basis for them (Kremer et al., 2016; Langemeyer et al., 2016). A more coherent approach would be to select resource efficiency indicators of the urban footprint (Eisenmenger et al., 2016) for Environmental Impact Assessments instead of describing selected ecosystem services. This refers also to the turned around concept of "disservice" (Gómez-Baggethun et al., 2013) of e.g. "plants can block views" by the "number and size of trees near buildings", or "the amount of water used for plant growth" can cause "decrease in water quantity/quality" or "urban green and blue spaces can obstruct traffic structure" as expressed in the "amount of affected traffic" (von Döhren and Haase, 2015).

Instead, there is an integrated ecosystem approach of the whole landscape necessary to cover the different values of biodiversity in urban and rural areas for the human being and on its own. The classification of cultural ecosystem services aims at putting all other values for the human being in one limited box (La Rosa et al., 2016) such as recreation without knowing if it is an aesthetic (psychological) value or a social one combined. Ecological functions as evaluation criterion need to be applied according to certain distinguished values of urban and rural biodiversity. They need to be measured through discipline specific measurement methods and indicators of natural sciences and humanities which is combined with a participatory decision-making process of the public directly and indirectly concerned (Zisenis, 2006, 2009; Zisenis et al., 2013).

3.2.3. Governance and management

The CBI integrates the science-policy aspect of managing urban biodiversity. The big challenge of the governance of sustainable urban development, including biodiversity, is balancing the different demands on urban landscapes of an unequally higher population density of citizens than inhabitants at the countryside. Furthermore, it is not only the quantity, but also the quality of urban biodiversity which counts for the quality of life and working conditions of citizens. Perceptions of biodiversity are individual. They depend, inter alia, on education, social norms, personal experience, knowledge, individual acting options, economic and other dependences (Zisenis, 2006, 2009).

The Millennium Ecosystem Assessment considers an ecosystem assessment as an interactive exchange of personal knowledge, interests and experiences for common decision-making with the people concerned (Ash et al., 2010), but not as a top-down driven process of so called experts (Zisenis, 2015b). For example, how can the beauty of biodiversity be assessed when its perception is individual? People develop individual relations to urban biodiversity which cannot be judged by others. Of course, there are common basic needs of the society in urban areas of urban biodiversity for human health and human well-being (Cilliers, 2010; Webster and Sanderson, 2013; van Dillen et al., 2012). How to organize public life, including urban biodiversity, is still a decision of the community to balance the different public and private interests and demands. Local Agenda 21 provides a forum for common decision-making of public and private executives, experts, and the public directly and indirectly concerned in cities (Coenen, 2009). It allows an integrated approach of urban planning and day-to-day management, including urban diversity.

Contrary, the CBI indicators on governance and management follow an administrative accounting approach instead of indicating a qualitative participative decision-making process. The relative "15. Budget allocated to biodiversity" related administration as percentage of the total budget of the city (Table 15) does not tell anything about the quality of administrative governance nor of quantitative and qualitative implementation of biodiversity measures. "16. Number of biodiversity projects implemented by the city annually" is already not valid, because this CBI indicator does neither differentiate the volume of each project nor the practical implementation efficiency. "17. Policy, rules and regulations – existence of Local Biodiversity Strategy and Action Plan" is not a necessary condition for good governance and management of urban biodiversity, which can be also covered by an integrated approach of other documents and practical governance. Its measurement through the number of associated CBD initiatives is also a highly theoretical descriptive approach, but not a structural, process or content related urban biodiversity evaluation indicator measurement.

The institutional capacity cannot be indicated by the purely quantitative "18. Number of essential biodiversity-related institutions used by the city" as fewer institutions might work much more effectively together than many split-up responsibilities. The same refers to the cooperation efficiency of "19. Number of city or local government agencies involved in inter-agency biodiversity cooperation".

CBI indicators of participation are reduced to consultation of the public in "20. Existence and state of formal or informal public consultation of biodiversity-related matters" instead of their involvement in decision-making. Rather than using a qualitative indicator, it is just an accounting one as the CBI indicators mentioned before. This refers also to CBI indicator "21. Number of stakeholder organization partners in biodiversity activities, projects and programmes". The strength of participation in decision-making, which includes also the different assessment steps of urban biodiversity, lies in the integration of the knowledge and gathering of support for implementation measures of biodiversity. It is an essential component for a comprehensive assessment of biodiversity (Zisenis, 2000, 2009; Zisenis et al., 2013).

CBI indicator "22. Inclusion of biodiversity or nature awareness in the school curriculum" needed to be more precise. For not just being a formal administrative approach, it should also include feedback analysis of the success. Effective education and awareness of the wider public of urban biodiversity cannot be counted by a general "23. Number of outreach or public awareness events held in the city per year". It depends rather on the content and quality of teaching and learning processes in contact with urban biodiversity. Direct contact with urban biodiversity needs to play an active role in supporting educational and motivation processes in developing ownership, sharing knowledge, and gathering support for urban biodiversity such as through school or community gardens. Thereby, an urban socio-ecological community can develop in the neighbourhood of social connectivity and knowledge sharing (Krasny and Tidball, 2009a; Bendt et al., 2013).

3.2.4. Aggregation of the different CBI indicators

There is an accounting aggregation method used for calculating the CBI in classifying the different measurements of indicators related to a point system which is then added together to a total value (Chan et al., 2014). However, it does not distinguish between completely different values of urban biodiversity, i.e. partly contradictory indicators of the CBI. For instance, community gardens have a high social value in getting people together from the neighbourhood (Krasny and Tidball, 2009b; Middle et al., 2014; Bendt et al., 2013; Fritsche et al., 2011) for planting also non-native ornamental flowers for their psychological beauty and appreciation. Non-native species are also frequently used in parks, as street trees and in public green space which is managed by the government.

An example is the neophyte London Plane-tree (*Platanus x hybrida*) as popular street tree in Central Europe in having different social, psychological, economic, educational, culture-historical, and scientific values for the public and as habitat for the intrinsic (ethical) value of biodiversity (Zisenis, 2006). Despite the fact that the number of phytophagous insects and mites associated with native trees is generally much higher in Central Europe (Brändle and Brandl, 2001). This is not a qualitative indicator precisely analysed versus the different values of the species on their own. Furthermore, it is just a question of time until species will evolutionary adapt to the newcomers (Zisenis, 2012) and the number of insect herbivores feeding on non-native woody plant species will increase (Brändle et al., 2008).

The aggregation method of the CBI neglects the different values of the urban biodiversity example, the neophyte London Plane-tree, because the CBI indicators of its ecological functions are contradictory such as "11. Regulation of quantity of water", and "12. Climate regulation: carbon storage and cooling effect of vegetation" to the criterion of naturalness of the CBI indicator "4.-8. Change in number of native species" which is measured according to the "total number of 4. Vascular plants, 5. Birds, and 6. Butterflies" (Table 15). Instead, different indicators of common evaluation criteria would be necessary to assess the values of urban biodiversity separately, transparently, and comparably (Zisenis, 2006, 2009).

3.3. Proposal of a first set of 10 alternative indicators for evaluations of urban biodiversity

Indicators for interdisciplinary evaluations of biodiversity in urban (and rural) areas need to be derived from their values and applied according to common assessment criteria to indicate the current status and development of biodiversity. For practical reasons, they need to be selected also taking into account the current data availability in urban areas without compromising the need for further extended monitoring and innovative decision-making processes of urban biodiversity. As ecosystems are in its entity highly complex dynamic open systems (Fisher et al., 2009; Zisenis, 2006; Rebele, 1994) which change permanently and discontinuously due to internal (e.g. gene flow, species turnover, natural succession) and external influences (e.g. diverse human influences, natural hazards). There is a practical need to cover main ecosystem structures and functions through "umbrella" indicators of structural, functional, and material processes as well as umbrella species to be used as key species for public relations (Zisenis, 2006, 2009, 2017). Several urban sustainability indicators and indices have been proposed (Mori and Christodoulou, 2012; Ahern et al., 2014; Alam et al., 2016; Maes et al., 2016a, 2018) and some simple quantitative green area ratios (Xing et al., 2017) which do not particularly focus on biodiversity in its complexity in urban areas apart from the leading City Biodiversity Index (Singapore Index) (Section 3.2. Analysis results of the City Biodiversity Index (CBI) on page 159).

Following the currently popular approach of ecosystem services (Fisher et al., 2009; Haase et al., 2014; Hansen and Pauleit, 2014) instead of the transparent and comprehensive concept of an interdisciplinary framework of the different values of urban and rural biodiversity (Zisenis, 2006, 2009; Zisenis et al., 2013; Section 3.2.2. Ecosystem services on page 162). I propose a first simple set of 10 of these structural, functional, and material "umbrella" indicators for evaluations of urban biodiversity from literature for the different supporting, provisioning, regulating, and cultural ecosystem services while taking into account the currently available data (Table 16). These indicators shall allow monitoring a certain moment of the development in time and space of urban biodiversity such as urban green space and its related values.

Table 16 - First set of 10 structural, functional, and material indicators for evaluations of urban biodiversity.

Ecosystem service	Evaluation criterion[11]	Evaluation indicator	Measurement
Supporting, provisioning, and regulating	Ecological functions	1. Sealed urban area	Area percentage of open soil (cardinal)
Supporting, regulating, and cultural	Ecological functions, usability	2. Accessible green space in walking distance	m² per inhabitant (cardinal)
Provisioning	Ecological functions	3. Groundwater recharge	Infiltration rate (cardinal)
Provisioning, and cultural	Usability, ecological functions	4. Area of allotments, community gardens	m² per inhabitant (cardinal)
Regulating	Ecological functions	5. Greening of buildings	Percentage of wall and roof greening (cardinal)
Regulating	Ecological functions	6. Tree volume in streets	m³ tree leaf volume per total street length (cardinal)
Cultural	Rarity and endangerment, typicalness, vulnerability, re-establishment ability	7. Red Lists of species and habitat types in urban areas	Number of Red List species and habitat types in urban areas (including established alien species, and typical urban habitat types such as ruderal flora and fauna)
Cultural	Naturalness/degree of human impacts, typicalness, usability	8. Aesthetic appeal of urban landscape features (e.g. garden architecture, native and non-native species)	Classified (ordinal): 1-beautiful and/or interesting, 2-neutral, 3-disturbing

[11] Zisenis 2006, 2009.

Cultural	Naturalness/degree of human impacts, usability, vulnerability, ecological functions, rarity and endangerment, re-establishment ability, typicalness	9. Degree of public participation in decision-making with impacts on urban biodiversity	Classified (ordinal): 1-generally, 2-frequently, 3-rarely
Cultural, and regulating	Usability, ecological functions	10. Area of school gardens	m² per pupil (cardinal)

Thus, ecological functions is a core criterion for evaluations of urban biodiversity to support, to regulate and to provide main biophysical needs such as fresh air, clean ground water, and moderate temperatures in cities (indicators 1-6). The usability for citizens of public and private green space in the neighbourhood, but also of trees along streets, indicates the quality of life for recreation, relaxation, inspiration, and communication (indicator 2). Furthermore, urban biodiversity serves as habitat for rare and endangered species, and its typical biodiversity needs protection (indicator 7). The typical and naturally grown or established biodiversity in urban areas is part of its identity and cultural history like the human managed ornamental and garden architecture (indicator 8). Effective decision-making of current and future influences on urban biodiversity needs to be democratic and bottom-up (indicator 9), instead of top-down and "expert" driven (Handley et al., 2003). The different subjective perceptions and socio-cultural backgrounds as well as people's knowledge shall be taken into account and public support gathered. Last not least, urban biodiversity is a great opportunity for citizens, children in particular, to learn about natural processes and to develop a personal contact to living organisms with their own hands (Cox and Gaston, 2018) (indicators 4 and 10).

3.3.1. Sealed urban area

The soil covered by concrete or asphalt hinders vegetation to grow which restricts the capacity to refresh the air with oxygen, to filter dust and other pollutants, and to generate groundwater. The high sealing rate of the ground in cities is the main factor for storing the heat together with buildings and other constructions (Schwarz and Manceur, 2014; Norton et al., 2015). There is a high potential for mitigating global climate change instead of losing the run-off or even causing flooding after heavy rainfalls (Rößler, 2015; Gómez-Baggethun et al., 2013) which impacts additionally macro- and microclimatic conditions in urban areas worldwide. Thus, the risk of hydro-meteorological hazards in urban areas can be significantly reduced in decreasing soil sealing (Depietri et al., 2012), but also the hindering impacts on energy transfer, water movement, gas diffusion, and biota (Scalenghe and Marsan, 2009). A simple, purely quantitative measurement of the degree of soil sealing in urban areas is the ratio of the area of uncovered soil to the total area of the city (Table 16). It allows getting an impression of how much soil is covered in relation to the total area of the urban area.

3.3.2. Accessible green space in walking distance

Basic psychological human needs depend on nature such as recreation, relaxation and inspiration apart from biophysical production of oxygen, temperature buffer, pollution and noise reduction (Keninger et al., 2013). Citizens can find it in parks or other green spaces nearby their home or working place. Thus, the physiological and psychological human health and well-being depend on urban green space (Egorov et al., 2016; Tzoulas et al., 2007; Lee and Maheswaran, 2011; Reklaitiene et al., 2014; Tyrväinen et al., 2014). Apart from other influences which determine the use of green space (Section 2.4.4. Social and further environmental factors on page 53), in particular the accessibility and use quality, but also the mobility (Rosso et al., 2011) and social inclusion of the user (Seaman et al., 2010). The walking distance is a quantitative indicator which influences significantly the daily use (Schipperijn et al., 2010) within the local community (Arnberger and Eder, 2012). The amount of m² accessible green space per inhabitant can be roughly used within a certain distance to their home to compare cities globally (Summer, 2012).

3.3.3. Groundwater recharge

Clean groundwater is needed in cities globally as major source of every-day life as drinking water, but also for other use in conjunction with surface-water (Foster and van Steenbergen, 2011). Groundwater recharge can be simply measured by infiltration rate.

3.3.4. Area of allotments, community gardens

Allotments and community gardens are opportunities for growing and providing fresh food for citizens (Guitart et al., 2012; Gómez-Baggethun et al., 2013). They have also high stress reducing components and social benefits for human health and well-being (van den Berg et al., 2010; Krasny and Tidball, 2009b). In addition, they can serve as open space for environmental education (Middle et al., 2014; Gomez-Baggethun et al., 2013) and learning (Bendt et al., 2013). For instance, New York City had about 20,000 citizens who were engaged in around 500 community gardens in 2013 (OASIS, 2013). Examples of temporary (mobile) community gardens exist on real estates in Berlin (Müller, 2017). It depends, however, on how many m² of allotments and community gardens are available for each citizen, which can be coarsely used at average to measure this urban biodiversity indicator purely quantitatively.

However, urban green commons ought not to be misused to substitute public duties of managing public urban green space on the burden of private initiatives or to prevent decay on public grounds. Rosol (2012), Colding and Barthel (2013), and Colding et al. (2013) mention examples in Berlin and other cities. Urban green commons should not be a forced substitute for the caused shortage of fresh food due to the lack of a social net and unequal income such as in the Anglo-American free market orientated socio-economic systems (historical overview of allotment gardens in Barthel et al., 2013) or the shortage of the former ineffective socialist planning system.

3.3.5. Greening of buildings

Wall and roof greening allow mitigating negative bioclimatic and aesthetic impacts of urbanisation on biodiversity although not compensating them. Furthermore, they buffer temperature fluctuations and reduce weathering processes on the building's surface in saving energy and restoration costs. Technically, direct and indirect wall greening is very well developed and its costs can be calculated (Perini et al., 2011). Moreover, green roofs and walls provide additional oxygen, filter dust and toxic substances, reduce noise, lower wind speed, save energy, and buffer the urban heat island effect (Rowe, 2011; Perini et al., 2011; Ling and GhaffarianHoseini, 2012; Berardi et al., 2014; Scheuermann et al., 2016). In addition, they are used as habitats by urban wildlife (Coffman and Waite, 2011; Braaker et al., 2014; Madre et al., 2014). Also regarding this biodiversity indicator, similar to the soil sealing indicator of the ground, the relative surface of covered wall and roof greening provides a simplified quantitative information on the extent to which the corpus of buildings is biophysically active in cities in comparison to the total bare stone or concreted surface of constructions.

3.3.6. Tree volume in streets

Trees fulfil many functions along streets and alleys as they provide shadow and fresh air. They filter dust and other pollution (Jennings et al., 2012; Nowak et al., 2013; Vieira et al., 2018) and reduce noise (Gómez-Baggethun et al., 2013). Moreover, they are also a cultural heritage (Lawrence, 1988) and they inhabit a certain flora (Wittig and Becker, 2010) and fauna (Klausnitzer, 1993). Often citizens develop particular affection to trees in front of their houses (Gorman, 2004) or on their way to work. Trees are a symbol of passed time and of withstanding various influences in standing steady. There are similarities of the personal perception of the characteristics of individual or grouped trees to the one of individual, cultural, and social characteristics of other people (Dwyer et al., 1991). Thus, the measurement of the tree volume in order to estimate the active vegetation crown surely does not cover all ecosystem services (values) provided by street trees. However, it is an easily calculable quantitative measurement for urban landscape planning (Nagendra and Gopal, 2010). Street trees can be mapped and their tree cover calculated by aerial photography (Nowak and Greenfield, 2012).

3.3.7. Red Lists of species and habitat types in urban areas

There are particular species evolutionary co-adapted to urban areas such as the House Sparrow (*Passer domesticus*) (Møller et al., 2012), but also typical urban habitat types exist such as the spontaneous ruderal flora and vegetation (Sukopp and Werner, 1983; Wittig, 2004). Non-native species play an as important role in providing ecosystem services as natives (Zisenis, 2012, 2015). About half of the urban flora of 32 central European cities consists of non-native species (Lososová et al., 2012). Furthermore, urban species assemblages are different in composition and abundance from their counterparts at rural areas even of the same species such as revealed for arthropods (Sattler et al., 2011). Thus, Red Lists of native and established non-native species in urban areas (Kühn et al., 2004) as well as of habitat types in cities are useful indicators for reducing threats to urban biodiversity. In a simplified non-qualitative manner, just the number of Red List species and habitat types in urban areas can be counted.

3.3.8. Aesthetic appeal of urban landscape features

The living and built environment are crucially connected in urban areas as they determine the urban landscape scenery, as well as the structural, functional and material connections within cities as they should be expressed in urban planning and landscape planning. There are many unique or typical elements of urban biodiversity like the garden architecture (Di Paola, 2010) or non-native and native species in urban areas such as ornamental plants (Jaganmohan et al., 2012) or spontaneous vegetation (Sukopp and Werner, 1983; Wittig, 2011; Mathey and Rink, 2010). They have a subjectively perceived aesthetic appeal to citizens apart from other values (Qiu et al., 2013; van der Meer et al., 2011) as they are part of our cultural heritage and identity (Müller and Werner 2010).

The application of various existing practical social participation methods in evaluation and decision-making (Puppim de Oliveira et al., 2011; Ash et al., 2010) is thus possible and necessary to involve people's judgement on the aesthetic appeal of urban landscape features. The perception of beauty and the interest in urban biodiversity are highly subjective (Qiu et al., 2013). It depends, among others, on personal experience, education, knowledge, emotional relationships, culture-historical background, social norms, economic and other dependences (Zisenis, 2006, 2009). The citizens' aesthetic preferences can be grossly classified on ordinal scale (Table 16).

3.3.9. Degree of public participation in decision-making with impacts on urban biodiversity

A high involvement of citizens in practical evaluation and decision-making with impacts on urban biodiversity is crucial for determining its subjective values in space and time, but also for integrating their specific knowledge and personal support (Zisenis, 2006, 2009; Zisenis et al., 2013). Scientists, experts, administrators and politicians can only estimate urban values of biodiversity to a limited extent from outside and for a certain moment of observation, in addition to their restricted knowledge and the systemic subjective perception of intrinsic values. Furthermore, it is a question of democracy to do not make judgements and decisions top-down, but bottom-up also regarding decisions with an impact on urban biodiversity. A practical question stays, however, how this participation in decision-making of the public shall be organized in a necessarily partly representative democracy when the issues become too complex or too time consuming to be evaluated on the ground (Zisenis et al., 2013)?

Governance of biodiversity and other issues on UN (Collins, 2012), EU (Rauschmayer et al., 2009) and national level (Suškevičs, 2012) show often democracy deficits, heavy burden bureaucracy (Biermann and Siebenhüner, 2009) and formal, but not effective stakeholder participation. This stands in contrast, for example, to the envisaged Local Agenda 21 initiatives on regional and local level (Barrutia et al., 2011). The classified frequency can be measured at ordinal scale of the participation of experts, decision-makers, stakeholders, as well as the public directly and indirectly concerned in decision-making with impacts on urban biodiversity. This is, however, only a simplified structural indicator of managing the different values of urban biodiversity which highlights the amount, but not the quality of public participation on urban biodiversity influencing decisions.

3.3.10. Area of school gardens

As relations to nature and urban biodiversity in particular are already founded in our childhood, but they can be still influenced in experiencing nature as adults (Ardoin and Heimlich, 2013). School gardens plays an important role in the education of pupils of a deeper contact for learning and appreciation of urban biodiversity, but also to build up responsibility and social behaviour (Blair, 2009). Therefore, a simplified quantitative educational value indicator of urban biodiversity is the area of school gardens in cities which can be measured in m² per pupil on cardinal scale.

3.3.11. Distinguished weighing of the 10 indicators for evaluations of urban biodiversity

Contrary to the City Biodiversity Index, the measurement of the different indicators for evaluations of urban biodiversity is not supposed to be aggregated to a single number such as Lopes and Camanho (2012) did for modelling the quality of life in 174 European cities including the proportion of accessible green space. Instead, the different values of biodiversity need to be separately considered and weighed according to transparent criteria of ecosystem services or better biodiversity values, respectively, within participatory decision-making processes of experts, decision-makers, stakeholders, and the public directly and indirectly concerned (Zisenis, 2006, 2009; Zisenis et al., 2013; Mori and Christodoulou, 2012). This allows a distinguished assessment of different urban biodiversity elements for political decision-making and governance in urban development and beyond.

3.4. Discussion of a new first set of indicators for evaluations of urban biodiversity

The international attempts to develop indicators for evaluations of the biodiversity of urban areas by the CBD, including public green urban areas, are driven by the desire to allow comparing the governance success of urban biodiversity in urban planning and urban development for the multiple benefits of citizens and for the particular values of urban biodiversity on its own (CBD, 2010b, 2014). However, the idea is misleading to aggregate different values (ecosystem services) of urban biodiversity in a single City Biodiversity Index (CBI) for individual self-assessments of city authorities and calculation in their urban development projects and plans. Furthermore, it becomes a risk for losing easily valuable urban biodiversity aspects in being reduced to an exchangeable figure instead of having a differentiated evaluation outcome of urban biodiversity assessments for participatory decision-making.

The proposed CBI indicators in particular use as criteria naturalness of species and natural (protected) areas in cities, different ecological functions (ecosystem services) of natural resources and limited human values as well as mainly numeric administrative governance and management figures. However, the CBI indicators do not sufficiently take into account the particular ecological conditions of biodiversity in urban areas. The urban biodiversity established itself in a more or less unnatural environment of habitat mosaics which were created by humans within dynamic open urban ecosystems as they are part of. The human influence has allowed a high amount of non-native species to settle and to reproduce, but it has also created typical urban habitats. Indicators for evaluations of urban biodiversity need to take them into account as valuable parts.

Urban biodiversity differs from the one at the countryside, even of the same species, in species composition, on genetic population level and as ecosystem complex of urban habitat types. Their interactions are crucial for providing different ecosystem services to citizens. These ecosystem services cannot be limited mainly to water and climate regulation as well as recreational and educational services according to the CBI, but they cover all parts of the life and working quality of citizens in the urban environment.

Furthermore, the governance and management success of urban biodiversity cannot be assessed without asking and involving the citizens concerned in their subjective evaluation of urban biodiversity elements such as of their perception of aesthetic beauty or preferences as bequest value. The number of urban biodiversity related projects, institutions, administrative regulations, formal programme inclusions or the amount of the budget spent on urban biodiversity, as considered in the CBI, belong to the method of numerical accounting. However, they are not a reliable indicating approach for the content and performance of related measures for the different values of urban biodiversity.

Therefore, there is a more "umbrella" structural, functional and material related indicator approach of urban ecosystems necessary to cover the different ecosystem services (values) of urban biodiversity for practical governance, project and planning purposes. I have proposed in this study a first set of 10 alternative indicators for evaluations of urban biodiversity which are embedded in an evaluation framework of common criteria of the currently most popular concept of different supporting, provisioning, regulating, and cultural ecosystem services. Of course, the set of 10 indicators for evaluations of urban biodiversity does allow only a very rough comparison of the biodiversity values of different cities, because these indicators are mainly quantitative without taking into account the qualitative aspects of biodiversity at each particular urban location in time. Nevertheless, they can be measured and mapped on different scale depending on available or reasonably accessible data.

Biotope mapping takes into account the urban land use, but also the mainly flora & vegetation based habitat mapping. It was particularly initiated in Berlin in Germany (Schulte et al. 1993). From this point on, it has been widely applied in German cities (Schulte et al., 2003), but also increasingly used in other European cities and beyond for spatial planning purposes (Gao et al., 2010). Biotope mapping is a good source and starting point to complement the information on the first set of 10 indicators for evaluations of urban biodiversity. Nevertheless, it needs to be supplemented by environmental data such as of Berlin's Environmental Atlas which covers spatial data on soil, water, air, climate, biotopes, land use, traffic/noise, and energy (Senate of Berlin, 2017a), and newly socio-economic data of its urban inhabitants for estimating the "green infrastructure" quality of city life (Senate of Berlin, 2015g; Section 2.5. Indicators of ecosystem services (biodiversity values) of public green space in the city of Berlin on page 57).

Green infrastructure extends the ecological network concept (Lafortezza et al., 2013) by socio-economic values such as employment and higher income of adjacent business, as well as the mitigation of climate change (European Commission, 2013). However, the EU Green Infrastructure concept seems still too much focused on the limited spatial scale of protected areas of the EU Natura 2000 network and those at national level to serve as core areas with buffer zones of sustainable development and theoretically connecting stepping stones (European Commission, 2016) instead of covering 100% of the urban and rural landscape (Zisenis, 2017). Furthermore, the EU Green Infrastructure concept is also limited to certain values of biodiversity, but it lacks of a comprehensive evaluation framework of values, common evaluation criteria, and survey and analysis methods of natural sciences and humanities (Zisenis, 2006, 2009), as well as related indicators (Zisenis et al., 2013).

Furthermore, there is crucially a need for participatory decision-making in evaluations of biodiversity and its resulting landscape management in urban areas. Bottom-up initiatives such as the Agenda 21 (Coenen, 2009; Barrutia et al., 2011) can integrate the subjective perception and local knowledge of citizens of biodiversity (Qiu et al., 2013; van der Meer et al., 2011; Handley et al., 2003) as well as their creativity and motivation (Zisenis, 2006, 2009; Zisenis et al., 2013). They allow putting theoretical mapping and planning into governance practice for the quality of life and working conditions in cities, last not least also for the living and evolutionary development conditions of urban biodiversity on its own.

4. Conclusions

The results of this research have shown that the moderate net population increase of Berlin is not the determining factor for the continuous deficit of public green urban areas of the city, in particular in the inner city districts. Instead, pure real estate speculation has contributed with developments on open green space to the high deficits of available public green space. Especially urban brownfields have been converted to building grounds in Berlin after 1989. These deficits specifically impact the poor, less mobile inhabitants and migrants among them who depend on accessible public green space within walking distance of their homes. On the contrary, the same population explosion argument of the “gold rush” period after the breaking down of the wall between Eastern and Western Berlin by the people in 1989 is used in the urban development policy of the Senate of Berlin nowadays to justify further densification through further constructions within downtown Berlin. Even war immigrants are used as argument against the direct democratic voting of the public for keeping open public green space such as the former Tempelhof airport practically and symbolically free from housing development as accessible recreational area of “Tempelhofer Freiheit” (Tempelhof's freedom). However, further high immigration of war refugees has been widely stopped at the EU borders as 20 out of 28 of the EU Member States do not support the humanitarian integration of foreigners (Traynor and Watt, 2016).

This study shows the deficits of the amount of available public green urban areas per capita in the downtown city parts of European metropolises of more than 1 million inhabitants in comparison to the whole core city. However, there was no significant correlation detectable on either side (two-sided) between the total area of each European metropolis and the public green urban areas of the inner city in 2011. The urban planning policy of the Senate of Berlin undervalues the different values of urban biodiversity for the living and working quality of its citizens as well as for urban biodiversity on its own. Integrative negotiated participatory urban planning tools and strategies over years have been overlaid with master plans and other construction plans to convert open green space into building grounds since the tearing down of Berlin's wall by the public in 1989. Monetary use values are preferred in urban planning of green space in Berlin. The main (hereby refuted) argument is the projected population increase.

There is a severe democratic deficit of public control of project driven urban planning decisions of the Senate of Berlin which is further exacerbated through the introduction of own publicly financed campaigns against direct democratic bottom-up initiatives for urban planning alternatives of the people on the ground. Participatory decision-making was already foreseen in the Agenda 21 which was adopted during the United Nations Conference on Environment and Development for sustainable development in urban and rural areas in 1992 (UN, 1992). However, it is widely neglected in favour of hearings and surveys of the public opinion in Berlin. Berlin's Landscape and Species Protection Programme is practically not sufficiently implemented although it was adopted by parliament in being mandatory for administrative governance, planning and project decisions,.

The question is whether Berlin is not losing the human openness and diversity of lifestyles and cultural expressions (Colomb, 2012) that makes it attractive for living, working and visiting in this still visible agglomeration of small villages since 1920 (Arandjelovic and Bogunovich, 2014). It is a long way for Berlin towards an international metropolis like London, Paris or New York City overseas. Berlin's historically grown small "Kiez" neighbourhood of human relations of a balanced population mixture of different income classes, sufficiently accessible public green space also in the inner city area in quantity and quality, and the creative freedom for artists and other initiatives of affordable rooms for off-culture liveliness distinguishes it from other European and international metropolises where rents and real estate speculations have already pushed out the lively heart of the former inner city inhabitants for a wealthier generation, shops and offices (Smith, 2002; Balicka, 2013).

Furthermore, Berlin's major urban planning tools and strategies lack scientifically of a transparent coherent and comprehensive biodiversity evaluation framework (Zisenis, 2006, 2009; Zisenis et al., 2013), including valuable and reliable indicators which are based on the different values mentioned in the preamble of the Convention on Biological Diversity (CBD, 1992). An anthropocentric "ecosystem services" orientated schematic structural approach focuses on mainly descriptive use values instead of a participatory evaluation and decision-making process of (urban) ecosystem assessments for sustainable development. Thereby, it undervalues non-use and non-monetary values of urban biodiversity. Urban planning of green space is not understood as an integrative planning process of the people directly and indirectly concerned. It is scientifically and in planning practice artificially cut into pieces of ecological functions of urban ecosystems which cannot compete with top-down decisions of Berlin's Senate for particular interests of housing, offices and other commercial constructions. The decoupling of rents from the basic human need for accommodation of Berlin's citizens since the breaking down of the wall in 1989 has allowed to make this speculation of real estates and successively increasing rents profitable for investors in a global market.

This research reveals that the schematically quantitative calculation of available public green urban areas per inhabitant and the mainly general description of the ecosystem services related to them are not sufficient indicators for considering the different values of public green space in urban development for the citizens concerned and urban biodiversity on its own. Already the complex socio-economic circumstances of inhabitants demand a more precise and adapted planning to the particular needs and values of green space as part of urban biodiversity (Wolch et al, 2014). Urban ecosystems are complex open dynamic and discontinuously developing systems as well as the different values of biodiversity related to them. There is a set of reliable and valuable indicators for comprehensive evaluations of urban biodiversity necessary which allows in more detail to compare the governance of urban biodiversity.

The detailed spatial analysis of this research, based on the data of Berlin’s Environmental Atlas (Senate of Berlin, 2017a), regarding inhabitants within walking distance of 500 m to public parks, public accessible managed green areas/parks, cemeteries, and allotments of a minimum size of 0.5 ha resulted in a comparison of their environmental (biophysical) and socio-economic conditions within the inner city boundaries of the S-Bahn circle compared to the entire city of Berlin. The microclimatic situation was equally unsatisfying for the inhabitants in the inner city and the whole city of Berlin due to the high degree of soil sealing. The vegetation volume of their streets could not compensate for the deficit of public green space. The sum of the soil functions provided by public parks and public accessible managed green areas/parks was generally much lower than in the whole city of Berlin. It was partly higher in comparison for allotments and cemeteries also with respect to the sum of soil protection values equally in the inner city as well as in the entire city of Berlin. Though public accessible managed green areas/parks in the inner city of Berlin had the highest average ground water production per m² per annum of all investigated four green space types.

As another exception, the naturalness of cemeteries (contrary: hemeroby) was much higher than of the other three investigated green space types in the inner city and the whole city of Berlin. This does not necessarily result in higher biodiversity values, because different use of public green space requires adapted varying management intensity (hemeroby). Allotments and cemeteries also had a higher water storage capacity, higher water supply, better filter capacity, higher binding capacity of heavy metals and other pollutants as well as of nutrients in comparison to public parks and public accessible managed green areas/parks. Again exceptionally cemeteries had more proportional areas of rare soil associations within the area of Berlin in the inner city than the other investigated three public green space types. Both can indicate more stable soils and less disturbed soil development. This refers also to higher filtration capacities of cemeteries of the topsoil and the subsoil of cemeteries in the inner city of Berlin compared to the other three investigated public green space types.

However, the results of the extensive spatial analysis of different biophysical ecosystem services, based on Berlin’s Environmental Atlas, do not allow the conclusion that public parks, and public accessible managed green areas/parks have lower biodiversity values than allotments or cemeteries or vice versa. It shows the dilemma that a comprehensive integrated evaluation of the different biodiversity values of the Convention on Biological Diversity is impossible without integrating the personal needs and demands of the public directly and indirectly concerned who lives in the near neighbourhood of urban green space and beyond in a representative democracy.

The further spatial analysis of the socio-economic conditions of inhabitants within a neighbourhood distance to public urban green space of the politically determined threshold within walking distance of 500 m to public parks and public accessible managed green areas/parks of a minimum size of 0.5 ha shows the necessity to adapt to the personal needs of the neighbours and their demographic structure, economic and social situation. Moreover, the results of a high proportion of inhabitants with migration and those of non-EU background result in a different individual, social and cultural use as well as in particular demands on public urban green space which needs to be taken into account in their management and alteration of deficits.

It becomes clear from the results of this study that the areas within 500 m walking distance of public parks of a minimum size of 0.5 ha with proportionally higher immigrants and inhabitants of low income (unemployed, inhabitants depending on social benefit transfer, and poor children) in the inner city faced stronger migration fluctuations than in the whole city of Berlin. However, the exchange of inhabitants by richer income classes does not solve the problem of deficits of accessible public parks in walking distance particularly in the inner city of Berlin nor it should be a balanced planning goal in urban development as it creates inequalities which shall be altered by e.g. Berlin’s Neighbourhood Management Programme (Senate of Berlin, 2017d). Crime and neglect can become a problem in socio-economically imbalanced neighbourhoods of public parks such as drugs and violence in the Volkspark Hasenheide in the former workers’ and immigrants’ district Neukölln (Gandzior, 2016) or the drug dealing hotspot Görlitzer Park in the multicultural district Kreuzberg (Leber, 2017). However, drug dealing and robbery can develop also to a severe problem in economically booming districts like “Mitte” (centre) of Berlin as the public park at Weinbergsweg shows (Mielke, 2007).

Public parks can support social networks for meetings and communication with other users of adjacent inhabitants (Gomez-Baggethun et al., 2014). They can pave the way for higher incomes and performance of adjacent shops and other business instead of a highly concreted anonymous urban environment of rapid fluctuation during the day and of their inhabitants over the year. Security guards and surveying measures need often to be installed to protect purely business areas with little green space to relax which empty in the evening as well as upper class housing neighbourhoods also in Berlin (Marquart et al., 2013).

On the contrary to Berlin’s Construction Act (BauOBln, 2018), the Senate of Berlin has widely abolished the need in development plans for children playgrounds and a green belt along the former wall (no man’s land) in favour of new office, hotel and shopping (mal) constructions with maybe an expensive loft on the top on former public grounds at central squares such as Potsdamer Platz and Leipziger Platz (Caygill, 1997). Their accompanying parks are rather sterile grasslands with some lower trees. Overriding master and other urban development plans of the formerly empty space due to Berlin’s inner wall (no man’s land) gave clear preference to selling public open grounds often below market prices for business and shopping development (Strom, 1996; Hammerschmidt, 2006) instead of developments for social or cultural purposes including large green spaces of high living and working quality.

This urban development target of commercializing the public treasure of open grounds as much as possible also upwards to building skyscrapers (Cochrane and Passmore, 2001) neglects the needs of people to live in the inner city. On the other hand, slum development is often combined with neglected public parks, vandalism and crime due to segregation of wealthier and lower income together with an increase of low educated immigrants (Mayer, 2013; Eksner, 2013; Paravicini, 2003). High public and private investments become necessary which are given up at a certain point as in shrinking cities as a whole (Martinez-Fernandez et al., 2012). This is the contrary to a balanced urban development.

The assessment of the much higher vegetation volume in public parks than public accessible managed green areas/parks in comparison in the inner city depends as well on the preferred biodiversity values of them, likewise of the less apparent situation in the whole city of Berlin. Although it can indicate certain biophysical ecosystem services. Surely, it can be generally assumed that as a result of the analysis in streets the negative aspects of missing or low vegetation volume reduced the different biodiversity values for citizens and urban nature on its own, which is equally severe within a distance of 500 m to these investigated green space types of a minimum size of 0.5 ha in the inner city as well as in the entire city of Berlin. Moreover, the analysis of the area of allotments showed a vegetation volume to a much lower extent than in the other three investigated green space types. However, this does not necessarily lead either to the conclusions that these circumstances would be of lower biodiversity values for the citizens nor fauna & flora which lives in allotments. Other preferences could be prioritized in the inner city as well as the whole city of Berlin such as the high yield functions of allotments in comparison to the other three investigated green space types.

The higher hemeroby of public parks, and public accessible managed green areas/parks indicated a higher use and management in the inner city than in the whole city of Berlin also in comparison to allotments and cemeteries. However, it is an uncertain and imprecise indicator for the different biodiversity values of the investigated public green space types. It would be more important to know for which particular purposes (biodiversity values) a certain area of urban green space is managed in time for whom for deriving concretised urban and landscape planning targets?

The City Biodiversity Index (CBI) or so called Singapore Index is the leading global urban biodiversity indicator set of the Convention on Biological Diversity. However, the separate analysis of the CBI shows that it does not allow sufficiently assessing the governance and management success of urban biodiversity through reliable and validate indicators. It would be very helpful as biodiversity indicators' tool to compare better different cities at European and global level. Although the CBI is supposed to serve just as self-assessment biodiversity management tool due to the incomparable individual urban developments of cities. This does not exclude to set baseline targets among different cities while using comparable urban biodiversity indicators that shall support a minimum quality and quantity of biodiversity values for its citizens and nature on its own.

Therefore, I propose instead of the CBI a first new set of 10 "umbrella" structural, functional and material urban ecosystems' related indicators for evaluations of urban biodiversity for practical governance, project and planning purposes of urban development. The embedded evaluation framework of common criteria and related values of biodiversity can be used for the currently most popular, but inconsistent classification in supporting, provisioning, regulating, and cultural ecosystem services of urban biodiversity. It does not imply automatically that the urban biodiversity assessments of different cities result in improving planning and project decisions with an impact on urban biodiversity. Nevertheless, it is a highly pragmatic proposal of a new first set of 10 indicators for evaluations of urban biodiversity depending on the currently available data. It shall make rough comparisons of the different ecosystem services (biodiversity values) in urban areas more reliable, validate, and comprehensive on a systemically rather limited basis of urban biodiversity indicators. However, it cannot substitute more comprehensive urban ecosystem assessments including the participatory decision-making of citizens directly and indirectly concerned (Zisenis et al., 2013; Zisenis, 2009).

A representative monitoring needs to be established which covers the different abiotic and biotic urban biodiversity aspects including keystone and umbrella species, structures, functional relations and material flows of urban ecosystem types as well as the dynamically developing human relations and values related to them. Substantial legal planning tools and strategies are available for European metropolises, but they are still partly not in state such as the mandatory monitoring of species and habitat types of Community interest by the EU Habitats Directive and birds of the EU Birds Directive within and outside the Natura 2000 network (European Commission, 1992, 2009). A representative monitoring concept for fauna & flora was already conceptualised for Western Berlin (Janotta et al., 1987; Fugmann and Janotta, 1990). However, it has not yet been implemented in practice after the urban planning unification of Berlin in 1990 despite legal obligations (NatSchGBln, 2013).

Berlin's city development had a kind of sleeping beauty period in heavily subsidized Western Berlin and socialist controlled Eastern Berlin until the breakthrough of the inner city walls by the people in 1989 which opened the perspective to the world. However, it brought in also speculation and crime from the first moment onwards. It has led to deterioration of formally socially mixed districts due to gentrification like the inner city districts of Prenzlauer Berg, Mitte, and Kreuzberg. It has pushed away inhabitants of lower income (Bernt and Holm, 2013; Holm, 2013; Eksal, 2013) as this study has shown for the same reasons as open green space to make rapid money. Main driving forces were the abolishment of thresholds to increase rents (rent control) in entire Berlin and the selling of public estates for new developments.

The key tool is scientifically and democratically to apply bottom-up an already existing interdisciplinary framework of the different values of biodiversity to urban planning based on participatory decision-making methods of the public directly and indirectly concerned (Zisenis, 2006, 2009). It would allow comprehensively to assess the different values of urban green space and other biodiversity components to be integrated into planning decisions in the city of Berlin and beyond in other European metropolises.

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Figures

Tables

Appendix

1. Available public green urban areas in the inner city parts of other European metropolises

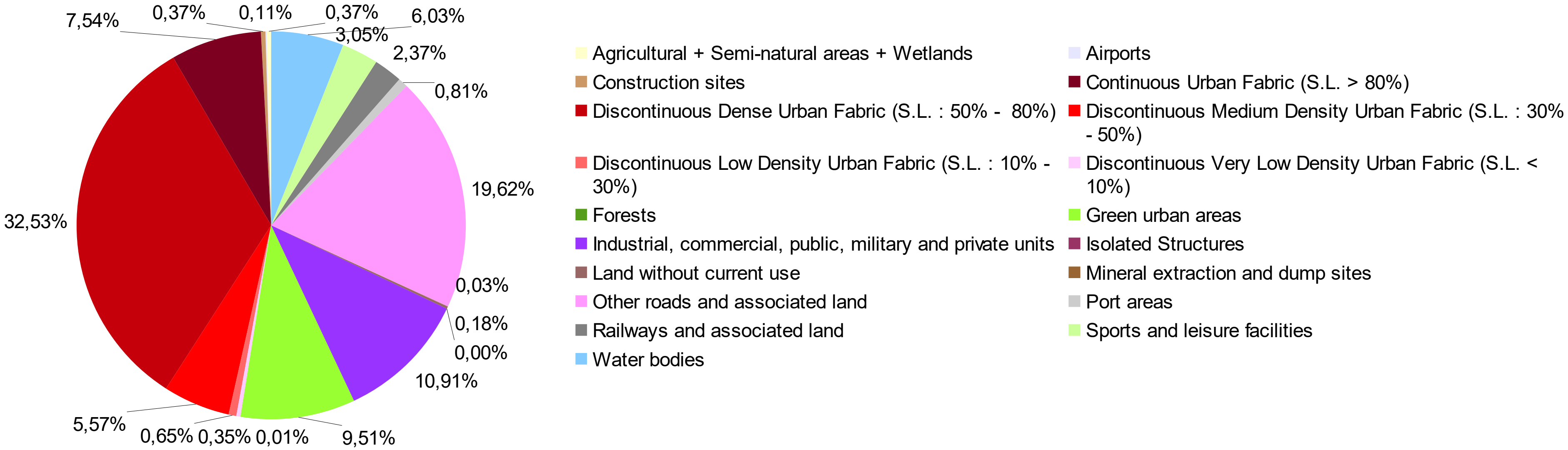


Fig. 92 - Proportion of different land use categories of the inner city area of London in 2010 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015a, 2015b; © EuroGeographics for the administrative EU city boundaries).

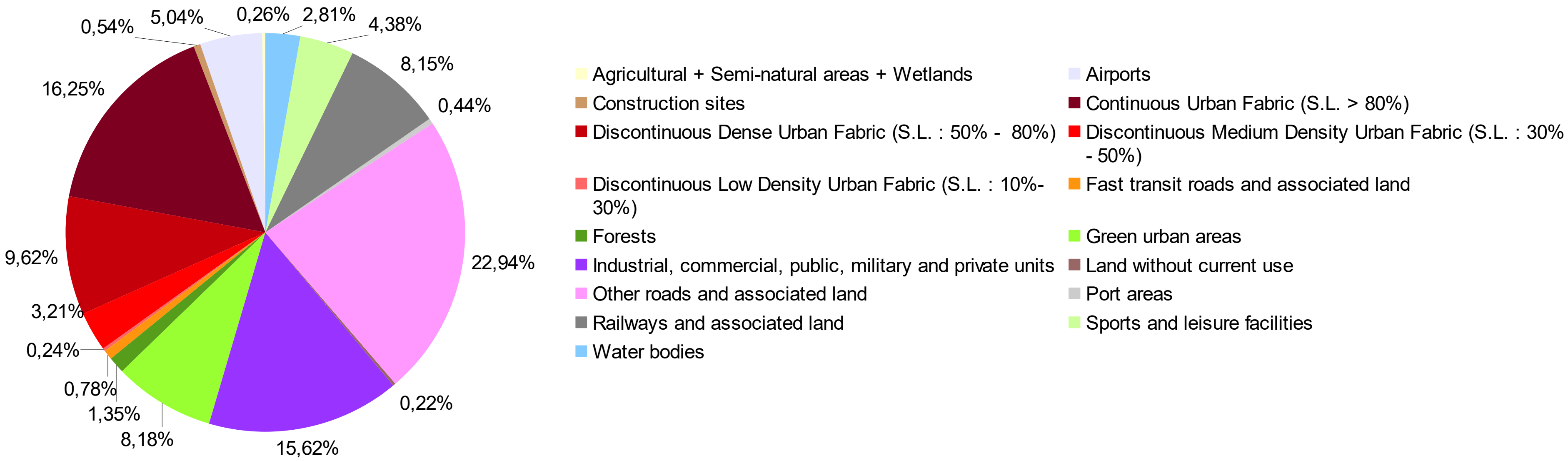


Fig. 93 - Proportion of different land use categories of the inner city area of Berlin in 2010 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 94 - Proportion of different land use categories of the inner city area of Rome in 2010 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

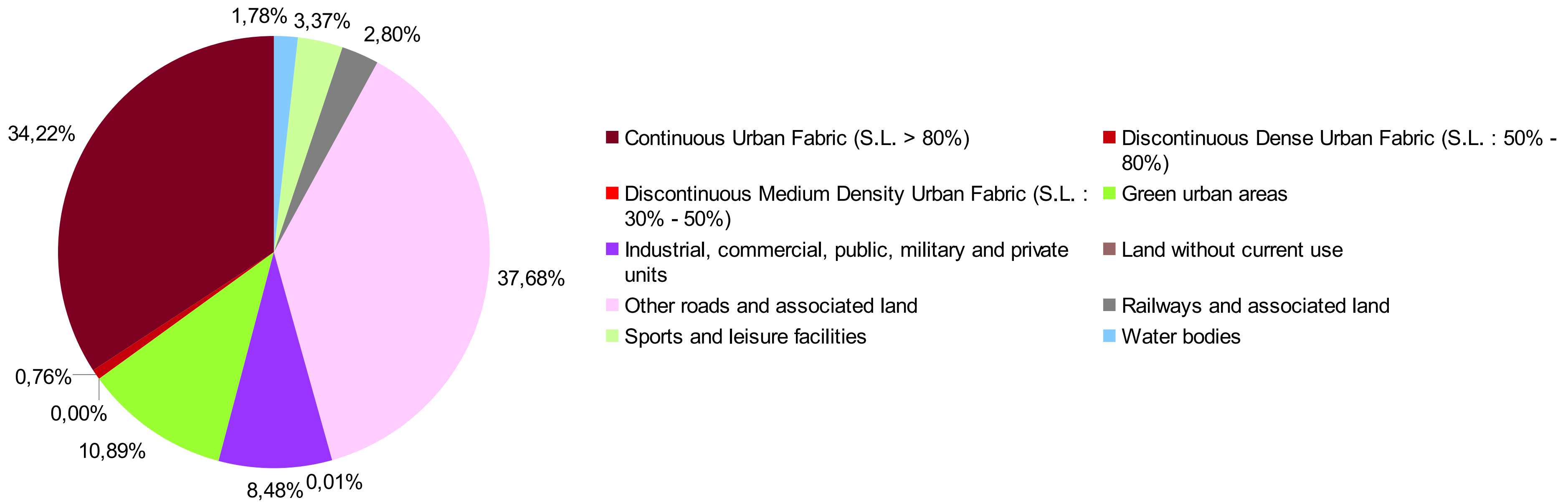


Fig. 95 - Proportion of different land use categories of the inner city area of Paris in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

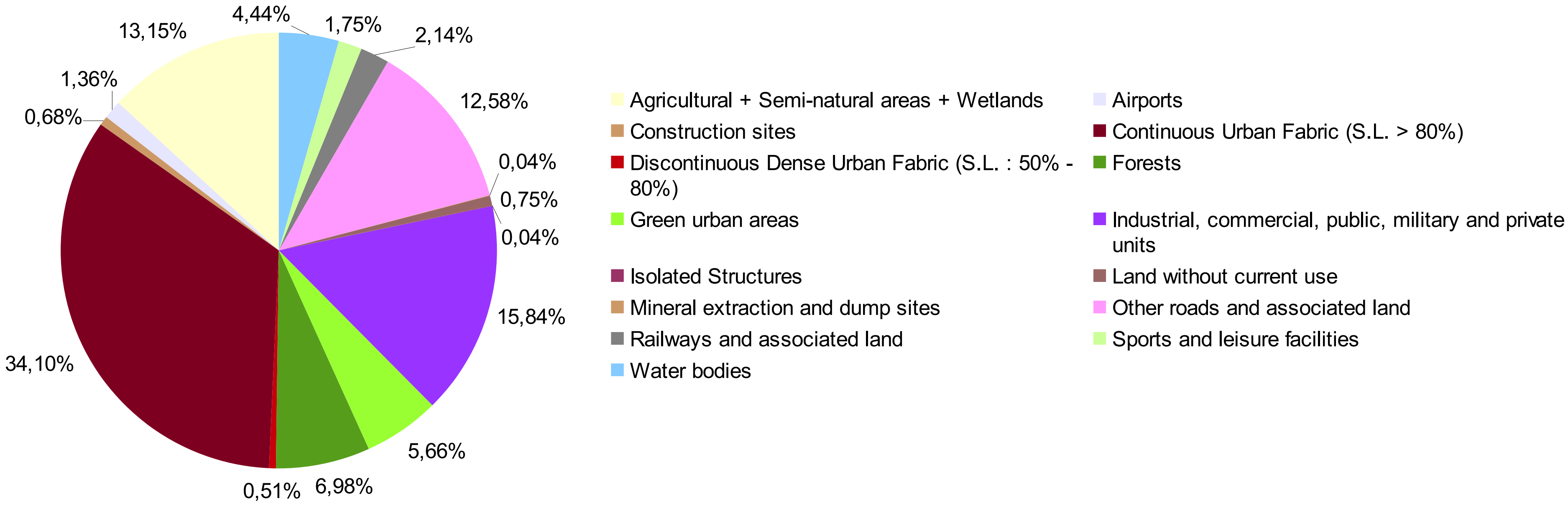


Fig. 96 - Proportion of different land use categories of the inner city area of Bucharest in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

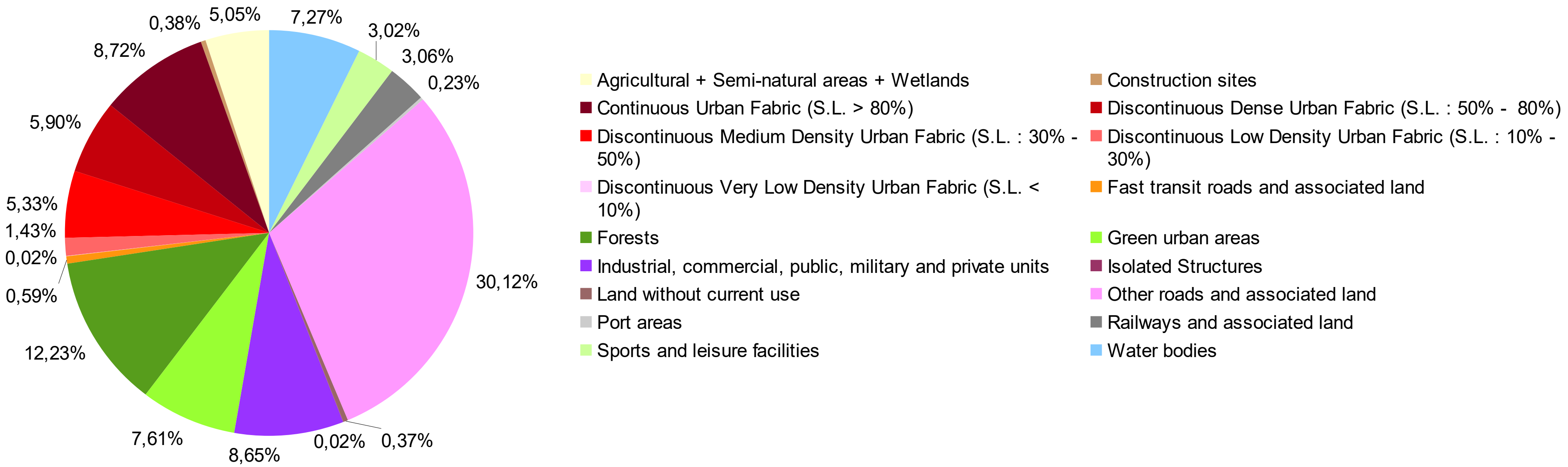


Fig. 97 - Proportion of different land use categories of the inner city area of Vienna in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 98 - Proportion of different land use categories of the inner city area of Hamburg in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 99 - Proportion of different land use categories of the inner city area of Budapest in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

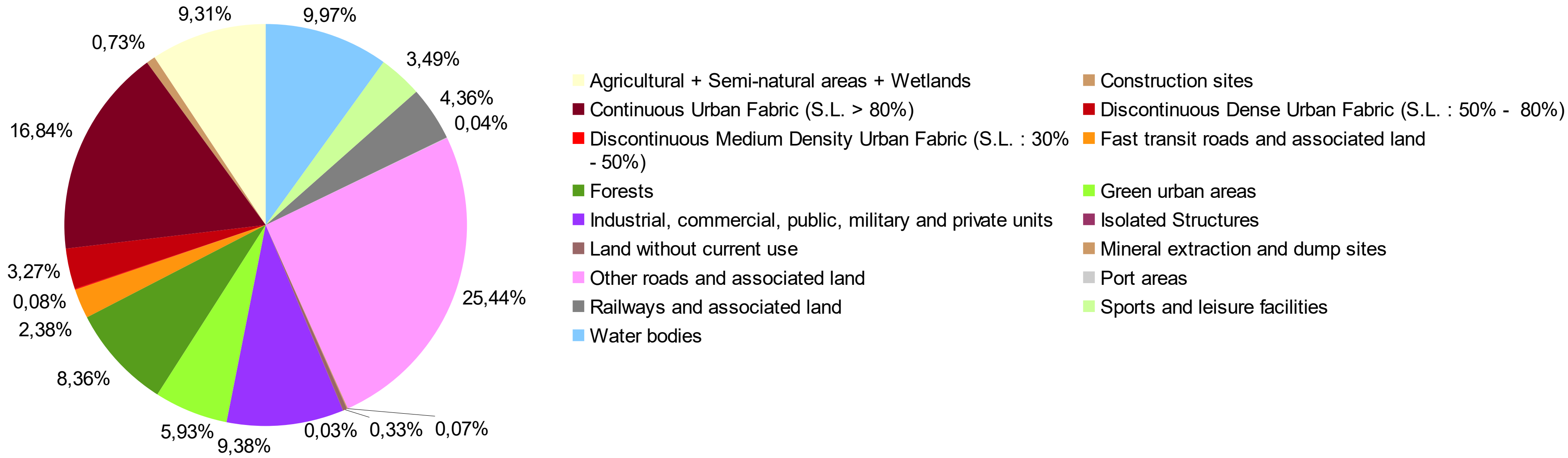


Fig. 100 - Proportion of different land use categories of the inner city area of Warsaw in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

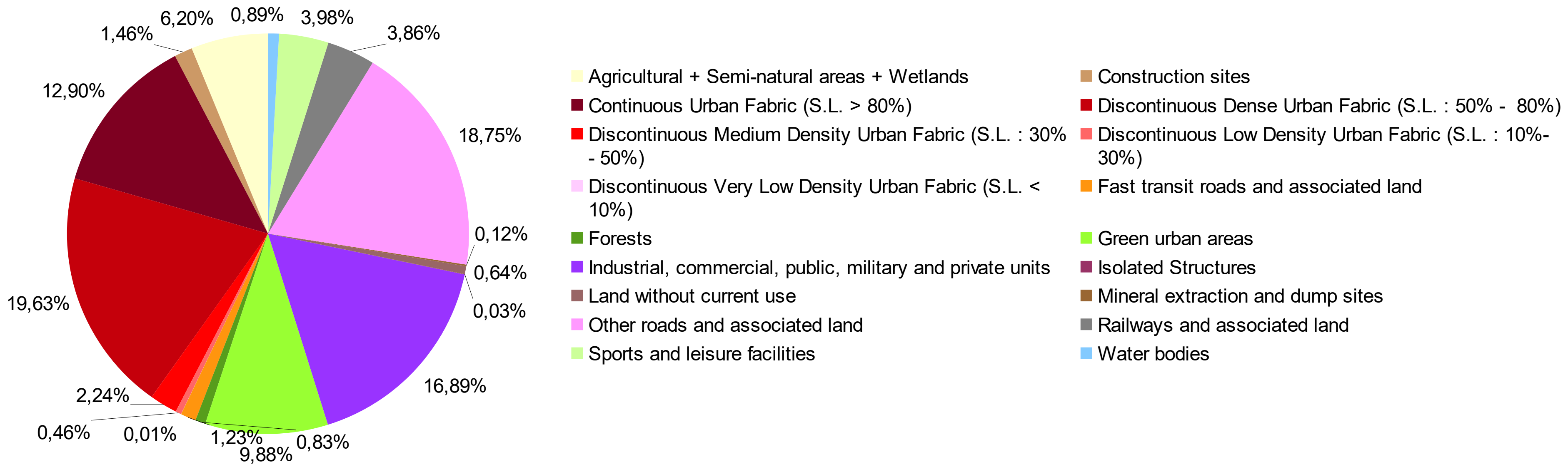


Fig. 101 - Proportion of different land use categories of the inner city area of Munich in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 102 - Proportion of different land use categories of the inner city area of Milan in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

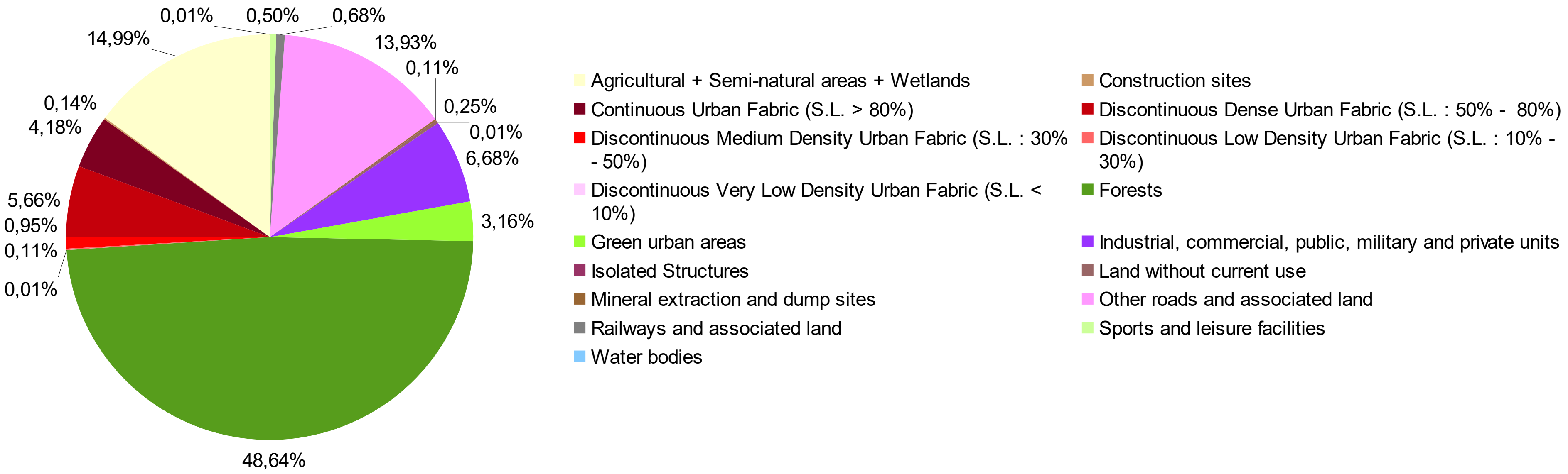


Fig. 103 - Proportion of different land use categories of the inner city area of Sofia in 2010 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 104 - Proportion of different land use categories of the inner city area of Prague in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 105 - Proportion of different land use categories of the inner city area of Brussels in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

Fig. 106 - Proportion of different land use categories of the inner city area of Birmingham in 2011 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

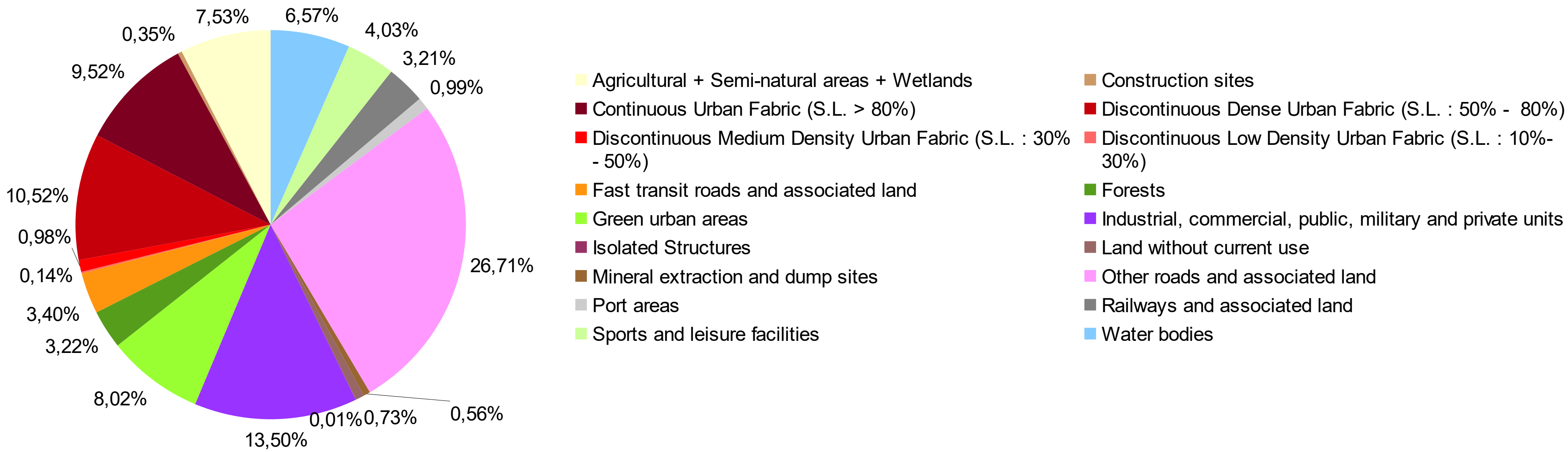


Fig. 107 - Proportion of different land use categories of the inner city area of Cologne in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

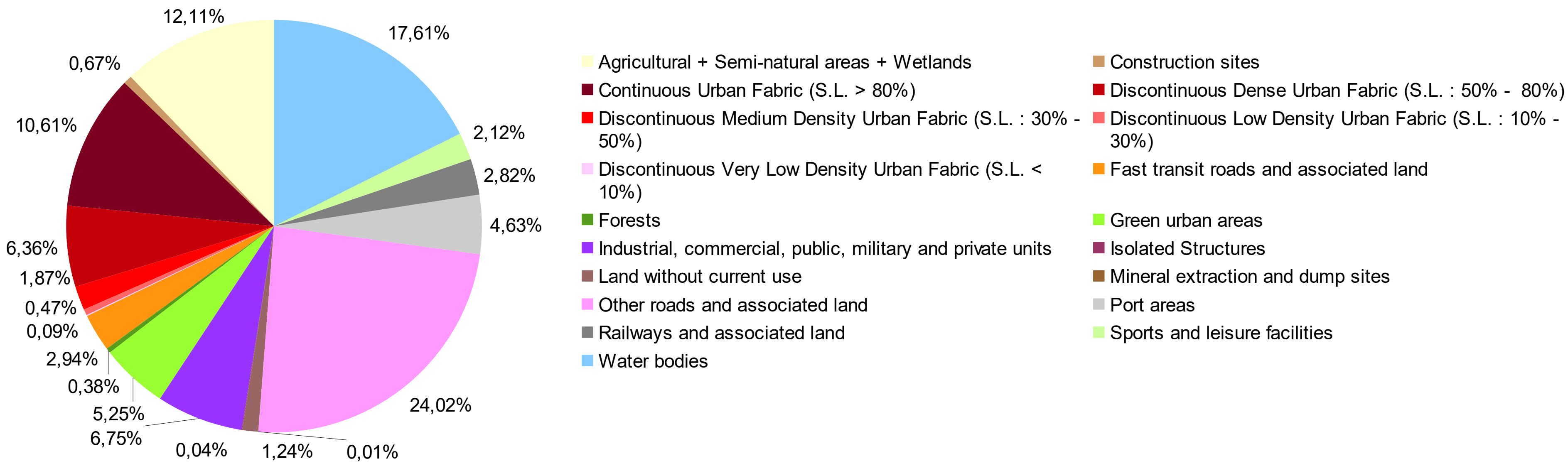


Fig. 108 - Proportion of different land use categories of the inner city area of Amsterdam in 2009 (own calculation based on data from the European Environment Agency, 2014; Eurostat, 2015; © EuroGeographics for the administrative EU city boundaries).

2. Indicators of ecosystem services (values) of green space in the city of Berlin

2.1. Microclimate

2.1.1. Public accessible managed green areas/parks (2010)

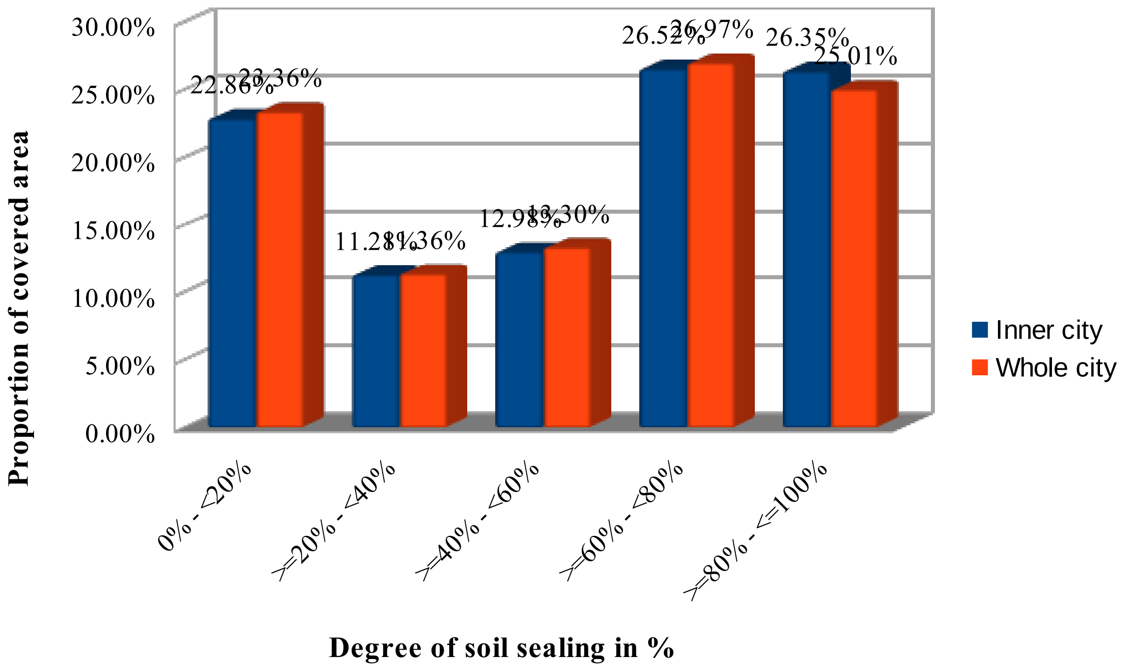


Fig. 109 - Degree of soil sealing in % in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

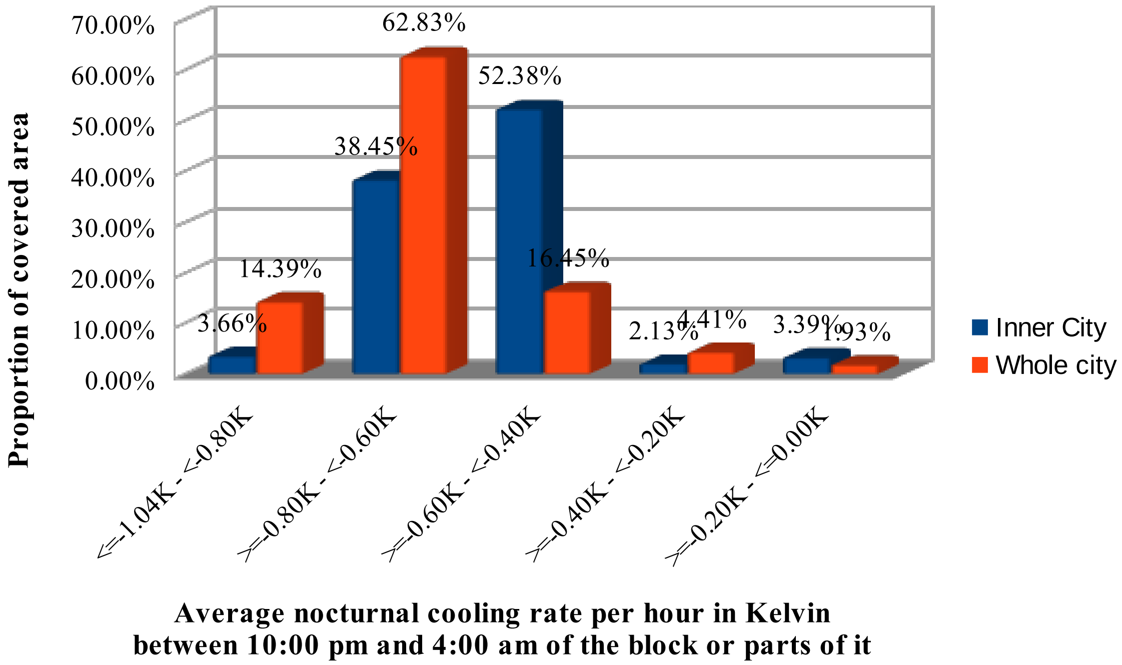


Fig. 110 - Average nocturnal cooling rate per hour in Kelvin between 10:00 pm and 4:00 am of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

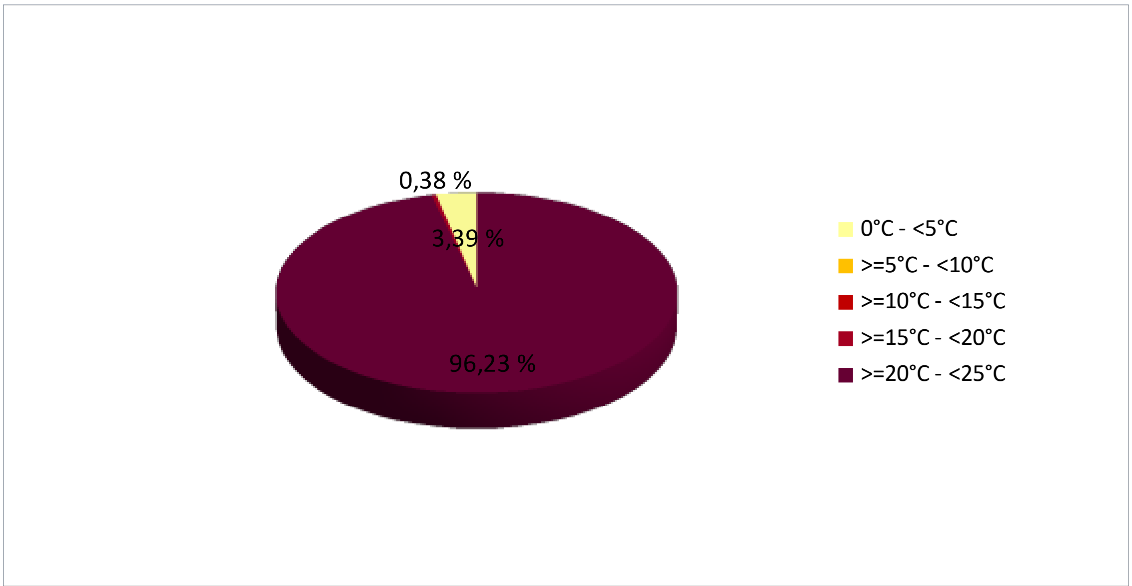


Fig. 111 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

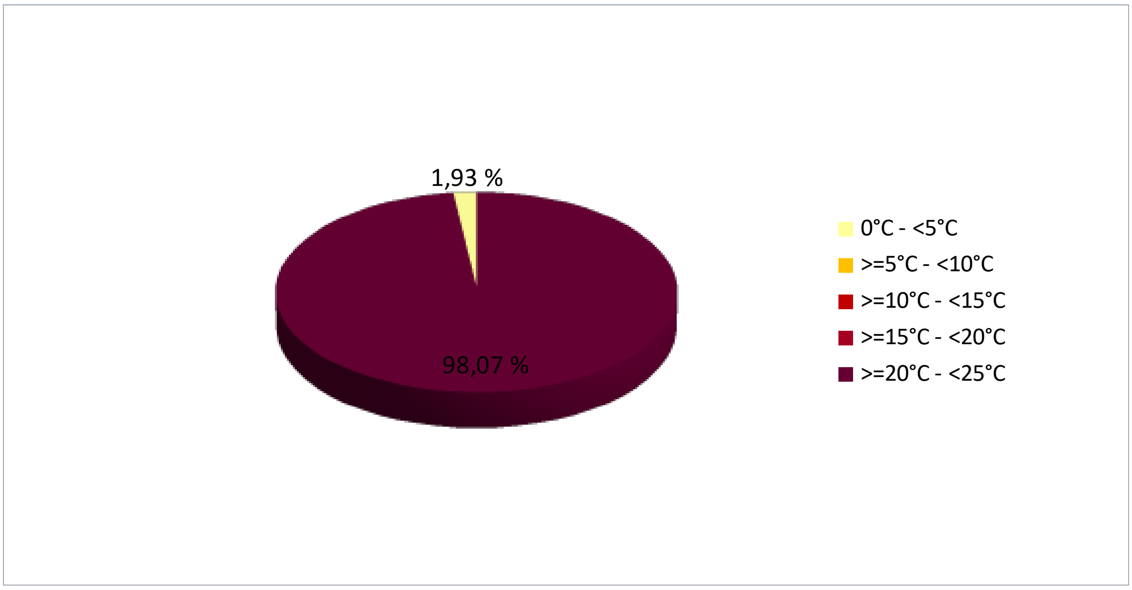
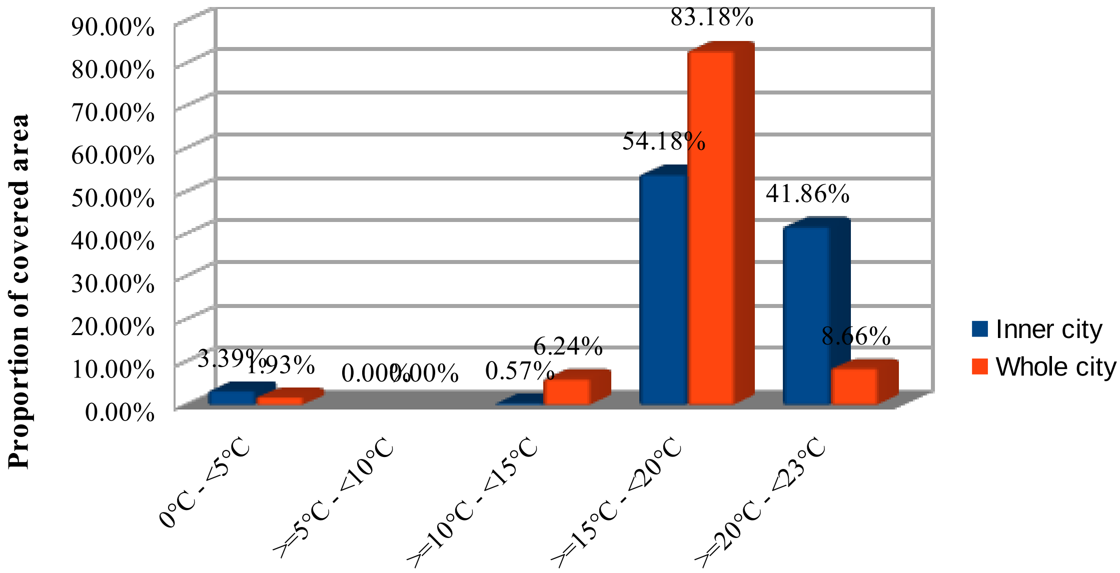


Fig. 112 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 4:00 am of the block or parts of it

Fig. 113 - Average evaluation index of the Physiologicaal Equivalent Temperature (PET) in Celsius at 2 m above the ground at 4:00 am of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

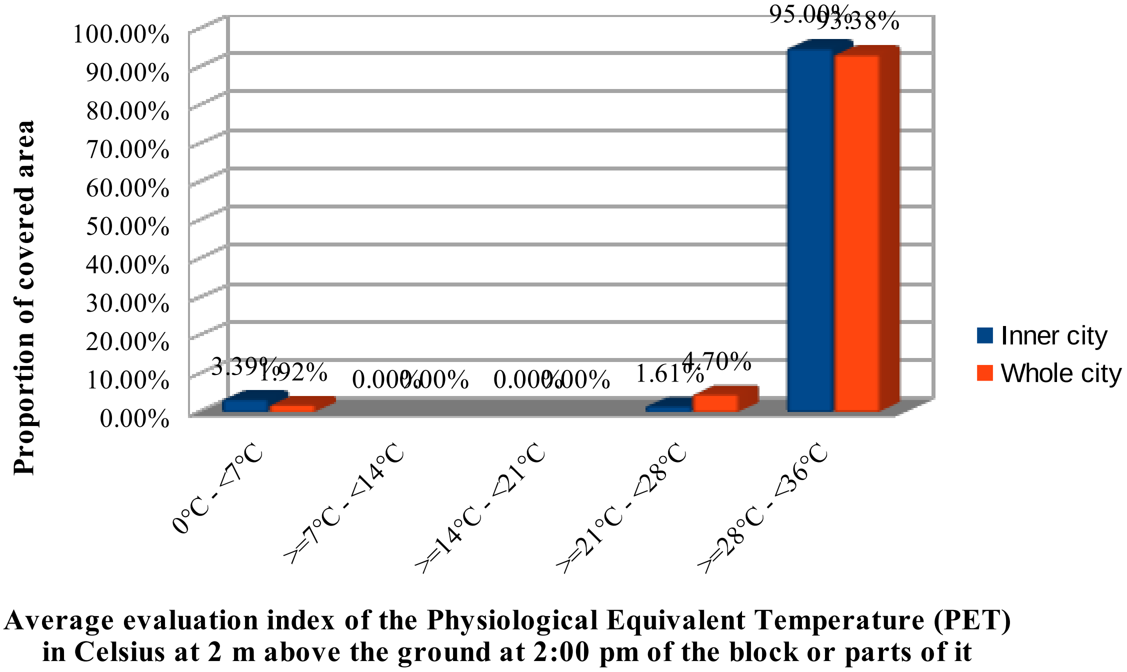


Fig. 114 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 2:00 pm of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

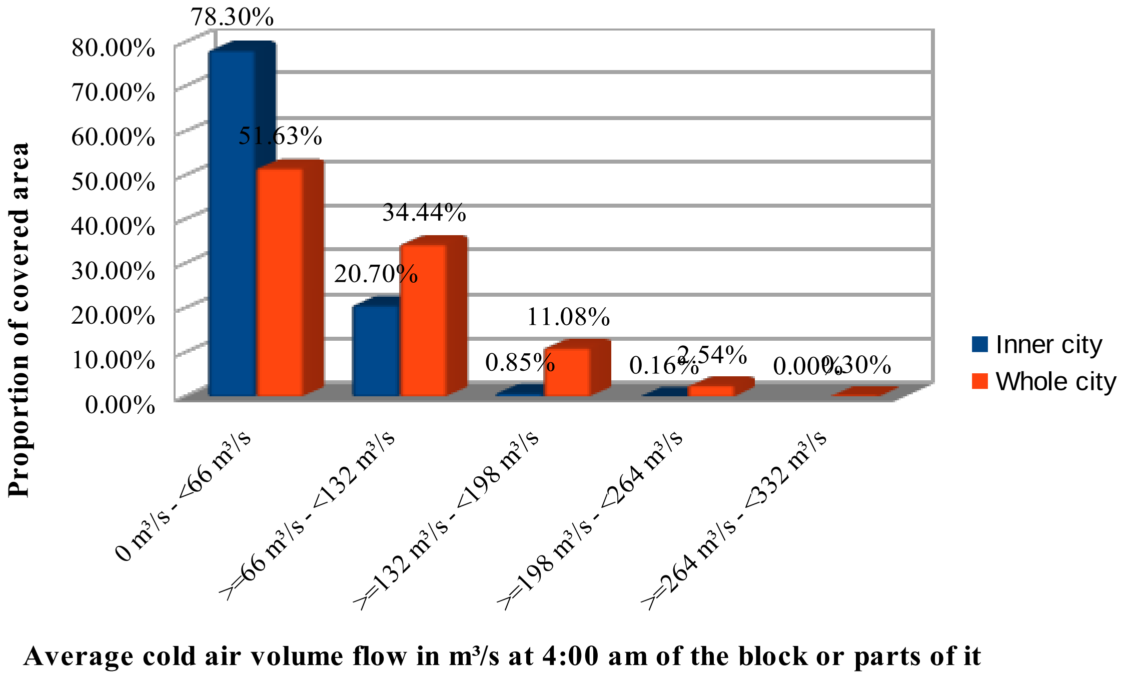


Fig. 115 - Average cold air volume flow in m³/s at 4:00 am of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

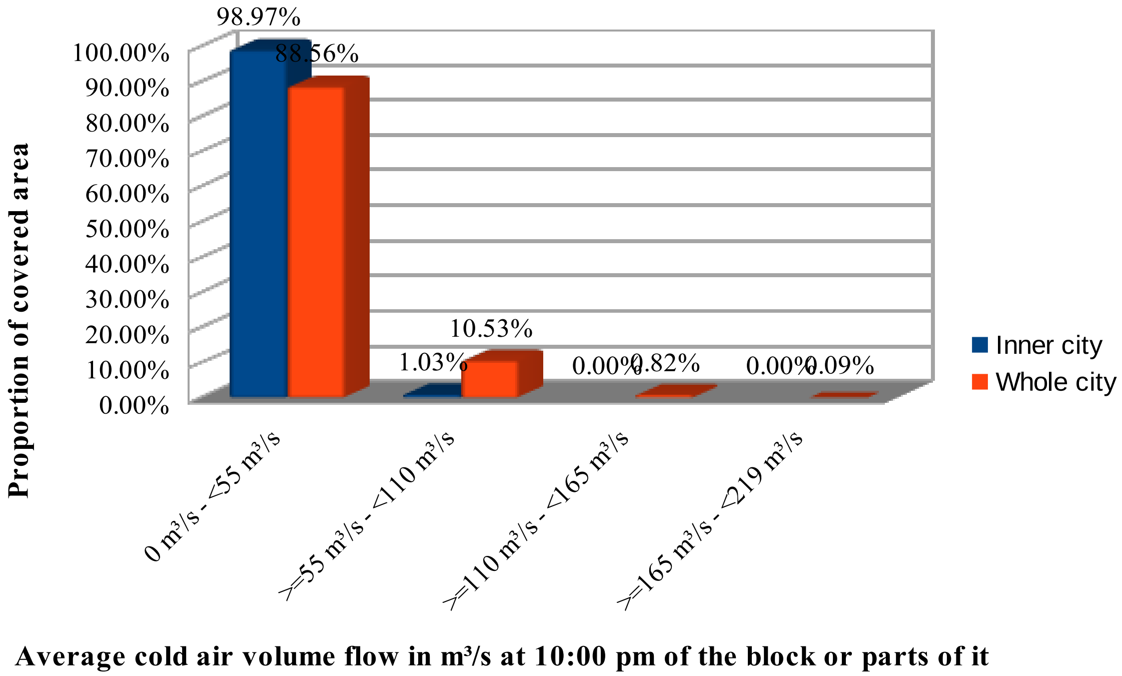


Fig. 116 - Average cold air volume flow in m^3/s at 10:00 pm of the block or parts of it in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

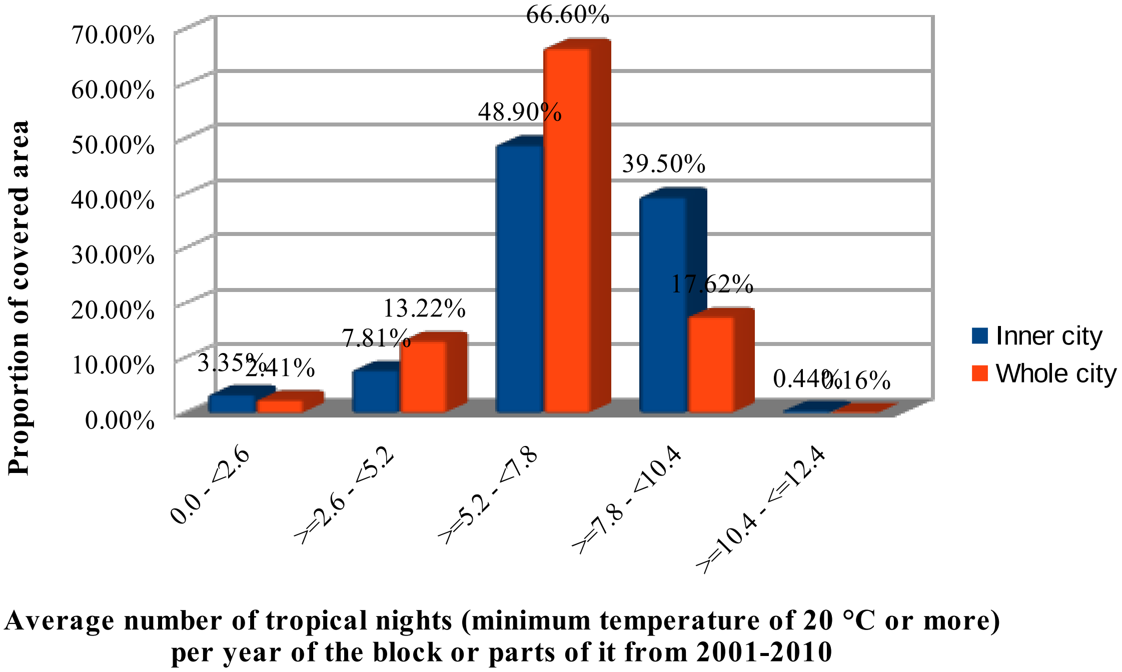


Fig. 117 - Average number of tropical nights (minimum temperature of 20 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

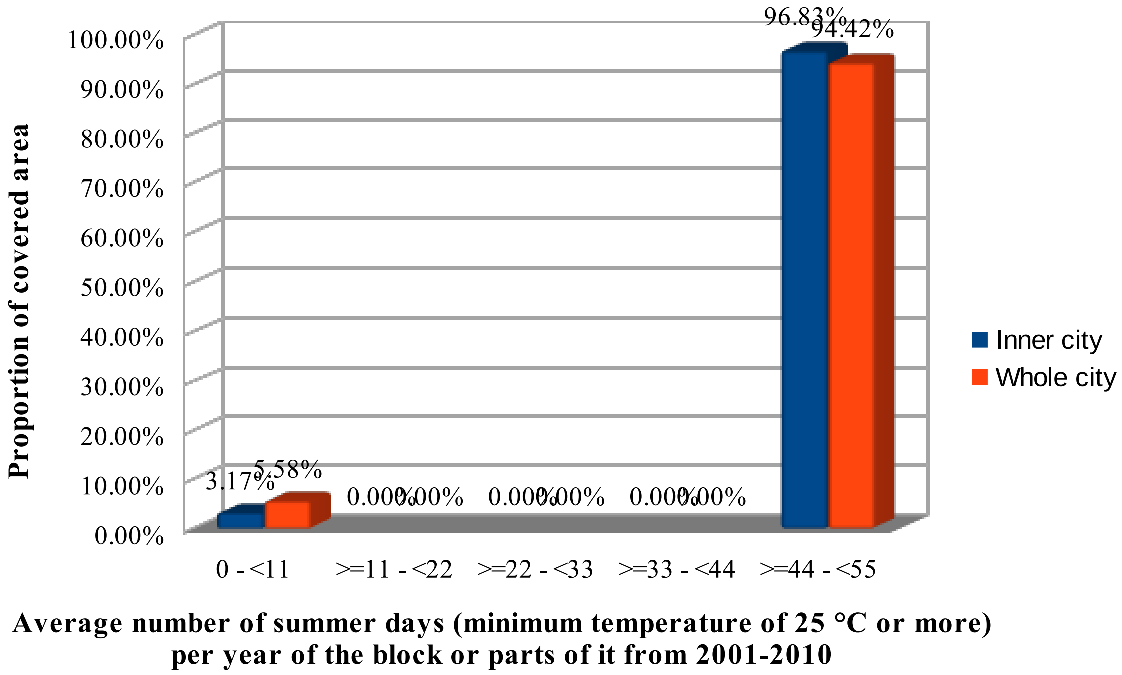


Fig. 118 - Average number of summer days (minimum temperature of 25 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

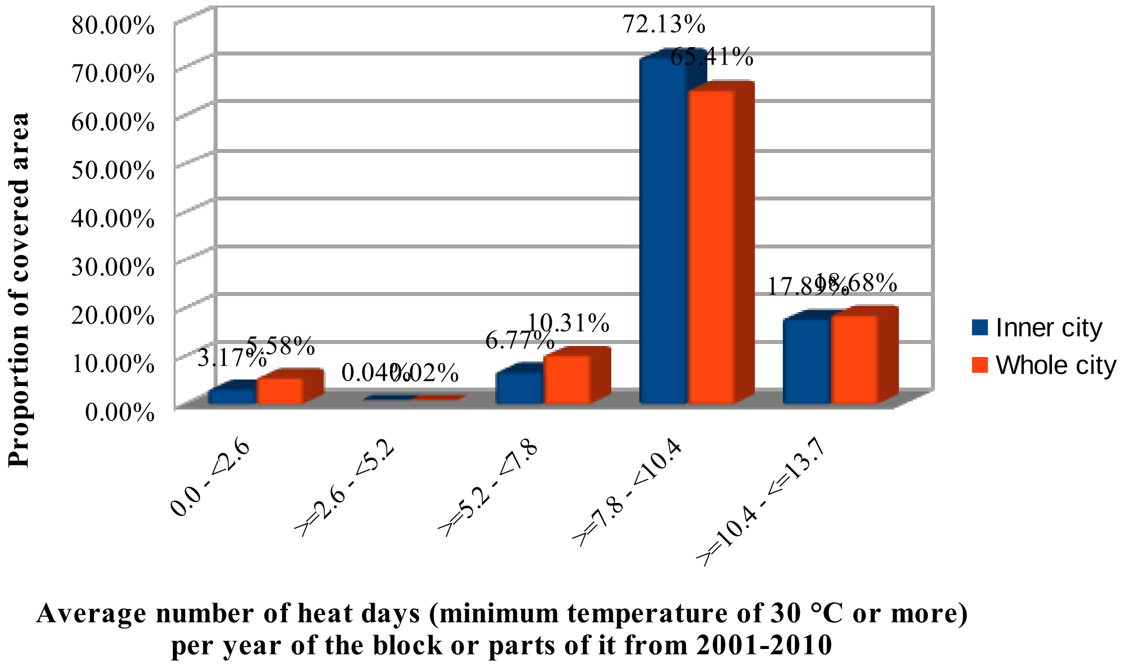


Fig. 119 - Average number of heat days (minimum temperature of 30 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

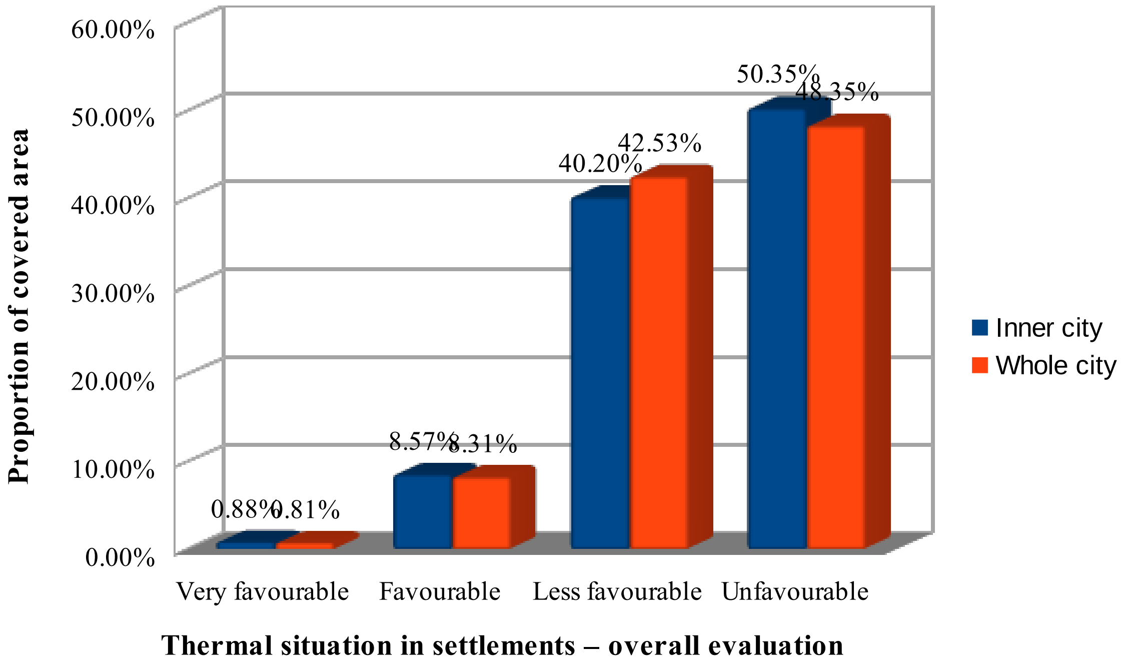


Fig. 120 - Thermal situation in settlements – overall evaluation in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

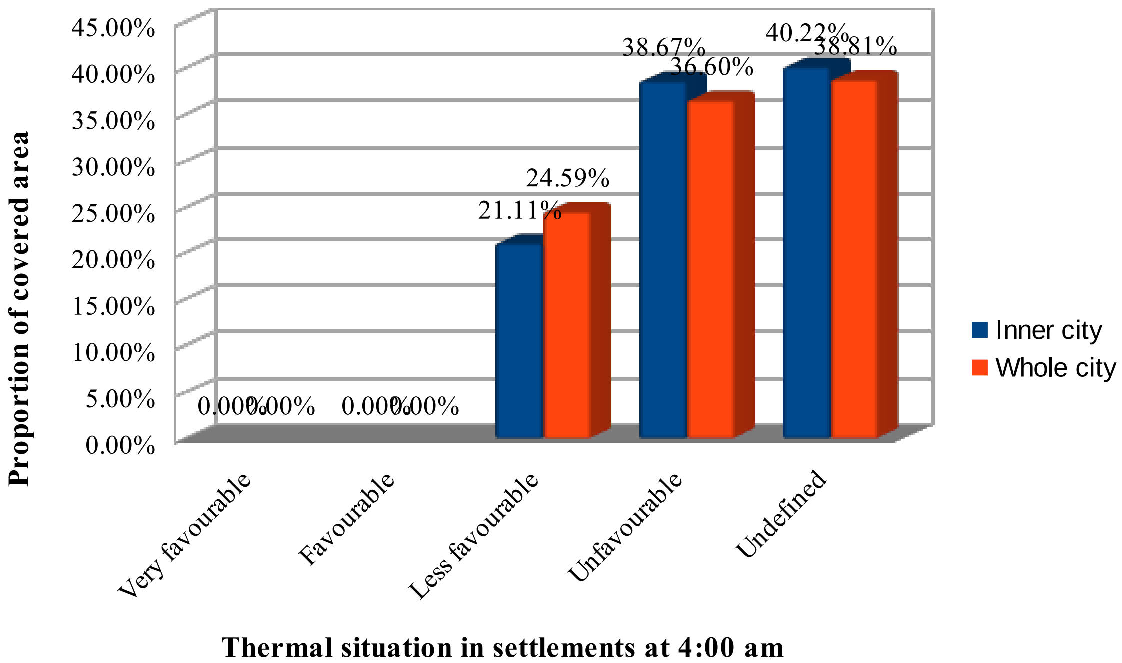


Fig. 121 - Thermal situation in settlements at 4:00 am in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

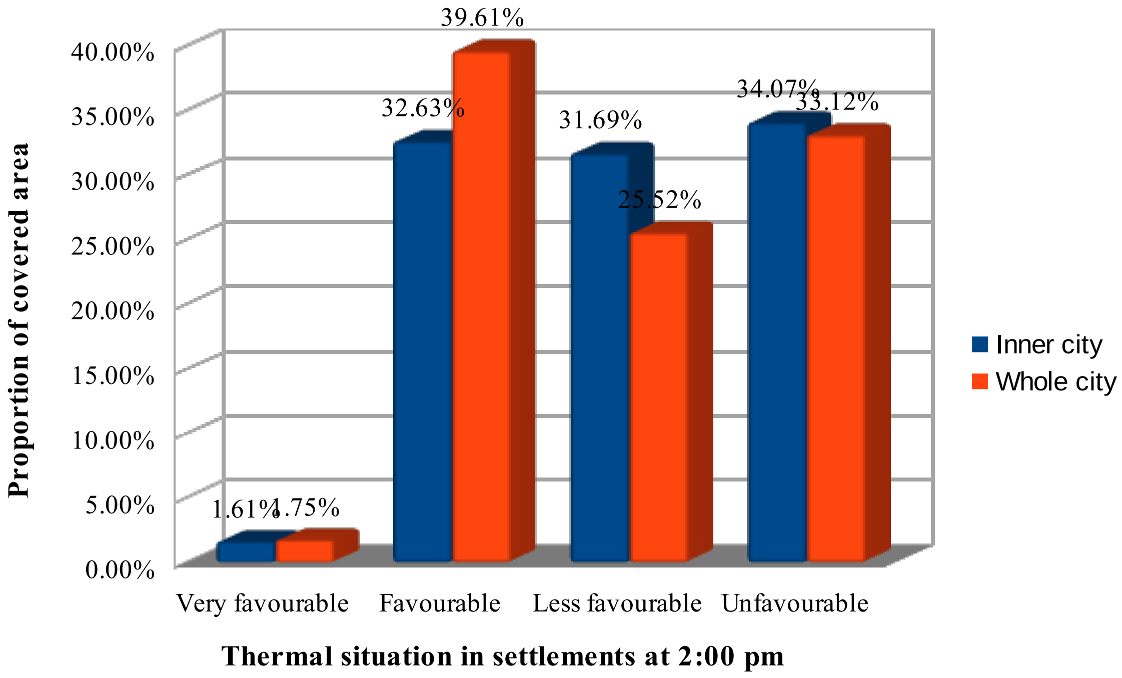


Fig. 122 - Thermal situation in settlements at 2:00 pm in 2015 within 500 m distance of public accessible managed green areas/parks of a minimum size of 0.5 ha in the inner and outer city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

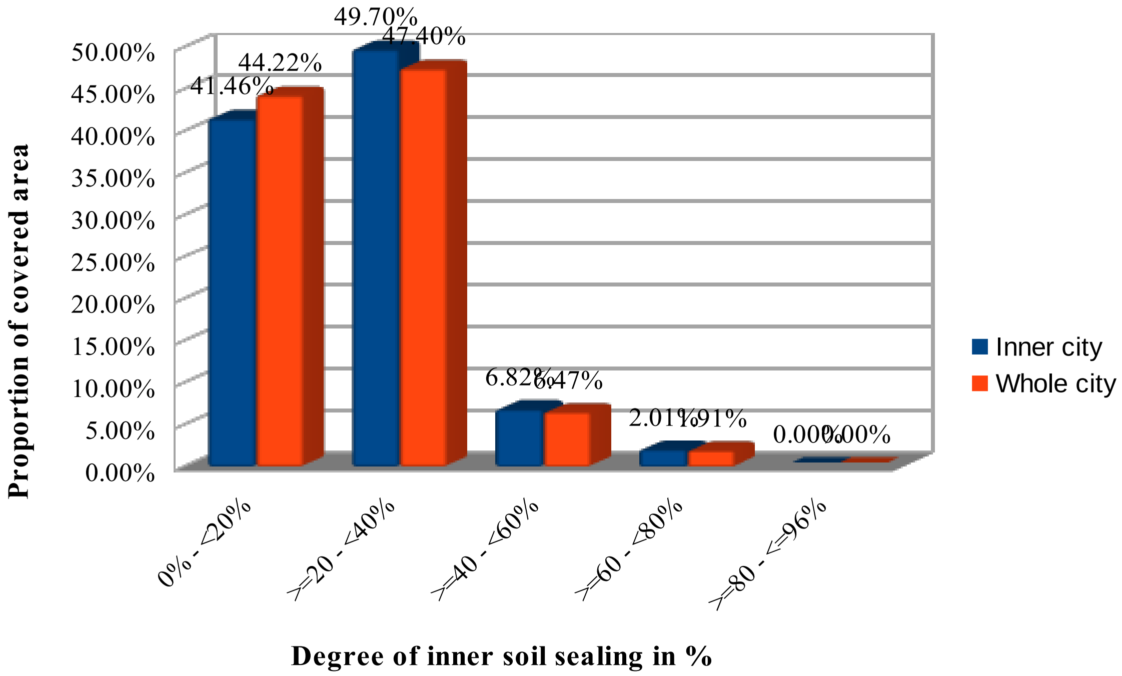


Fig. 123 - Degree of soil sealing in % in 2015 of public accessible managed green areas/parks in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

2.1.2. Allotments (2015)

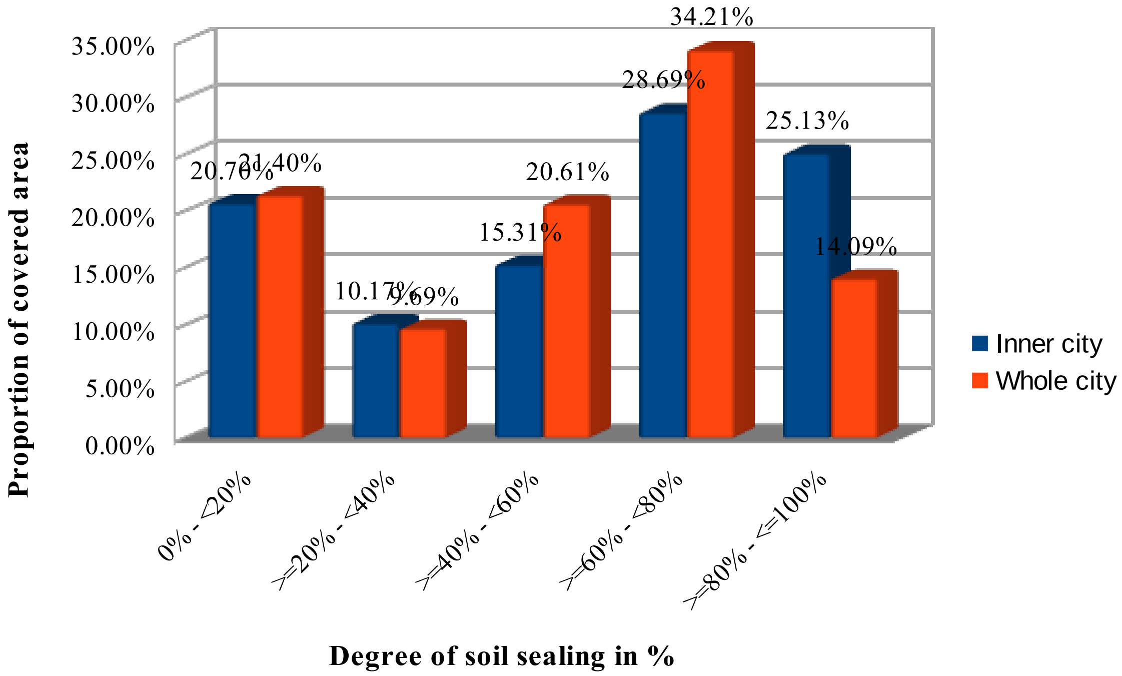


Fig. 124 - Degree of soil sealing in % in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

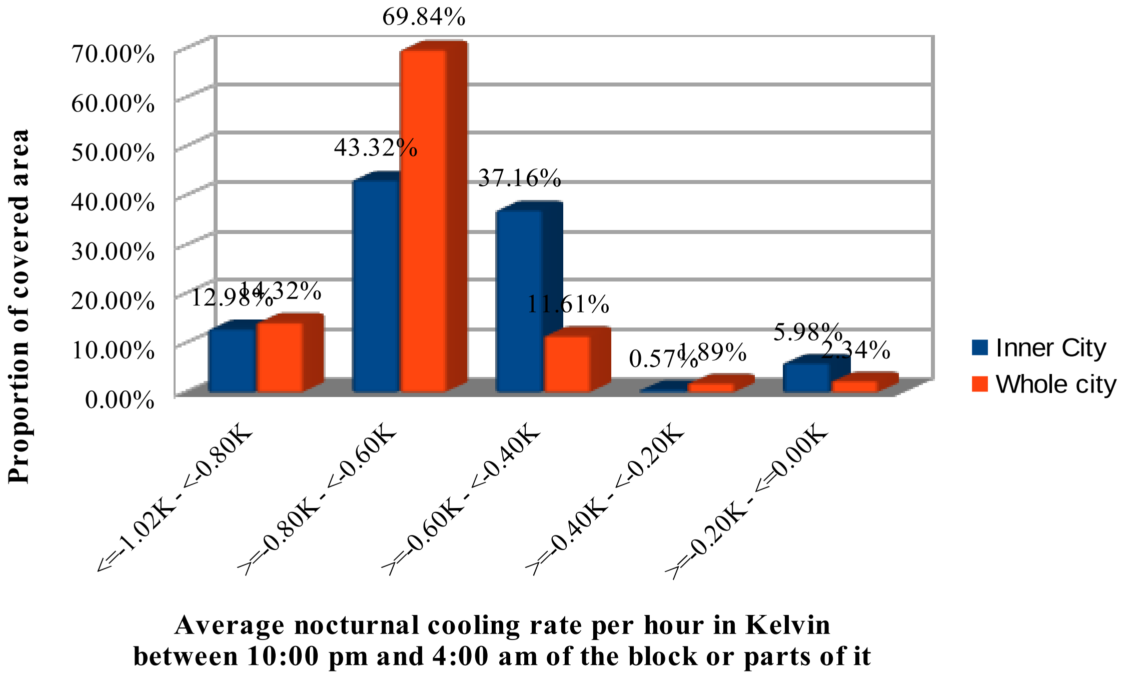


Fig. 125 - Average nocturnal cooling rate per hour in Kelvin between 10:00 pm and 4:00 am of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

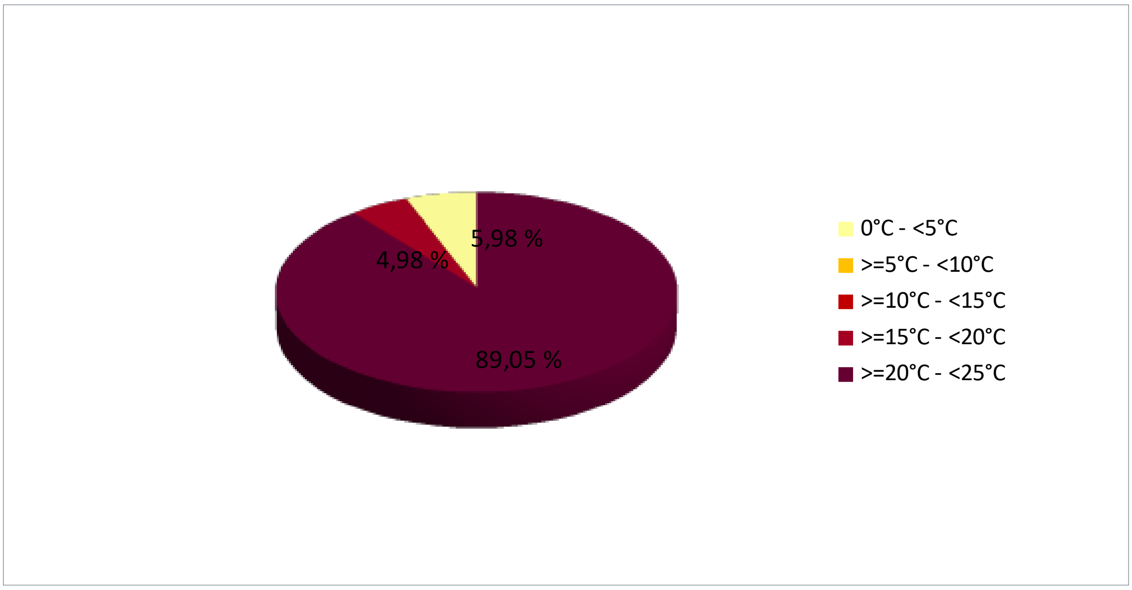


Fig. 126 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

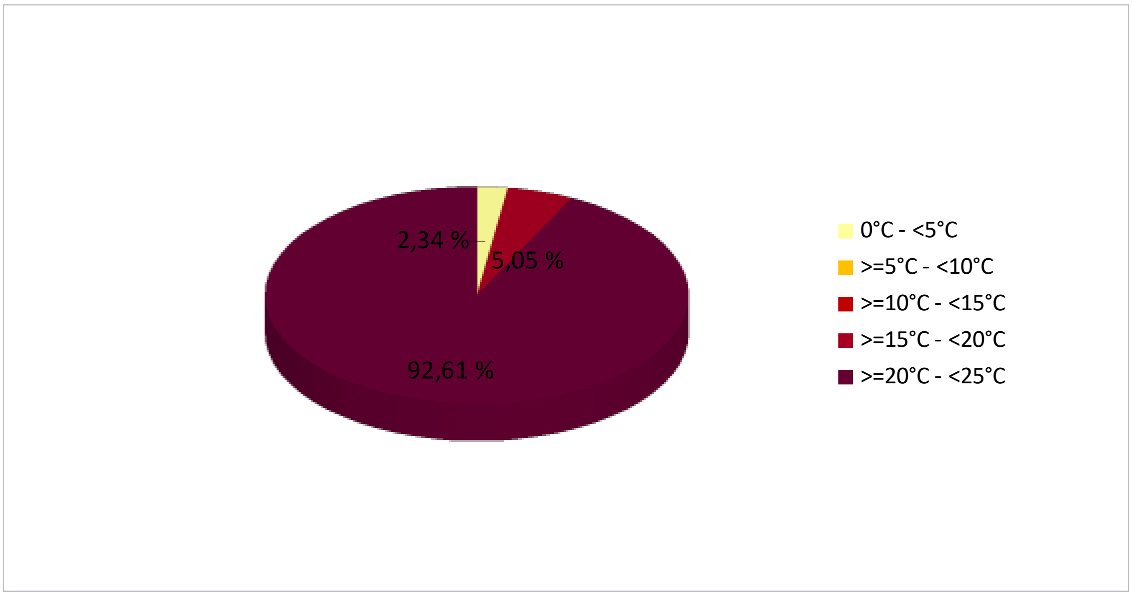


Fig. 127 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

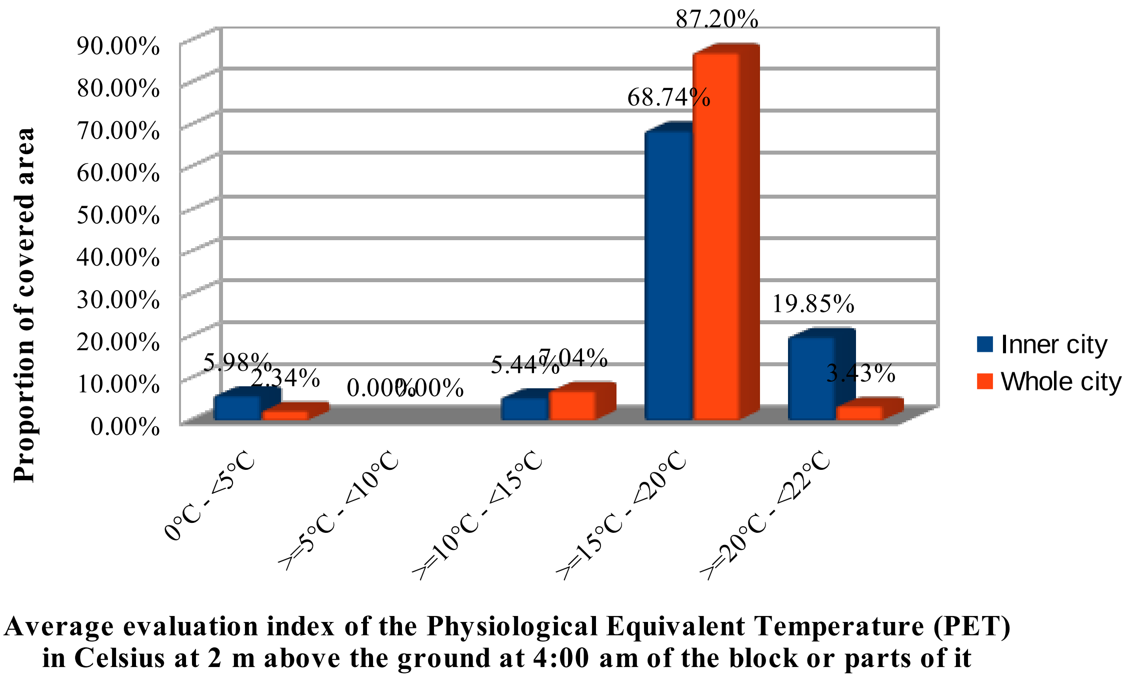


Fig. 128 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 4:00 am of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

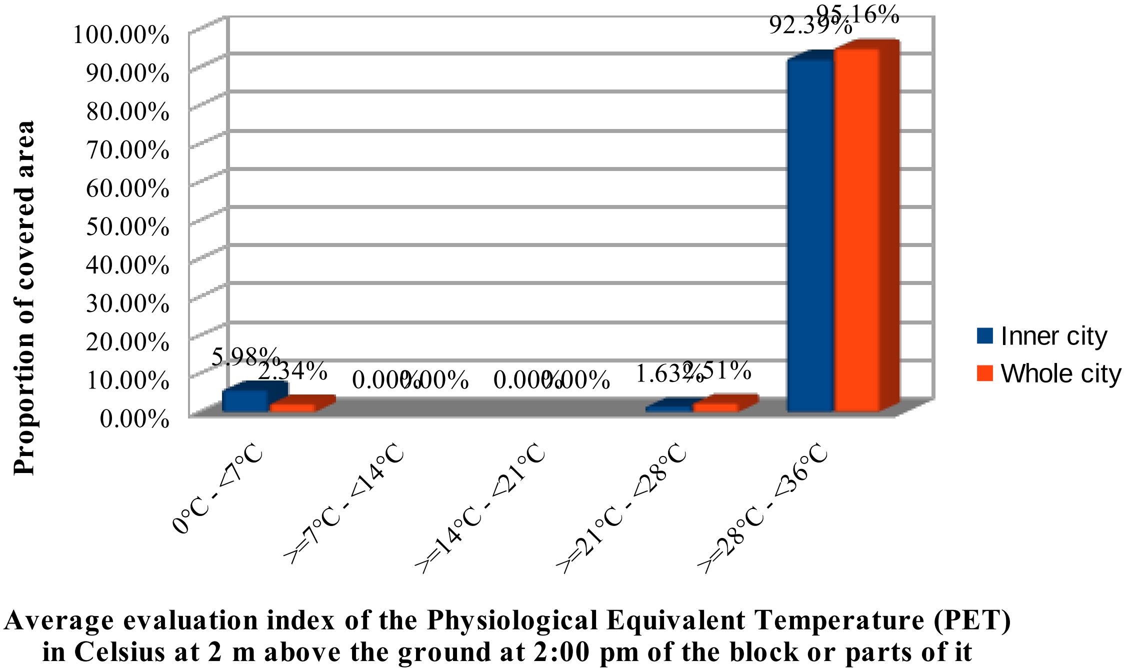


Fig. 129 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 2:00 pm of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

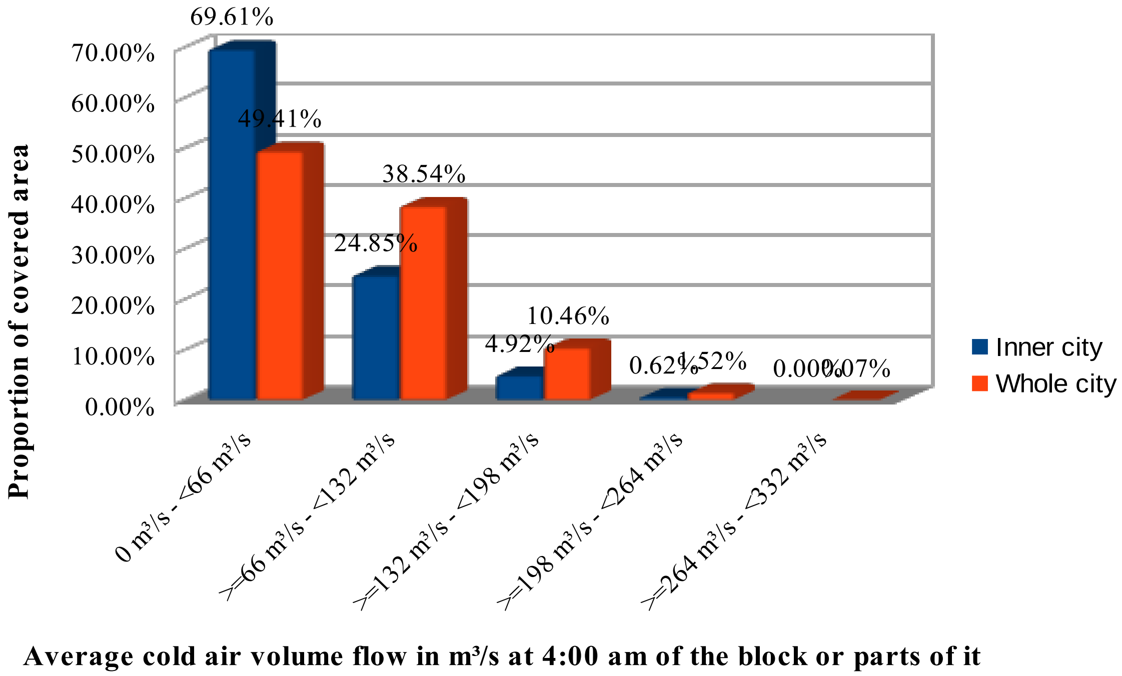


Fig. 130 - Average cold air volume flow in m³/s at 4:00 am of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

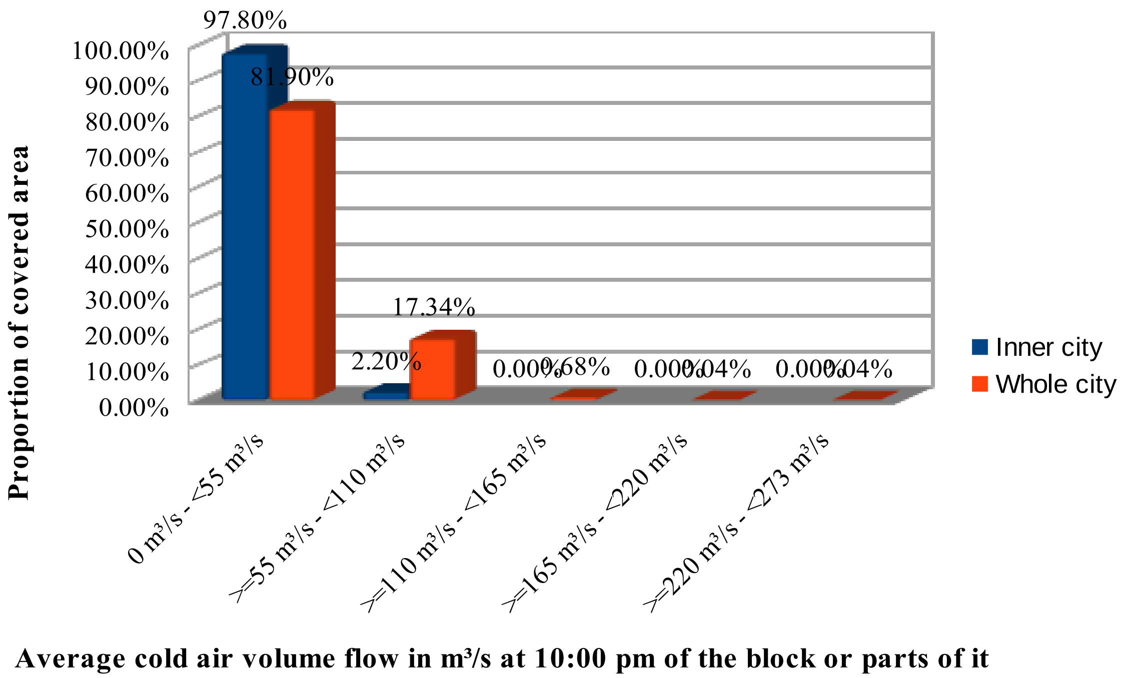


Fig. 131 - Average cold air volume flow in m³/s at 10:00 pm of the block or parts of it in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

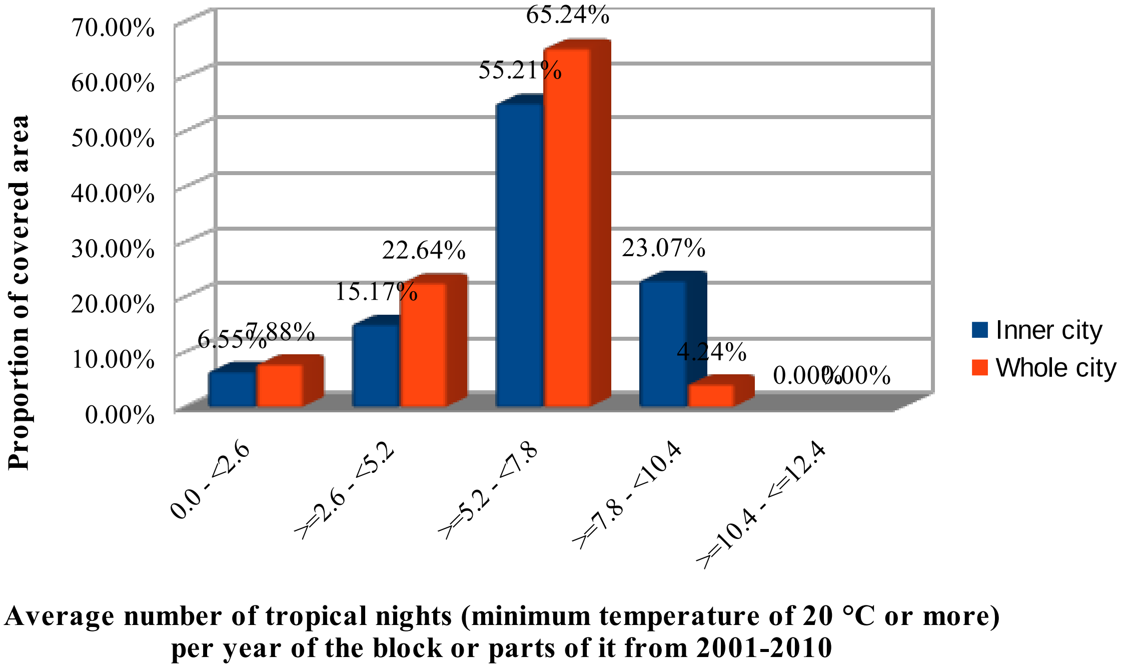


Fig. 132 - Average number of tropical nights (minimum temperature of 20 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

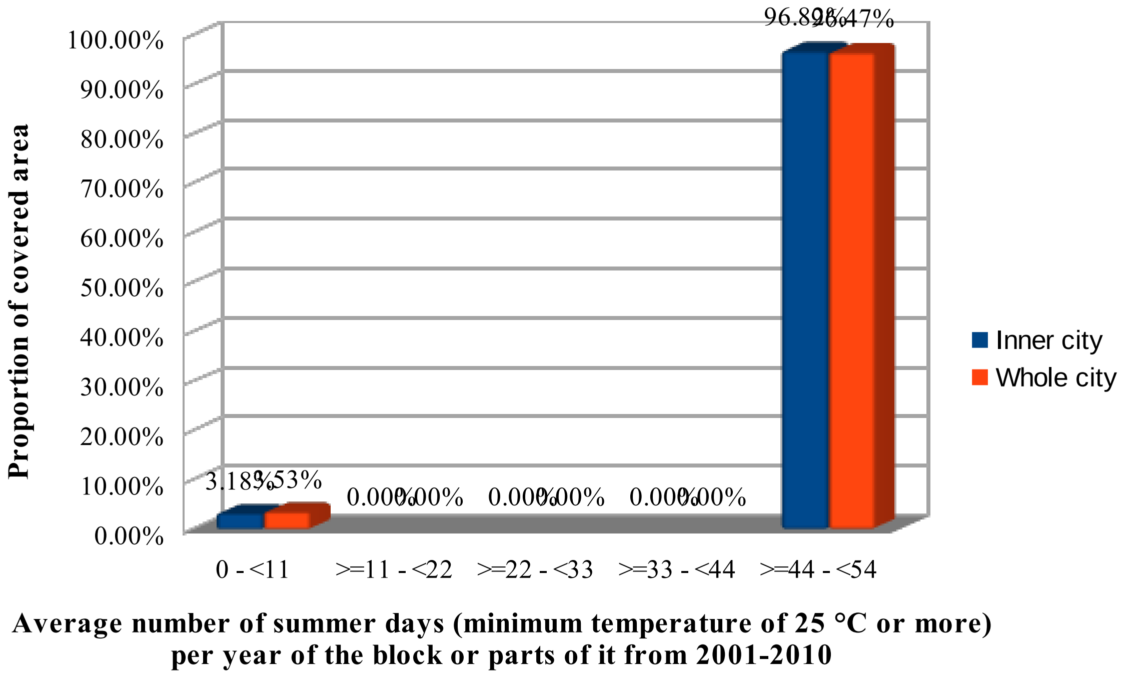


Fig. 133 - Average number of summer days (minimum temperature of 25 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

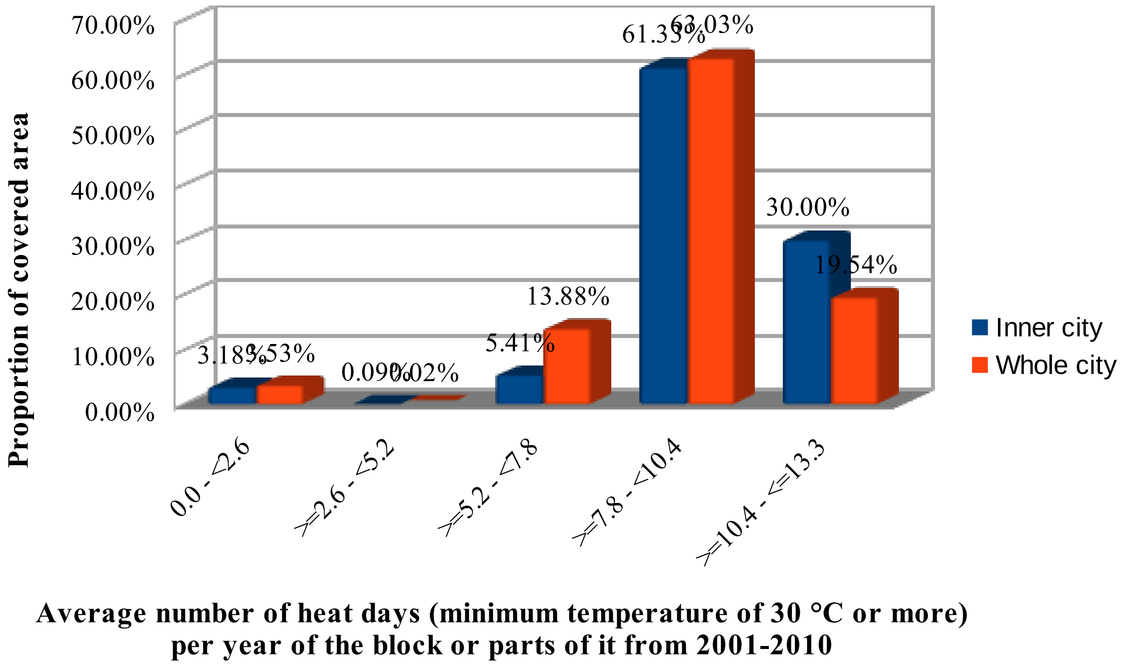


Fig. 134 - Average number of heat days (minimum temperature of 30 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

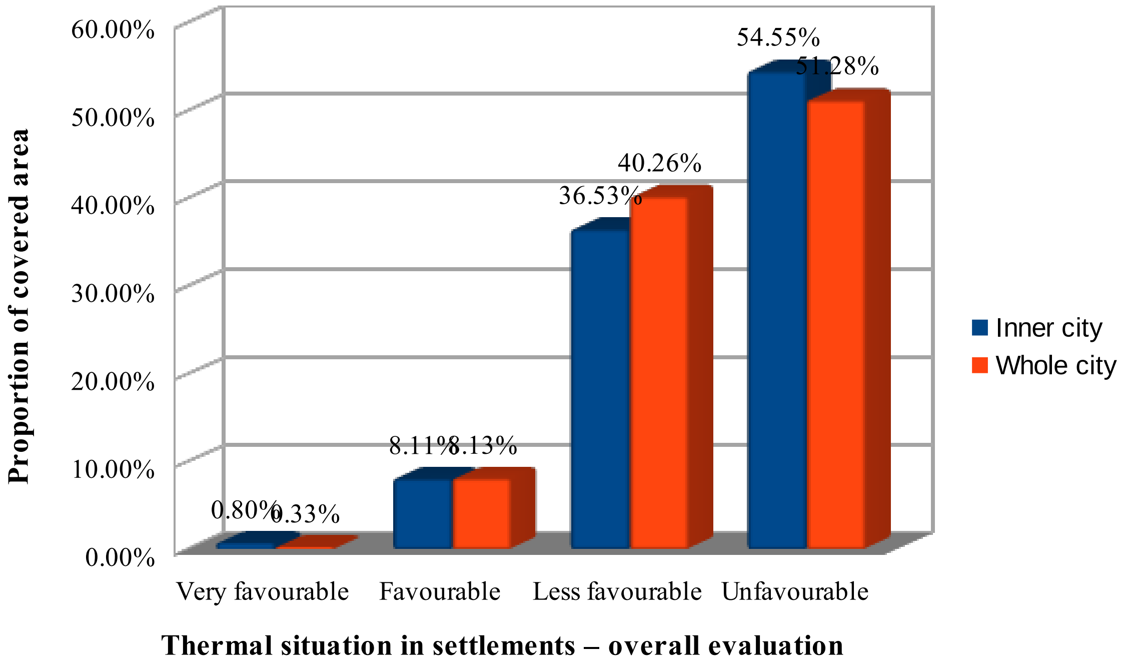


Fig. 135 - Thermal situation in settlements – overall evaluation in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

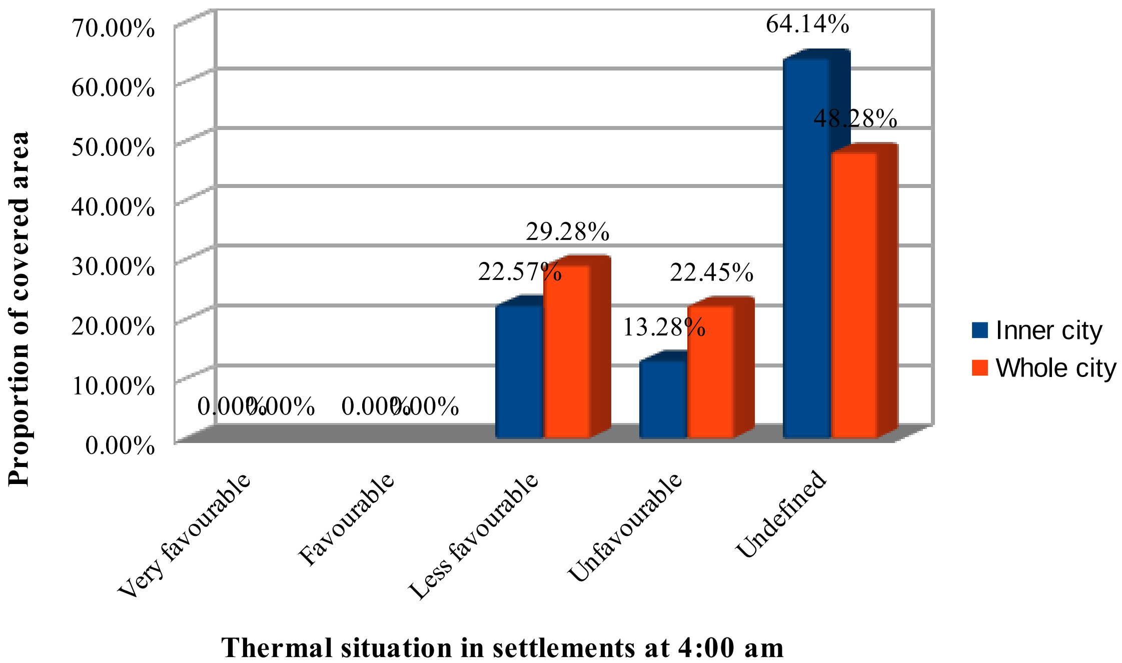


Fig. 136 - Thermal situation in settlements at 4:00 am in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

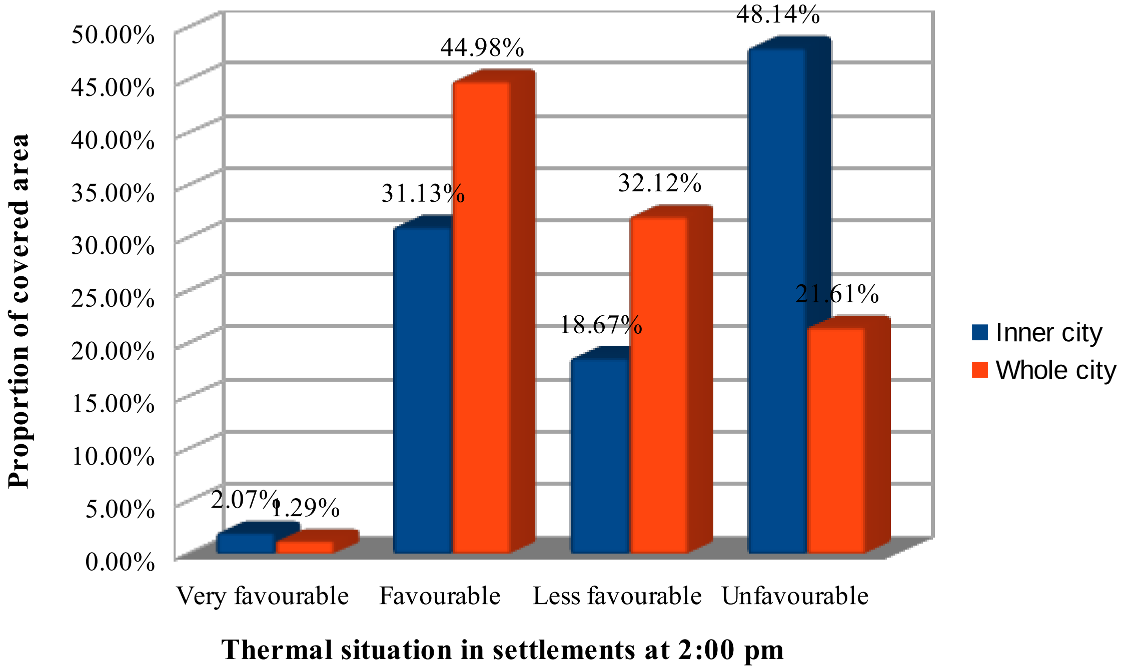


Fig. 137 - Thermal situation in settlements at 2:00 pm in 2015 within 500 m distance of allotments of a minimum size of 0.5 ha in the inner and outer city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

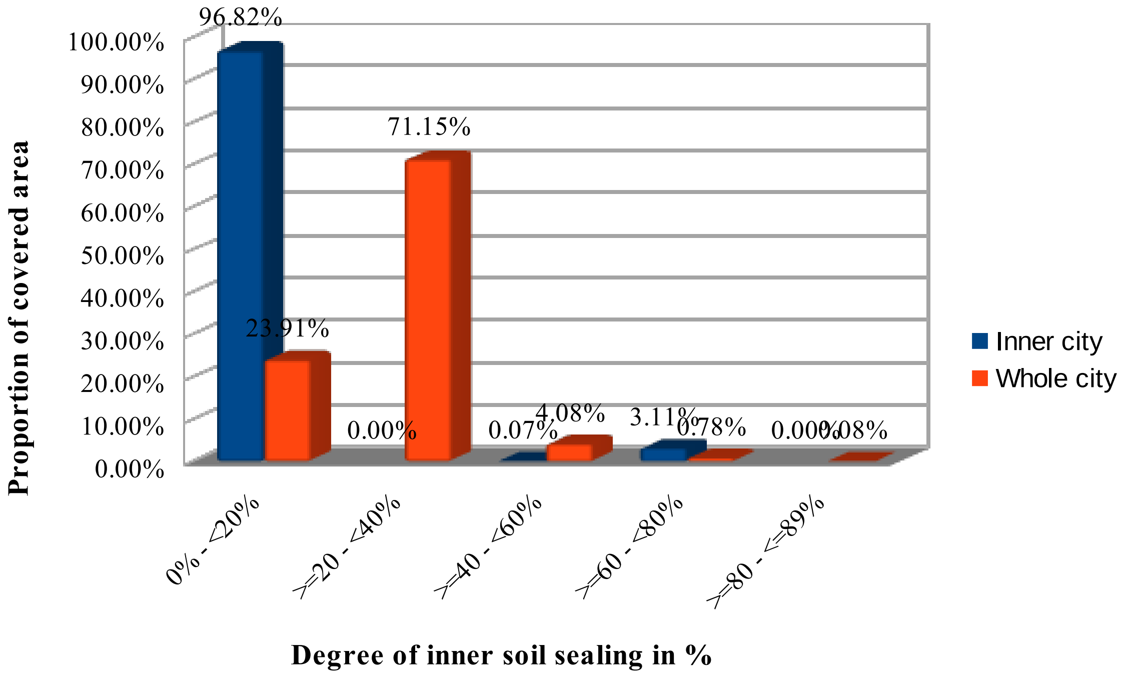


Fig. 138 - Degree of soil sealing in % in 2015 of allotments in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

2.1.3. Cemeteries (2010)

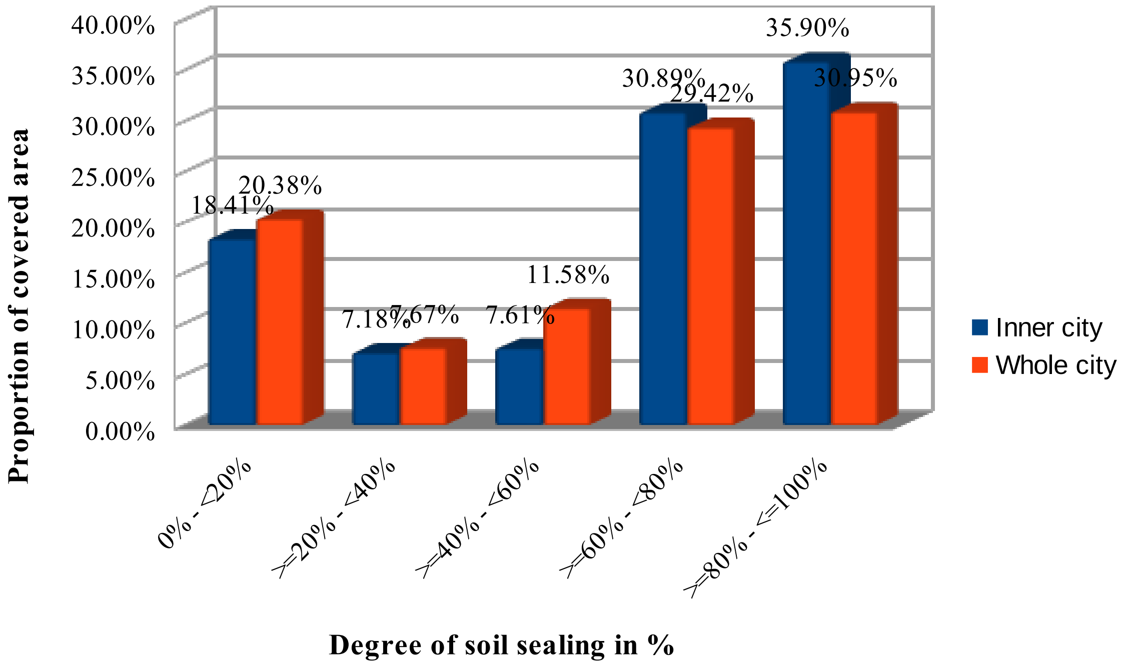


Fig. 139 - Degree of soil sealing in % in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

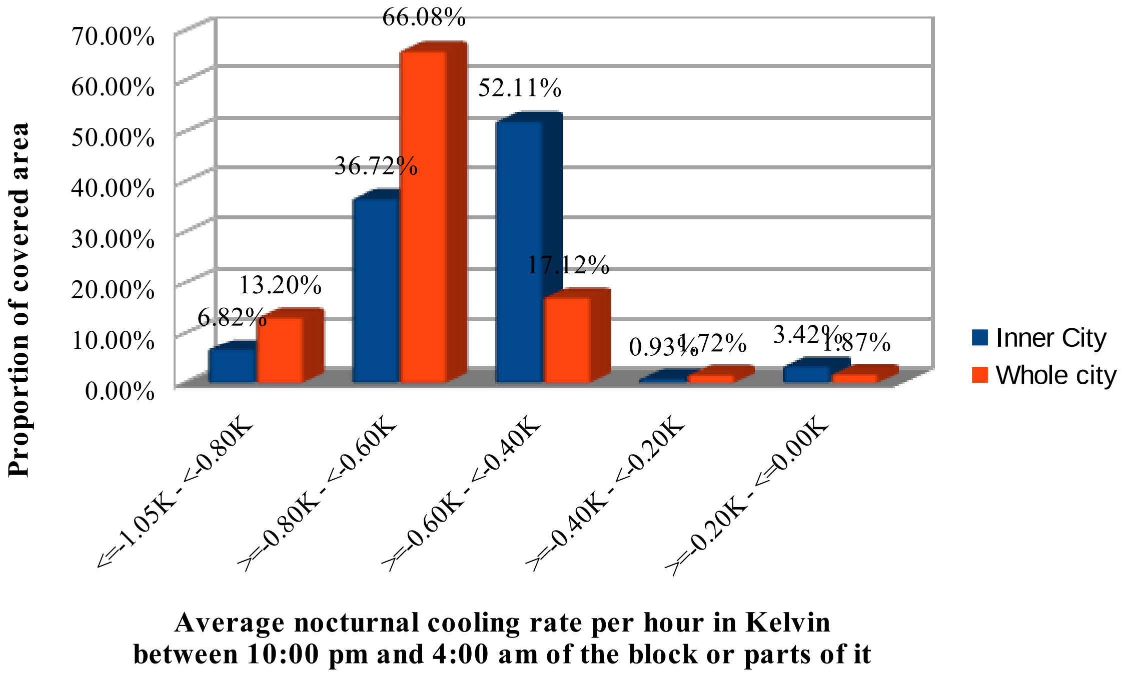


Fig. 140 - Average nocturnal cooling rate per hour in Kelvin between 10:00 pm and 4:00 am of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

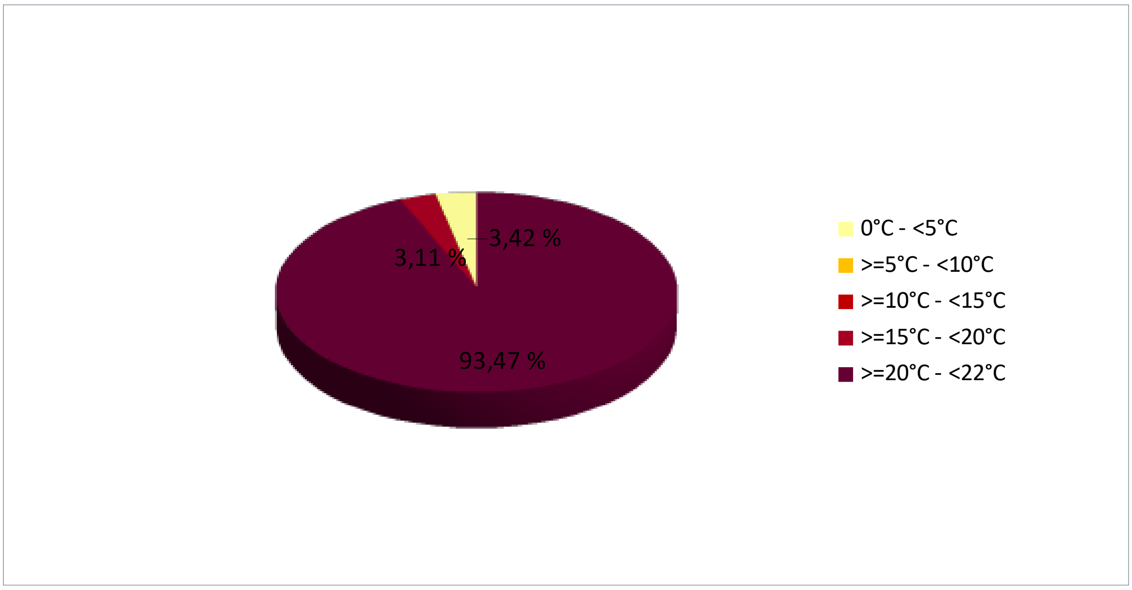


Fig. 141 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

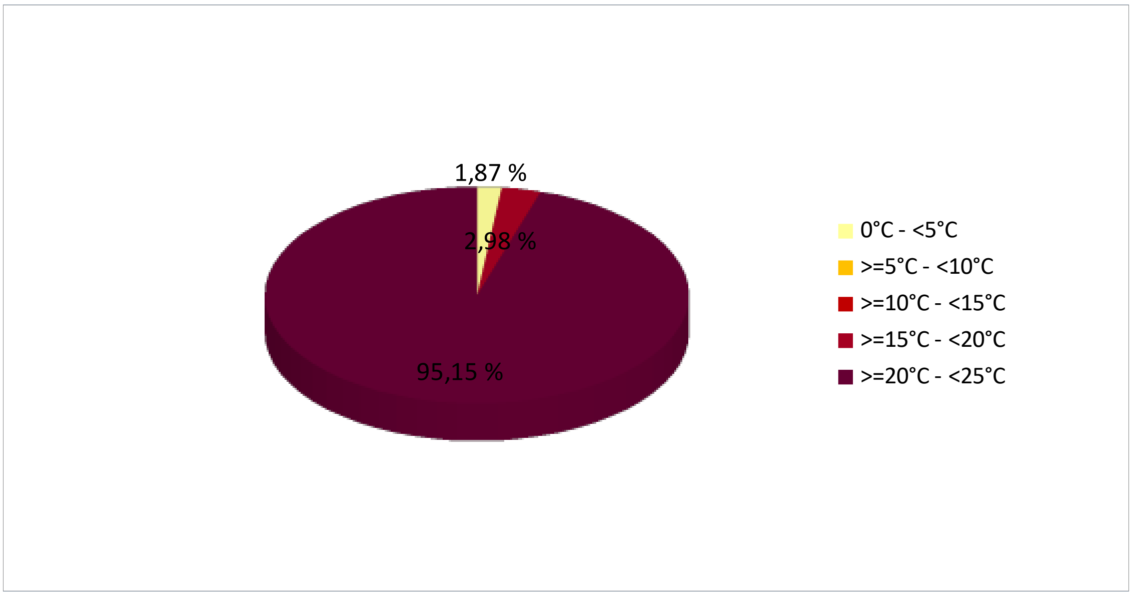


Fig. 142 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 10:00 pm of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

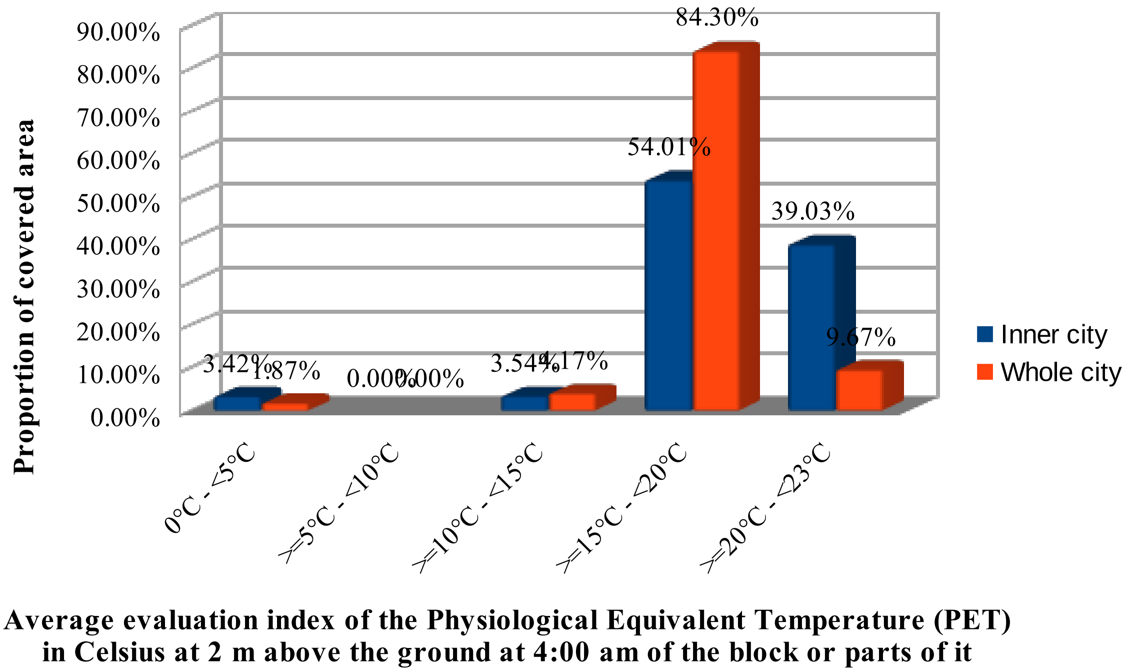


Fig. 143 - Average evaluation index of the Physiologi100al Equivalent Temperature (PET) in Celsius at 2 m above the ground at 4:00 am of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

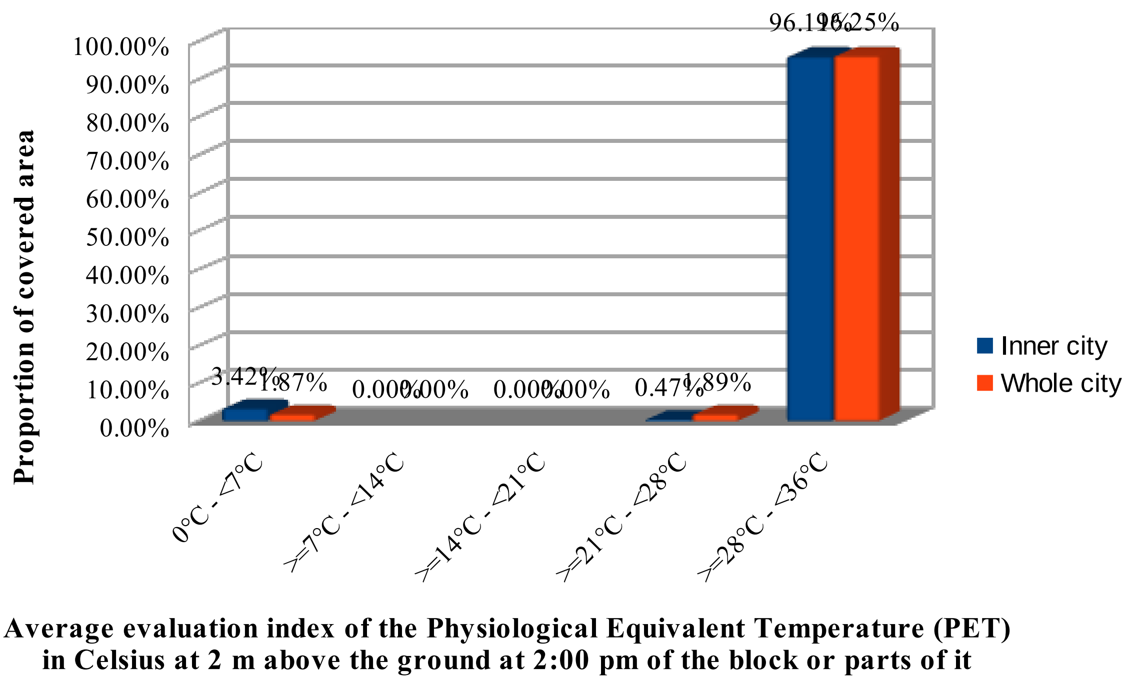


Fig. 144 - Average evaluation index of the Physiological Equivalent Temperature (PET) in Celsius at 2 m above the ground at 2:00 pm of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

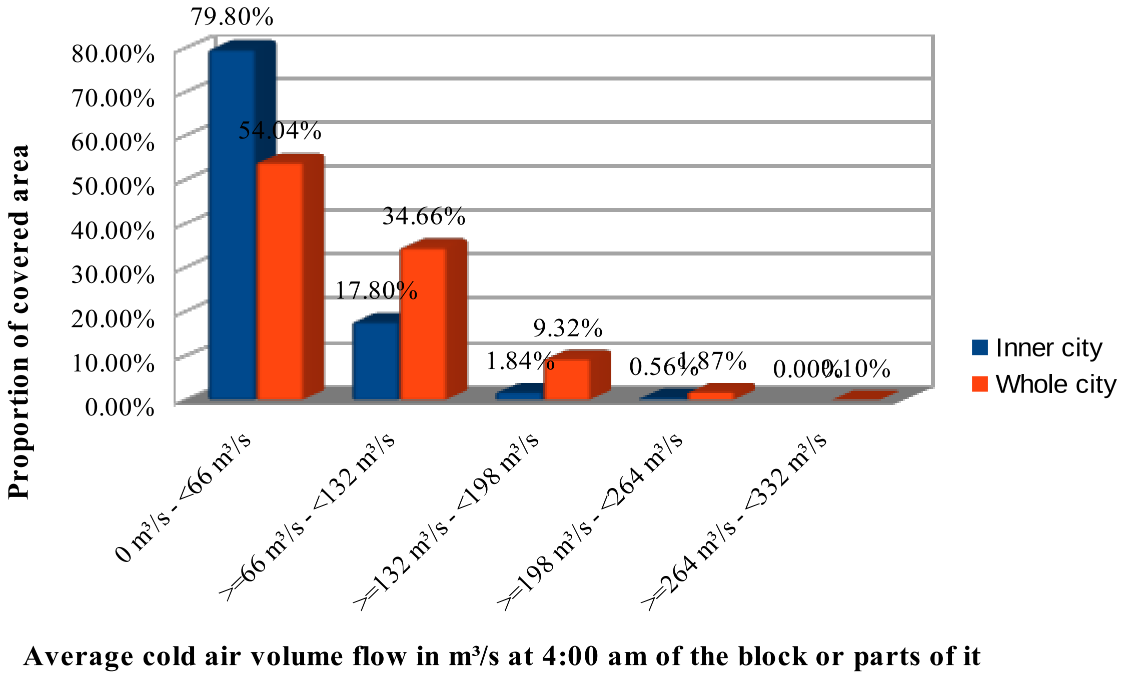


Fig. 145 - Average cold air volume flow in m³/s at 4:00 am of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

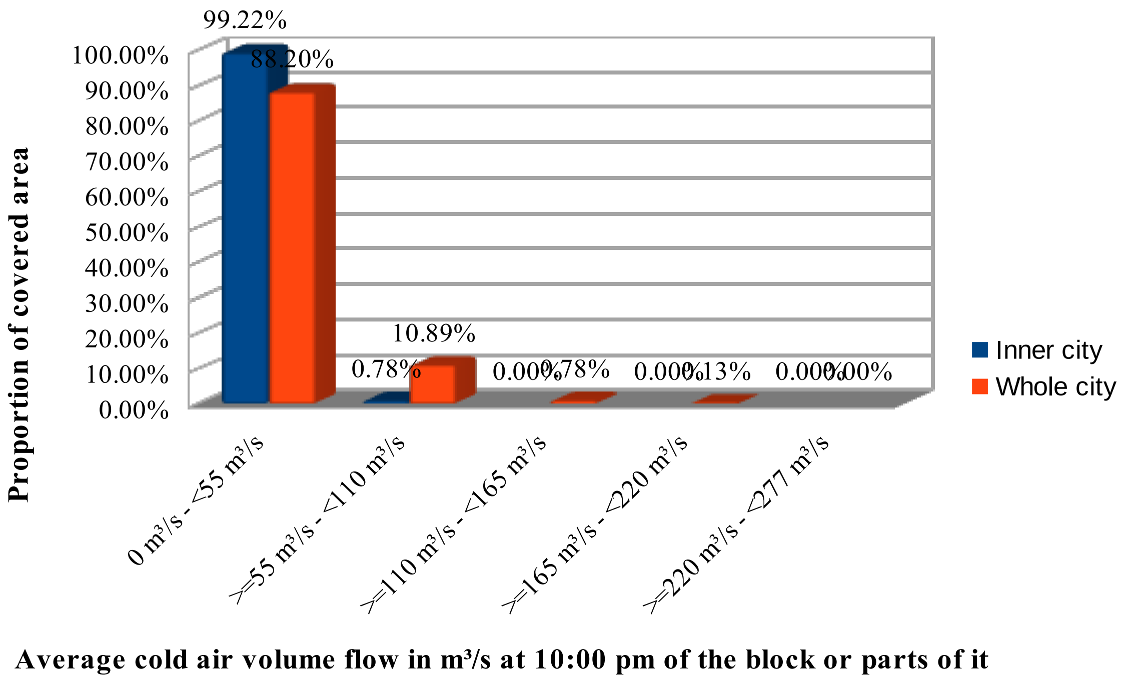


Fig. 146 - Average cold air volume flow in m³/s at 10:00 pm of the block or parts of it in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

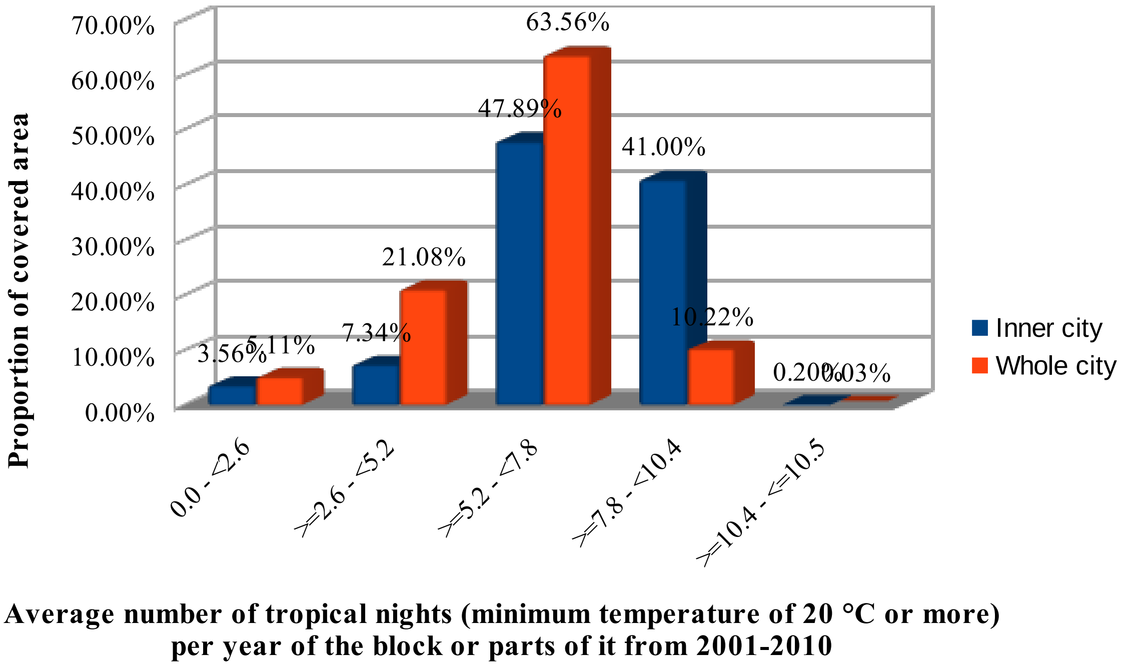


Fig. 147 - Average number of tropical nights (minimum temperature of 20 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

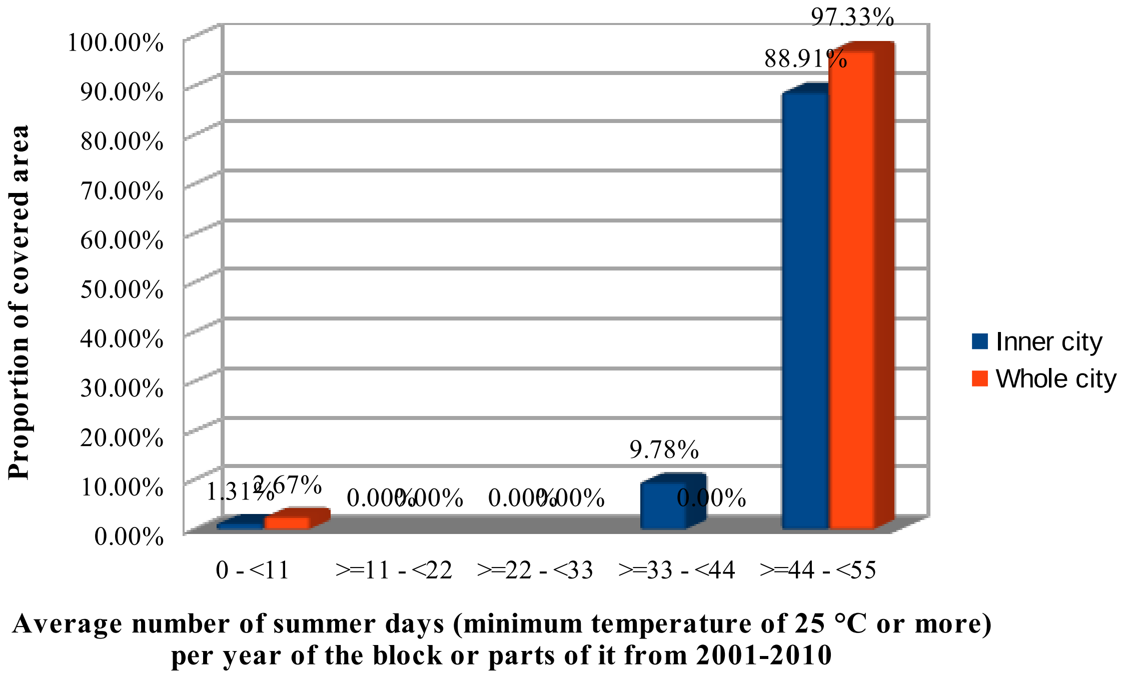


Fig. 148 - Average number of summer days (minimum temperature of 25 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

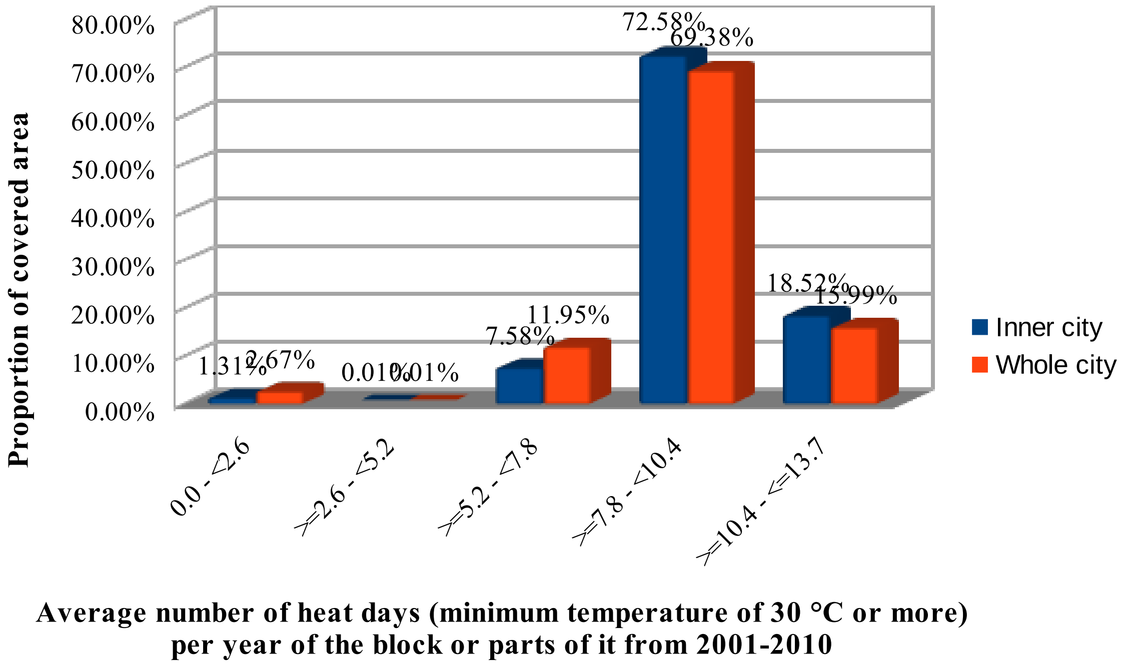


Fig. 149 - Average number of heat days (minimum temperature of 30 °C or more) per year of the block or parts of it from 2001-2010 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

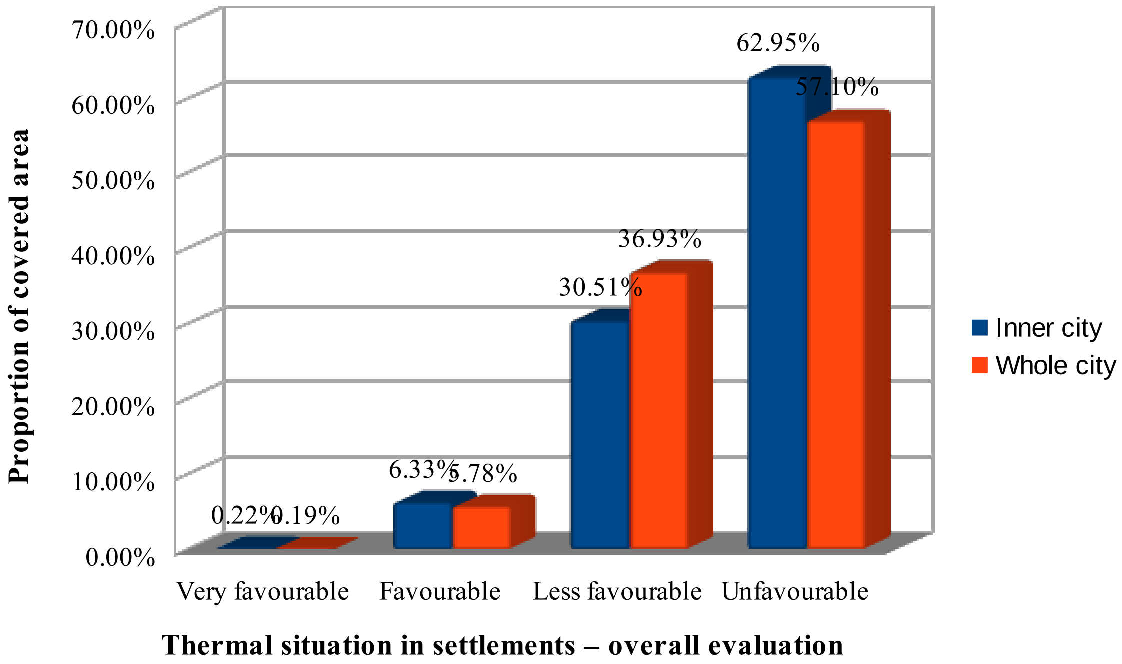


Fig. 150 - Thermal situation in settlements – overall evaluation in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

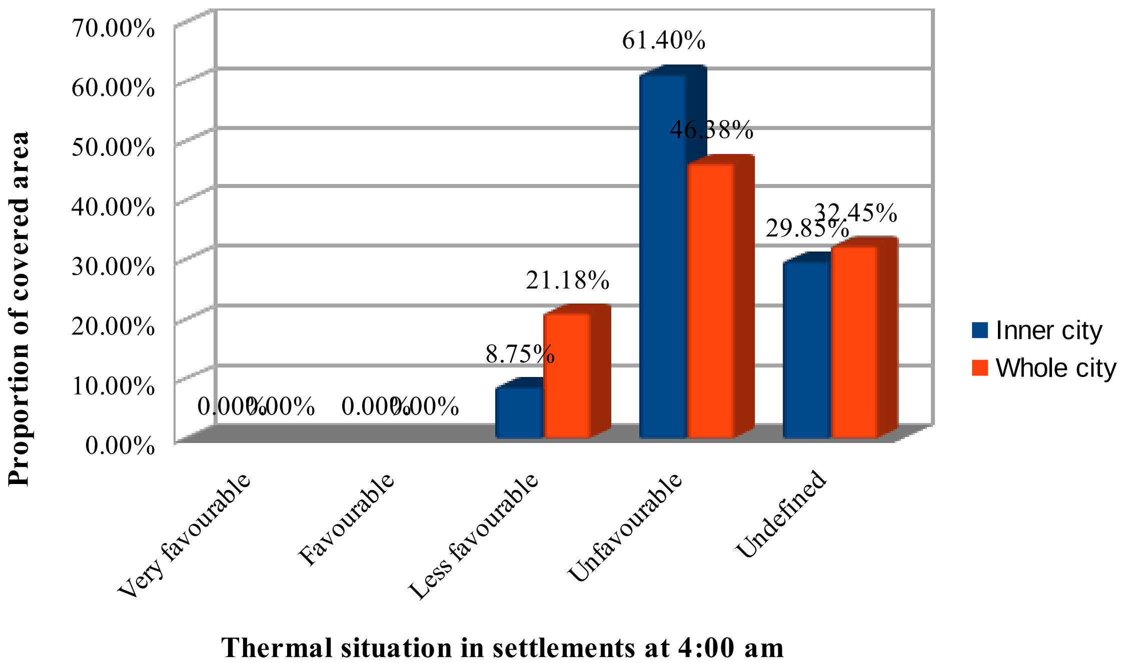


Fig. 151 - Thermal situation in settlements at 4:00 am in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

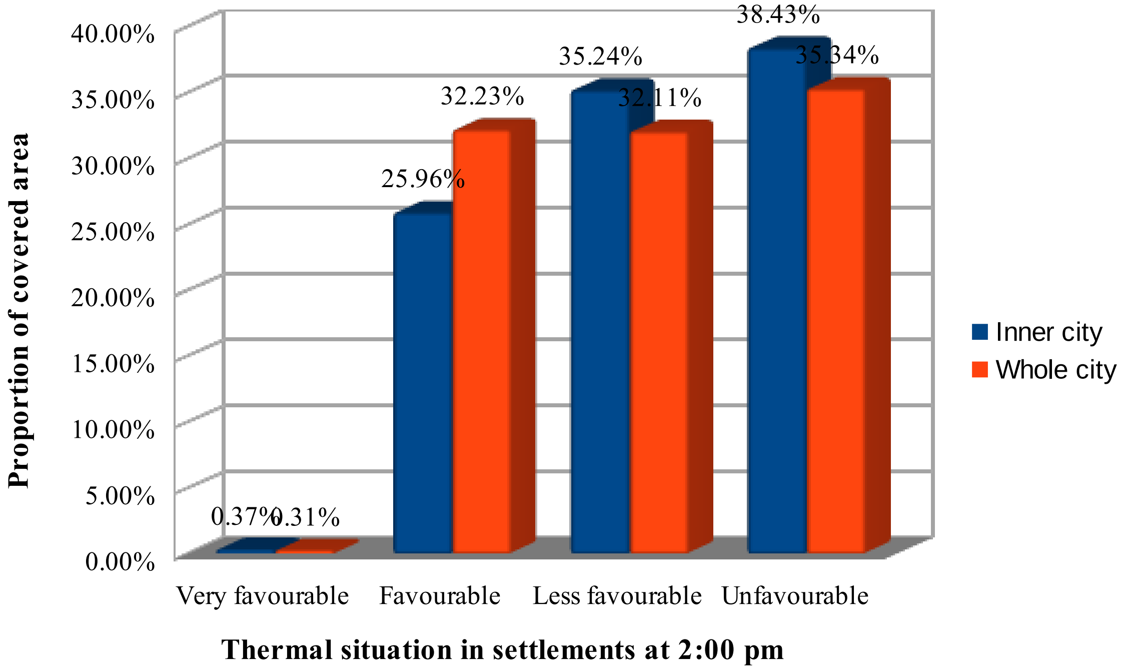


Fig. 152 - Thermal situation in settlements at 2:00 pm in 2015 within 500 m distance of cemeteries of a minimum size of 0.5 ha in the inner and outer city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

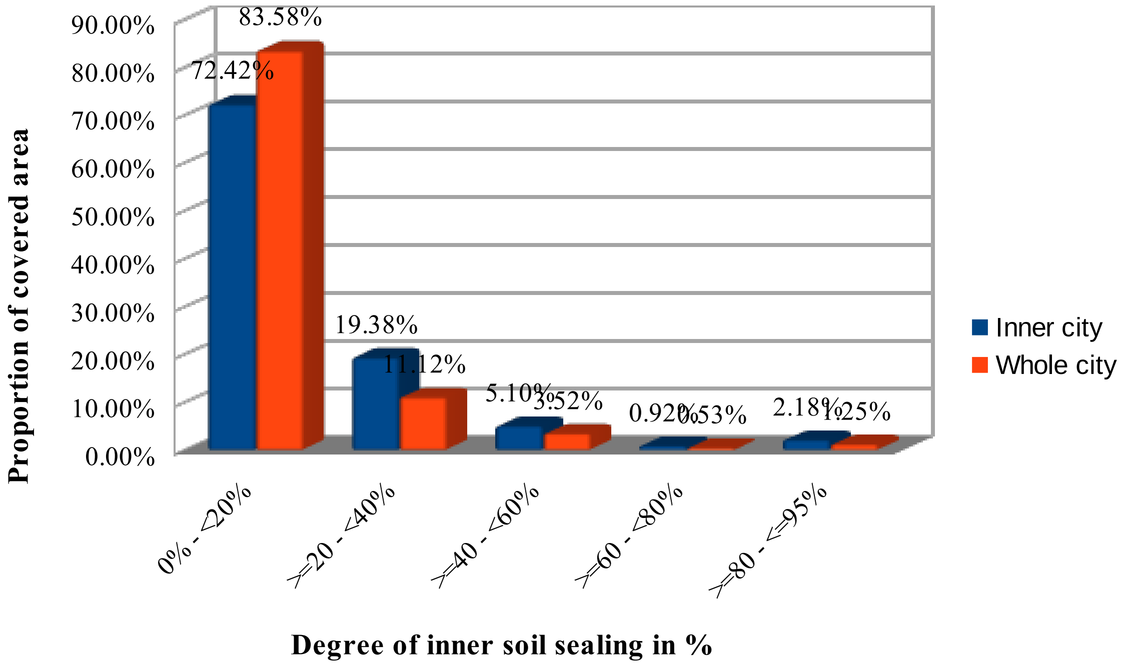


Fig. 153 - Degree of soil sealing in % in 2015 of cemeteries in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

2.2. Soil functions

2.2.1. Public accessible managed green areas/parks (2010)

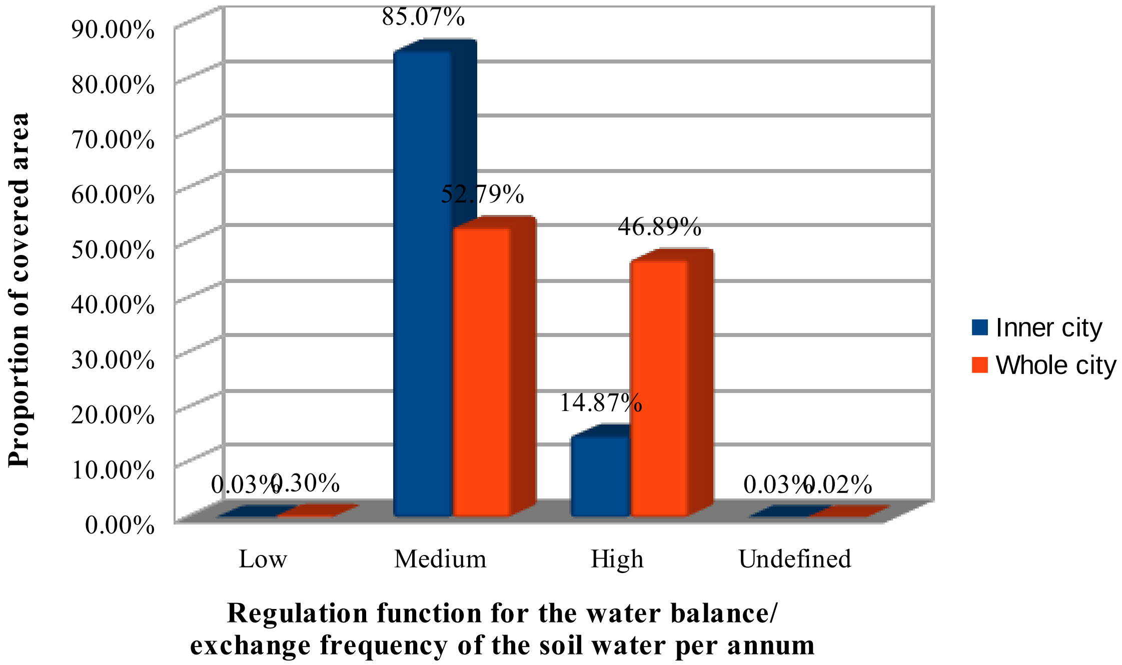


Fig. 154 - Regulation function for the water balance/exchange frequency of the soil water per annum of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

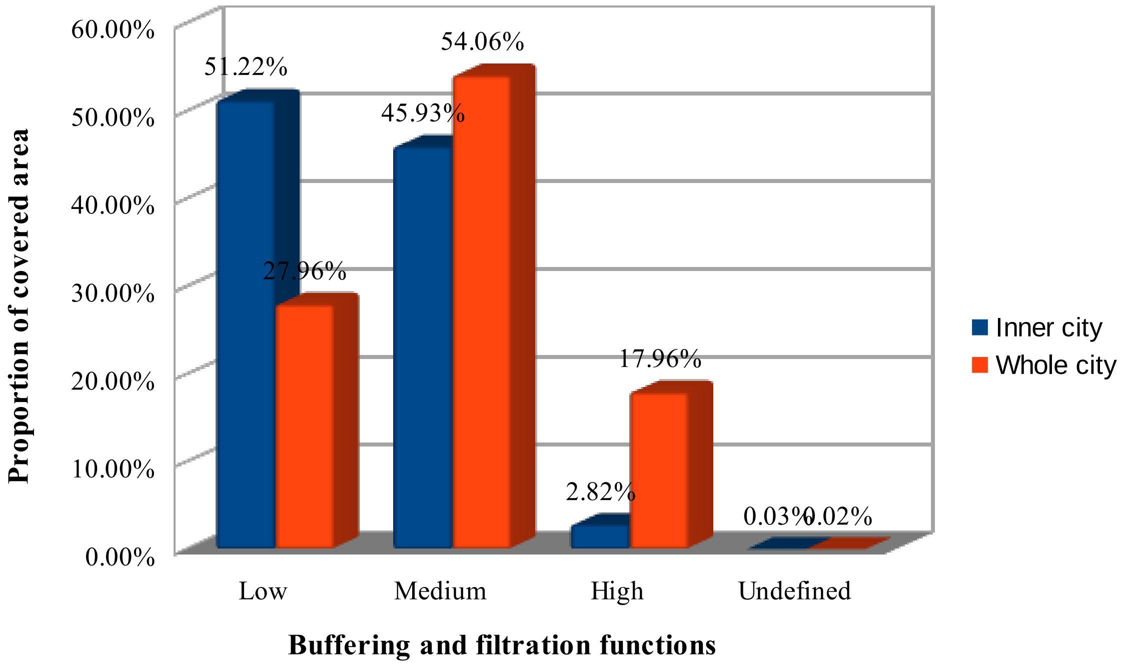


Fig. 155 - Buffering and filtration functions/sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange capacity, and binding capacity of heavy metals of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

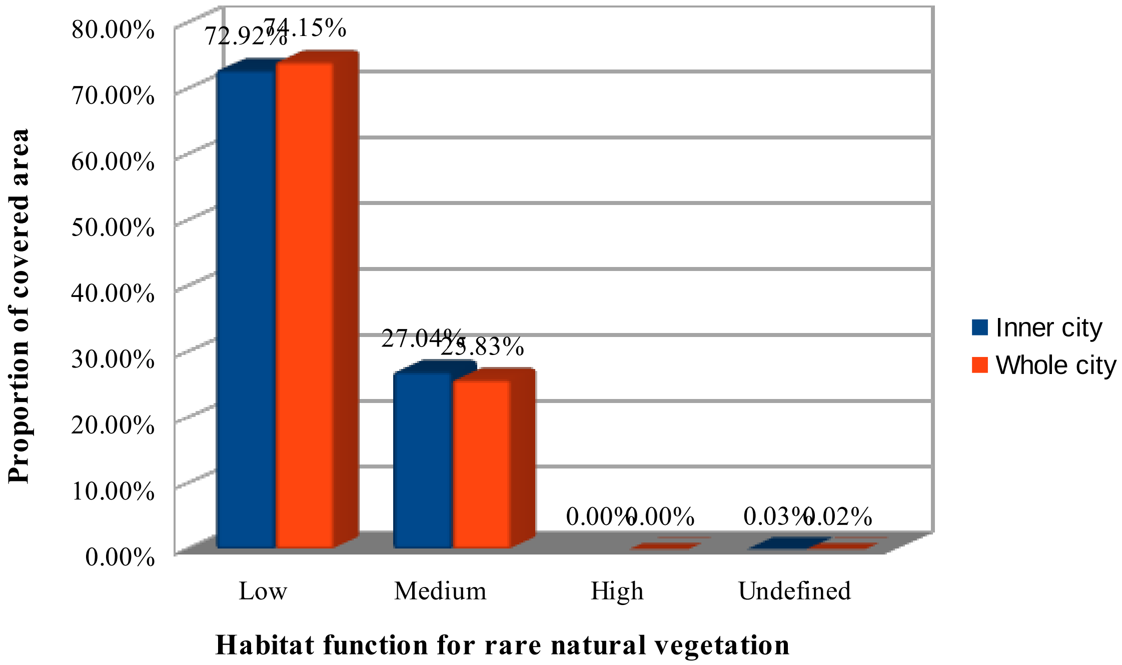


Fig. 156 - Habitat function for rare natural vegetation/indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

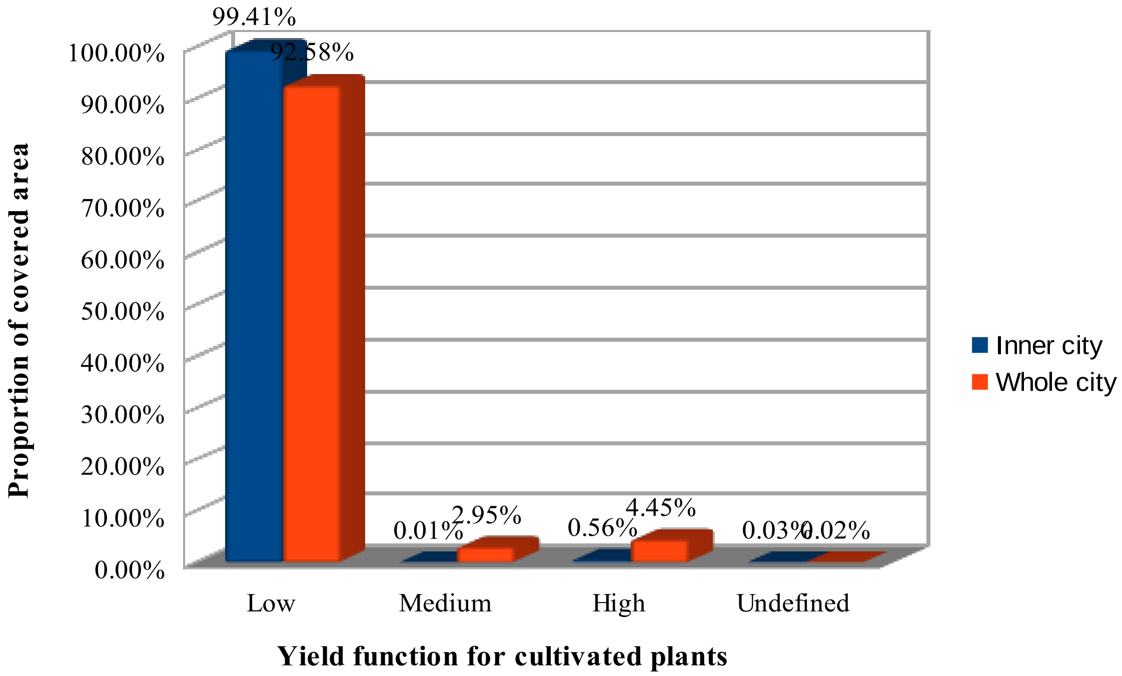


Fig. 157 - Yield function for cultivated plants/sum of water and nutrient supply indicators of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

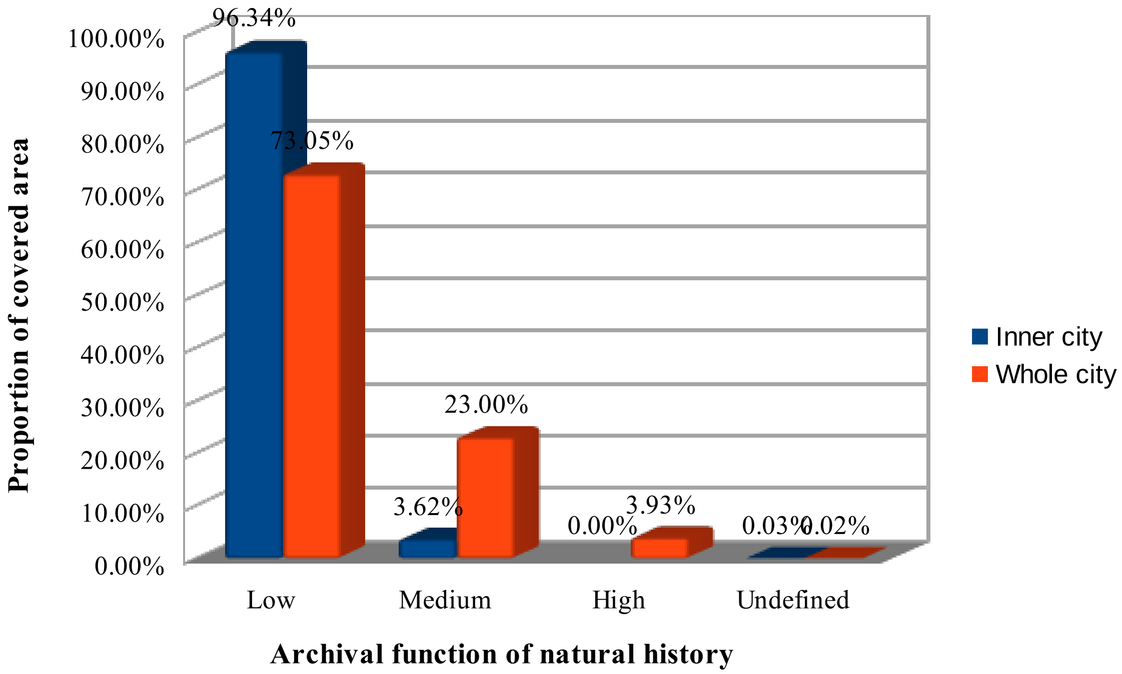


Fig. 158 - Archival function of natural history/rarity of soil associations, and particular soils of the nature region of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

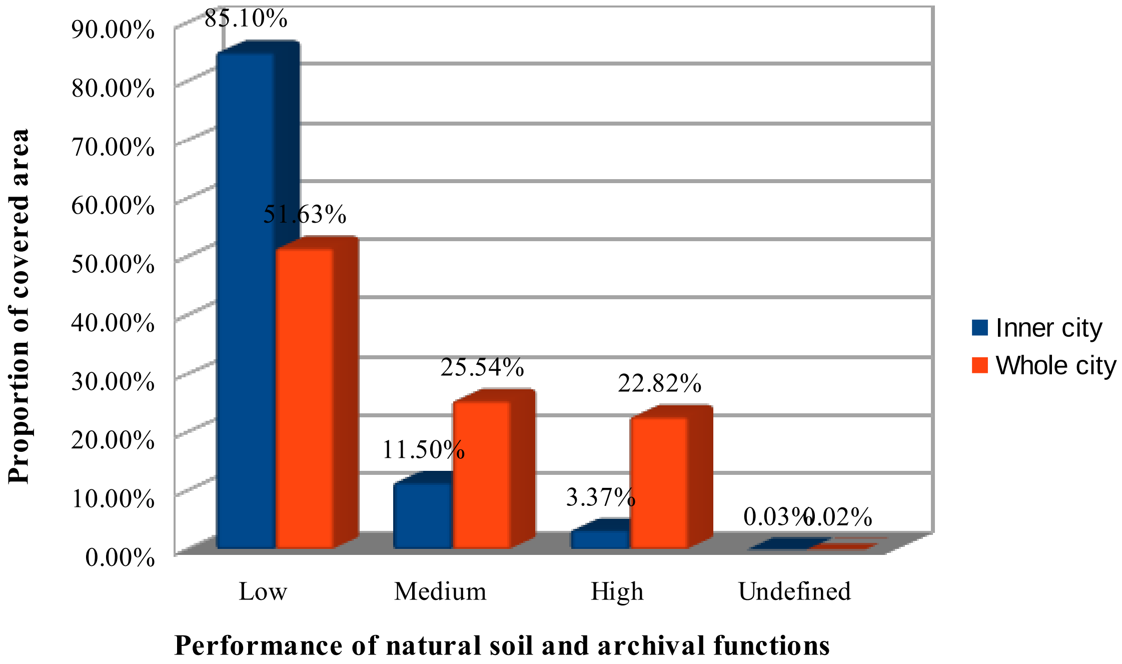


Fig. 159 - Performance of natural soil and archival functions/sum of soil functions of the five analysed soil functions above of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

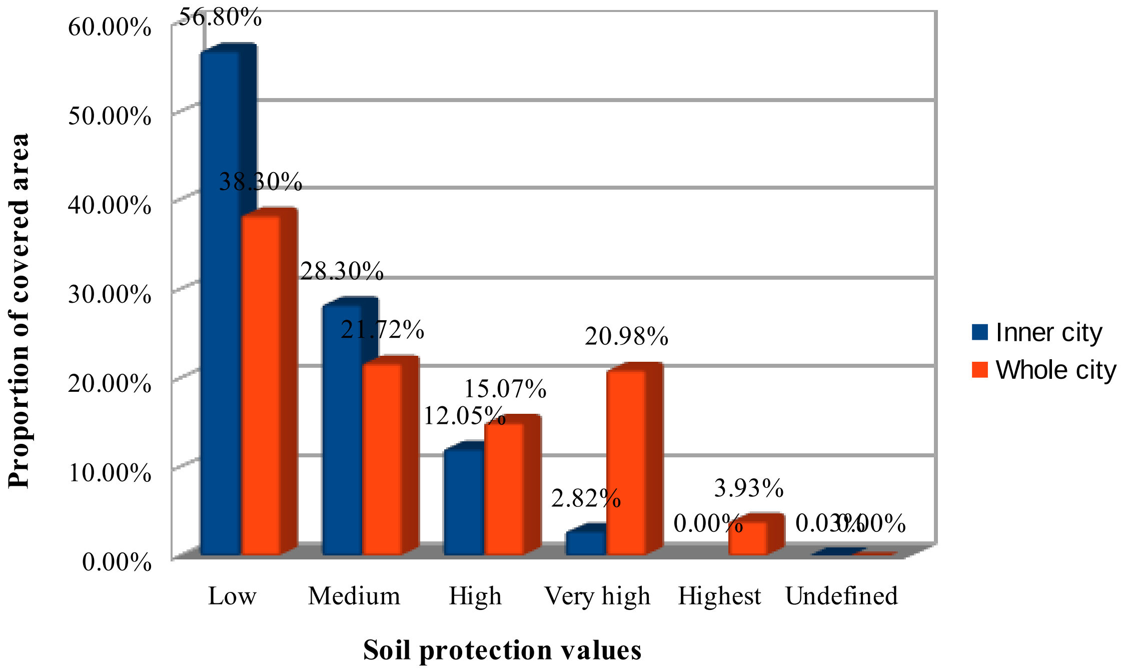


Fig. 160 - Soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance, as well as soil sealing degree of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

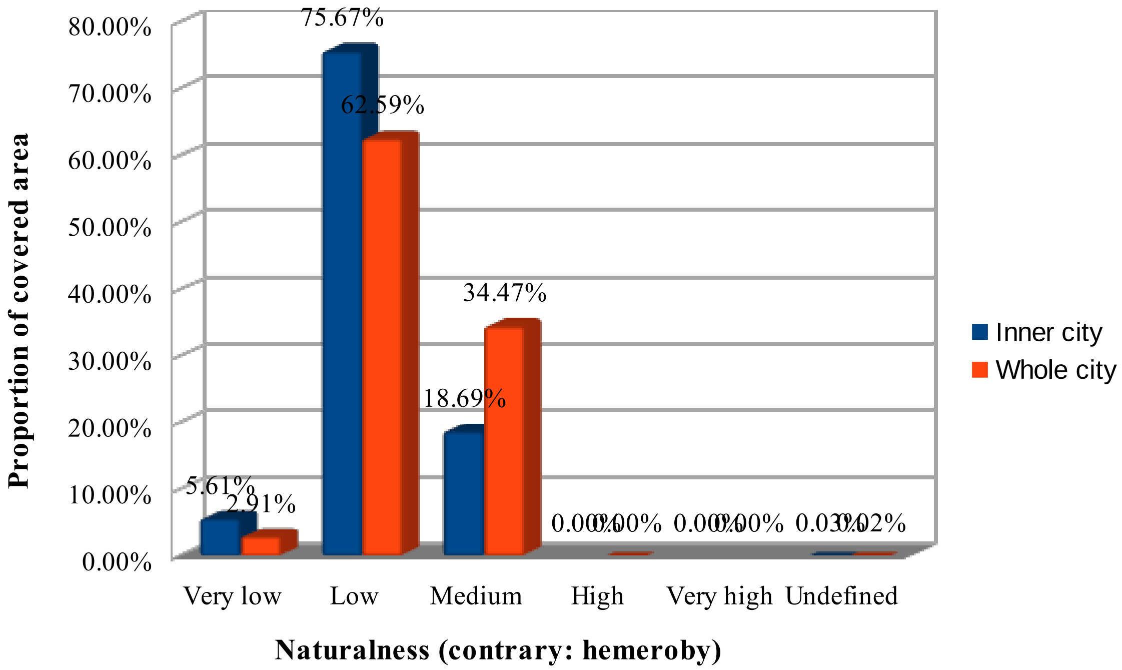


Fig. 161 - Naturalness (contrary: hemeroby) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

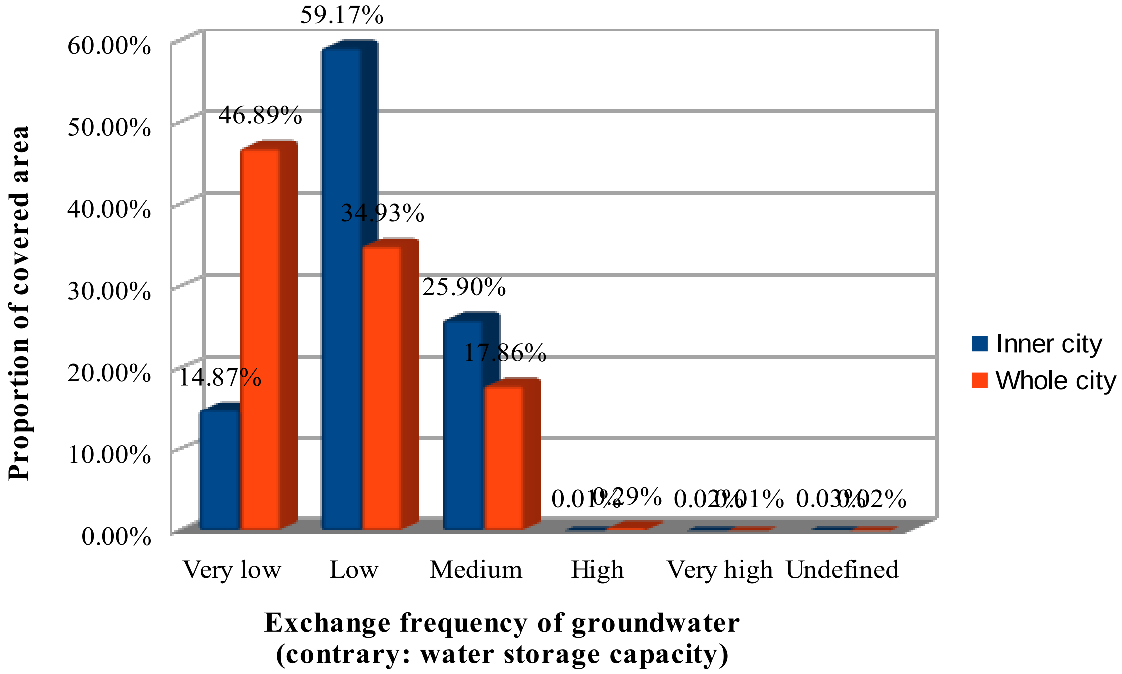


Fig. 162 - Exchange frequency of groundwater (contrary: water storage capacity) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

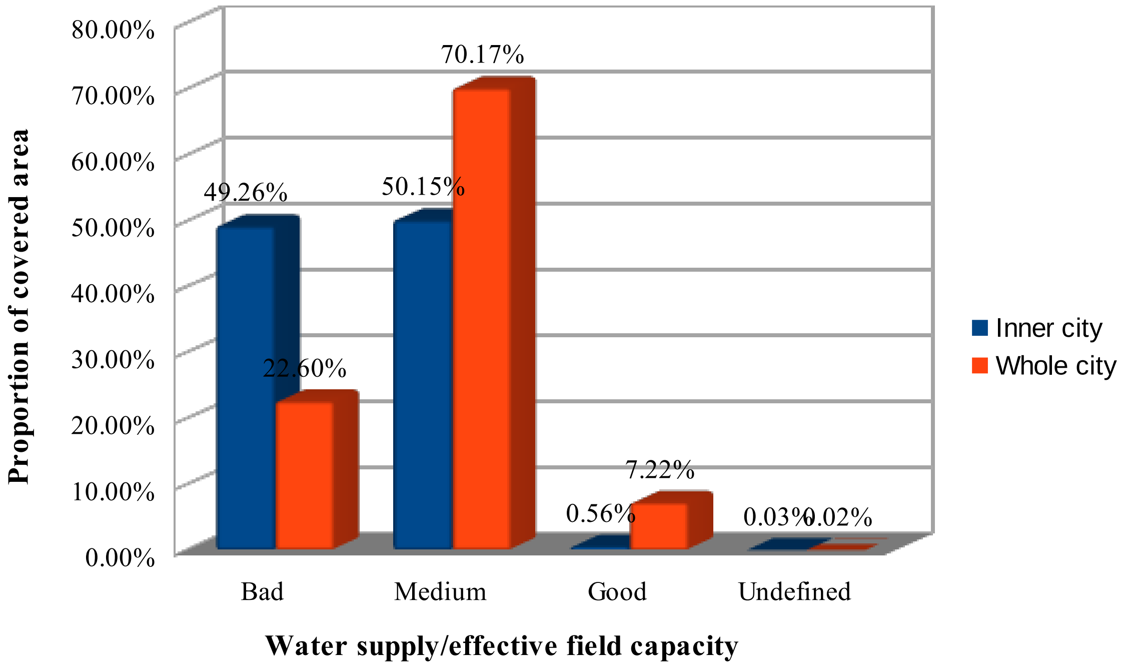


Fig. 163 - Water supply/effective field capacity of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

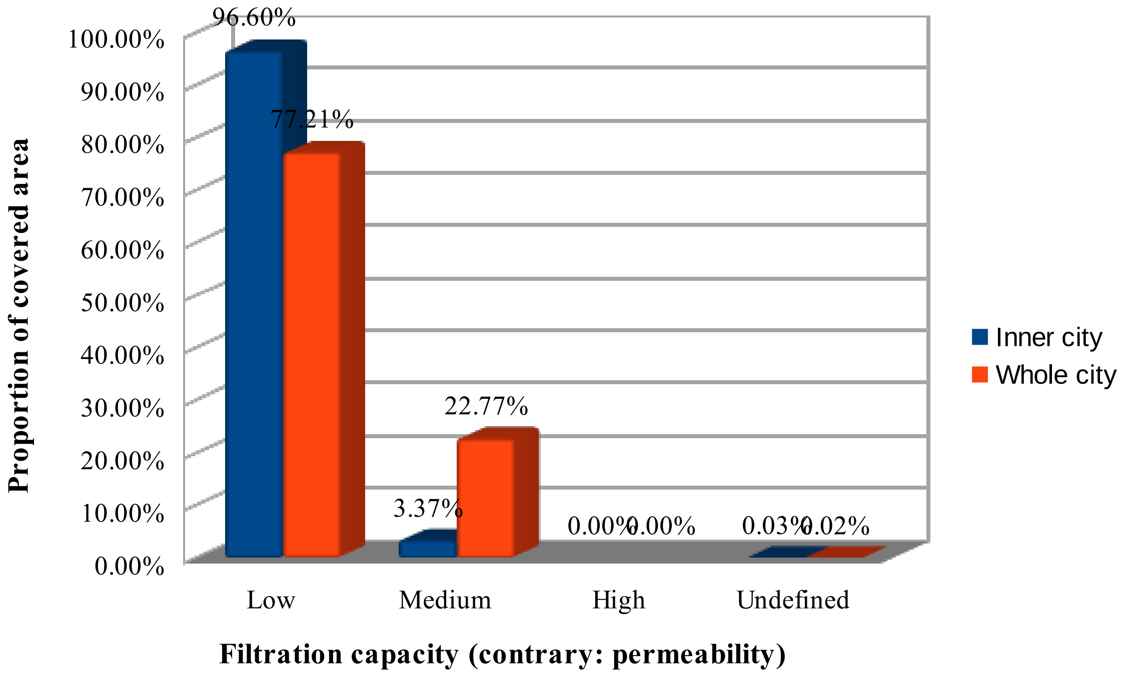


Fig. 164 - Filtration capacity (contrary: permeability) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

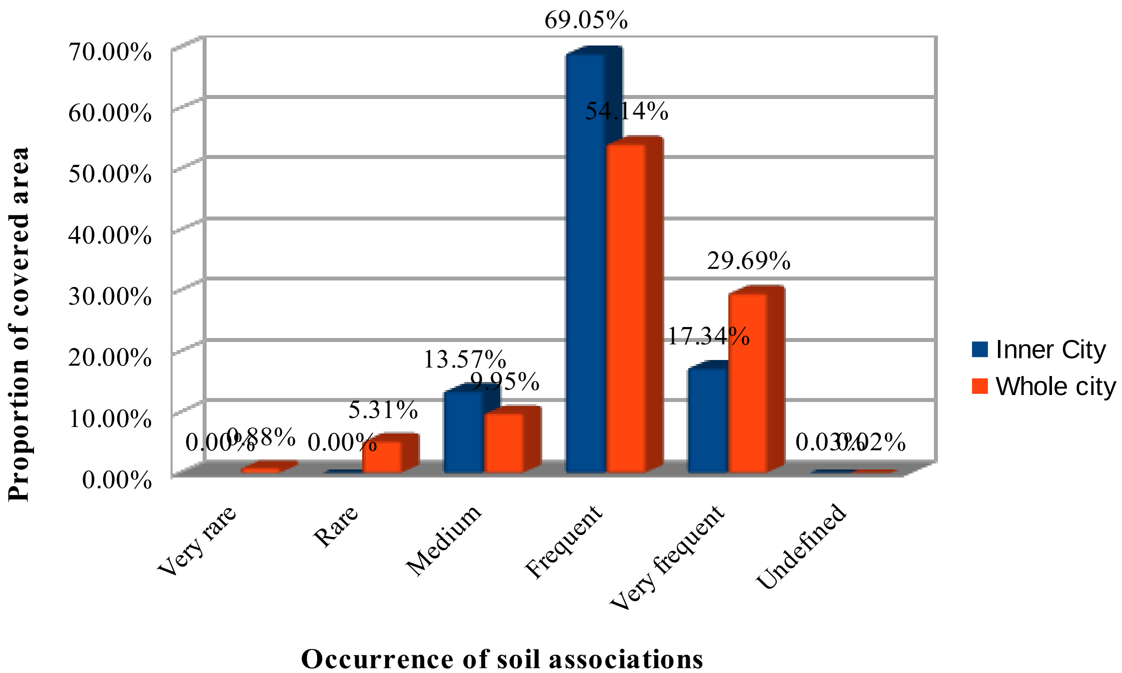


Fig. 165 - Occurrence of soil associations within the area of Berlin of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

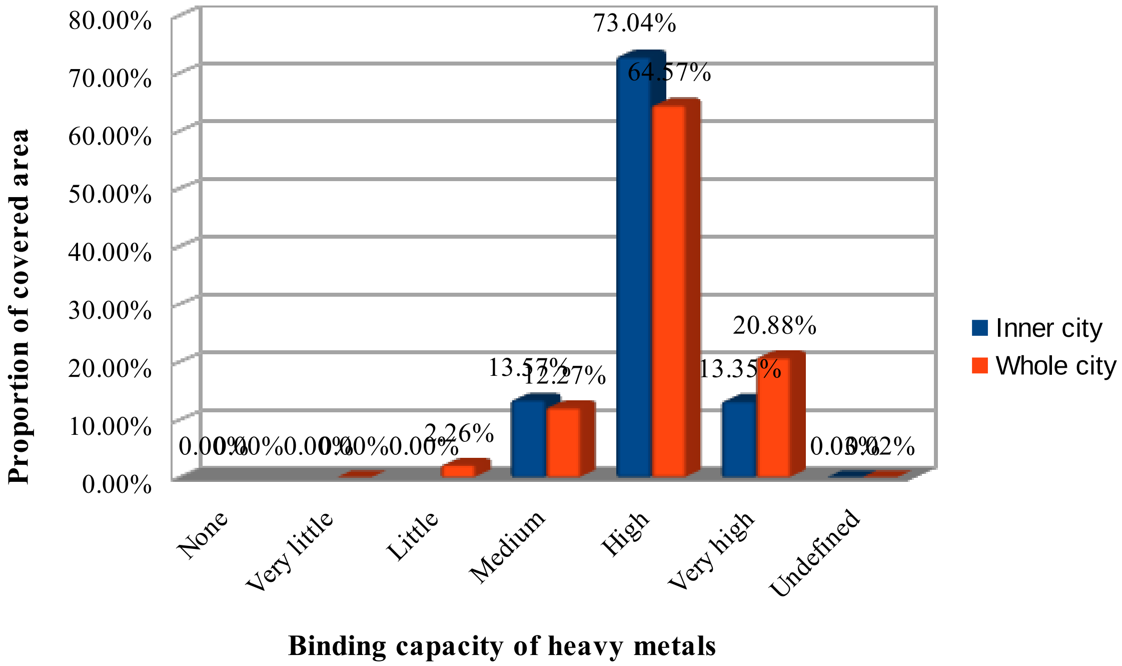


Fig. 166 - Binding capacity of heavy metals of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

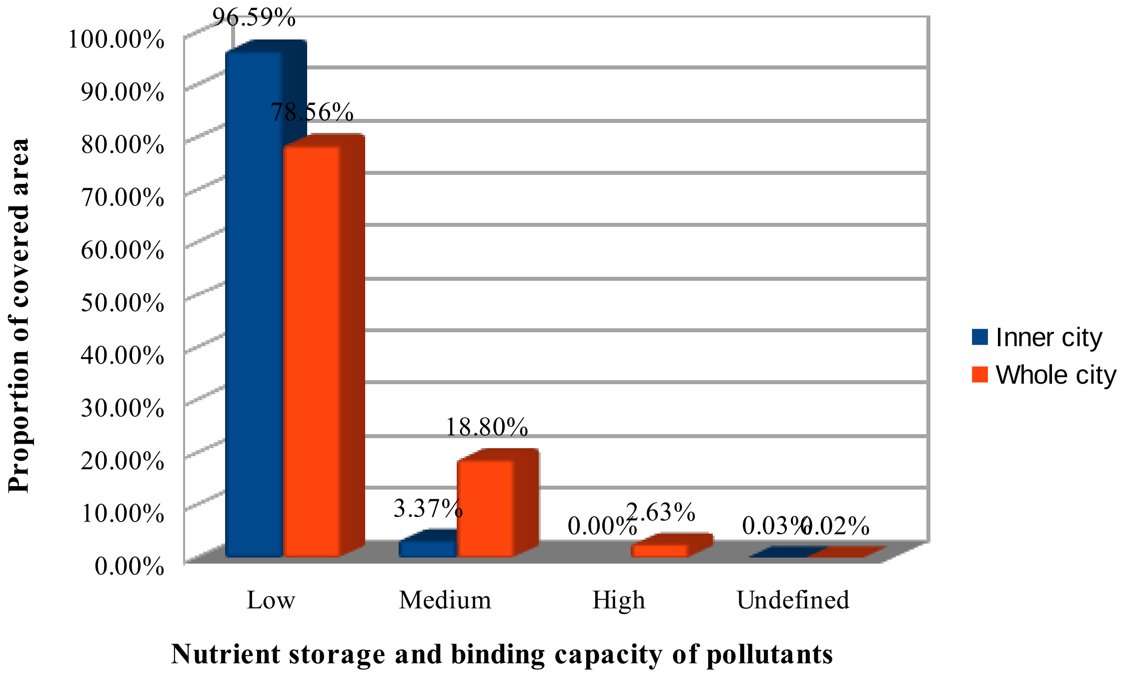


Fig. 167 - Nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

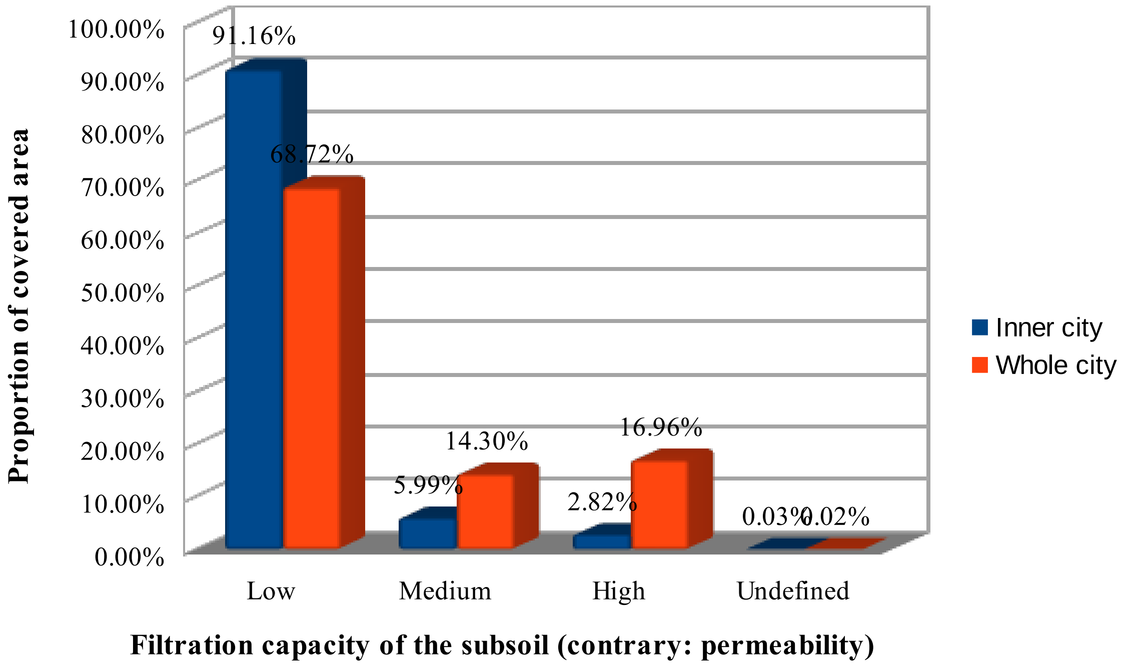


Fig. 168 - Filtration capacity of the subsoil (contrary: permeability) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

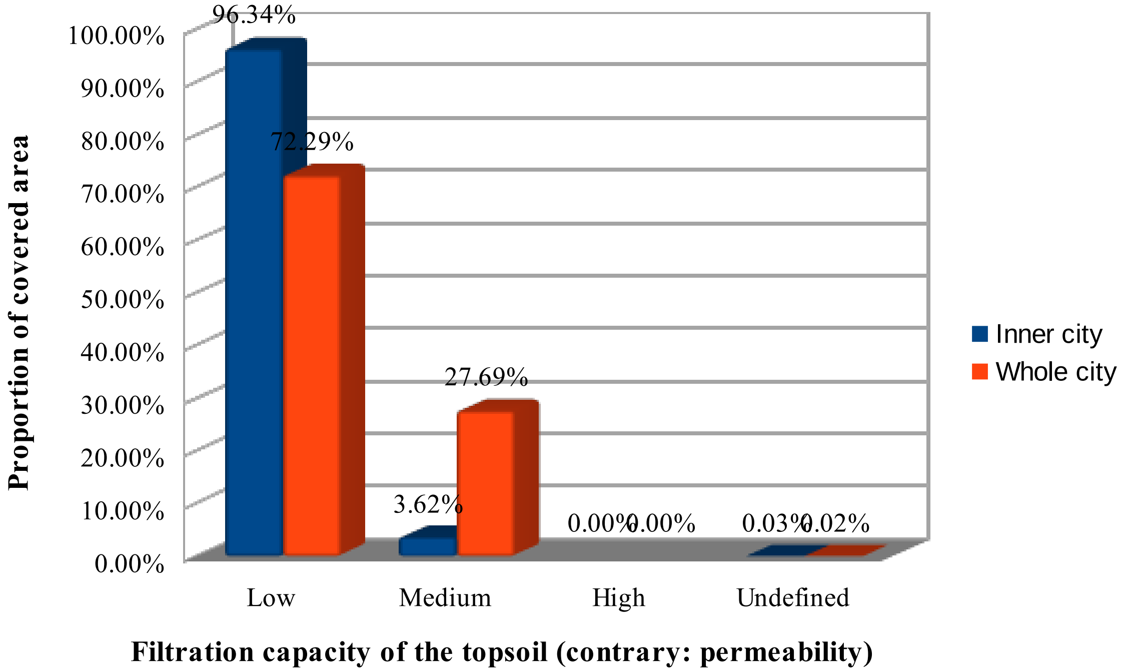


Fig. 169 - Filtration capacity of the topsoil (contrary: permeability) of the proportion of the area of public accessible managed green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

2.2.2. Allotments (2015)

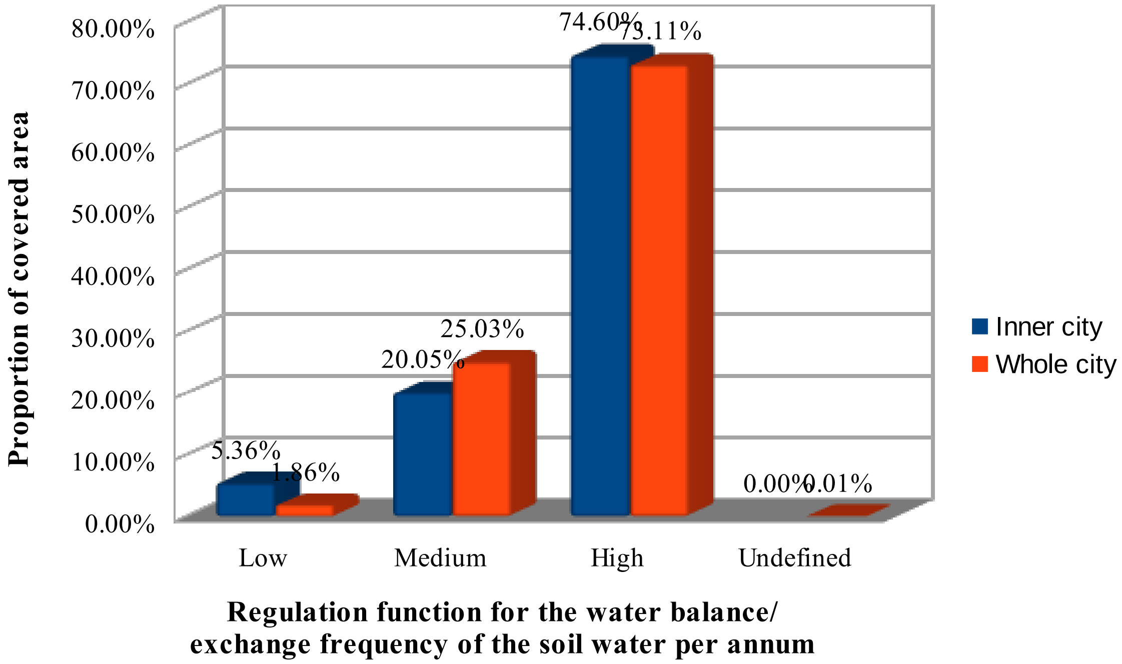


Fig. 170 - Regulation function for the water balance/exchange frequency of the soil water per annum of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

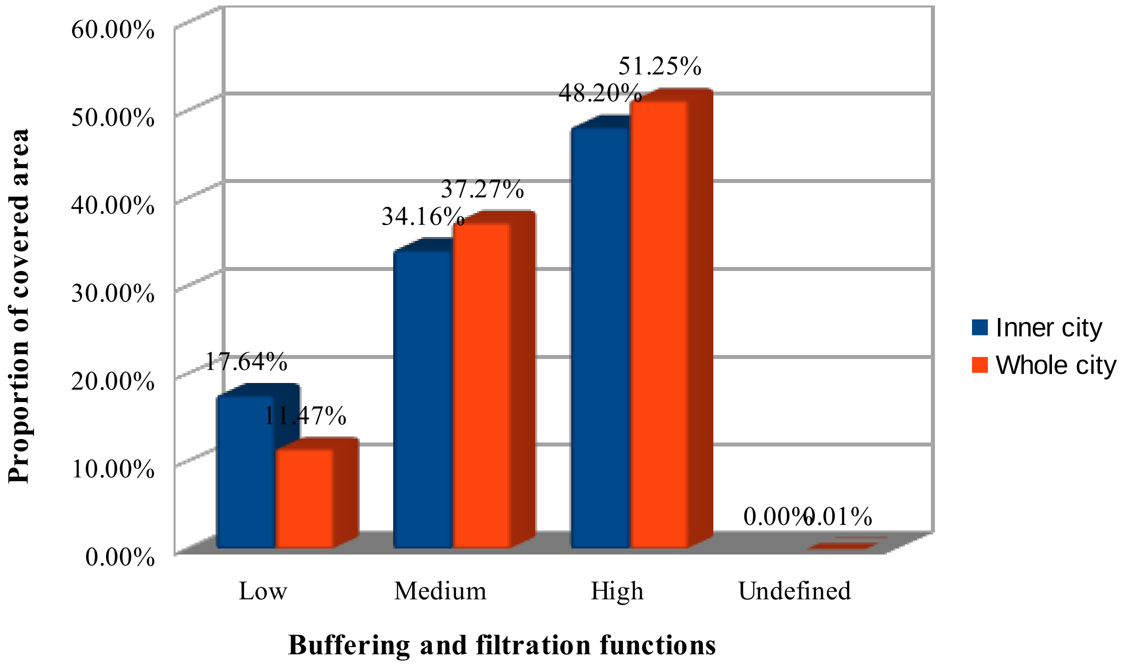


Fig. 171 - Buffering and filtration functions/sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange capacity, and binding capacity of heavy metals of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

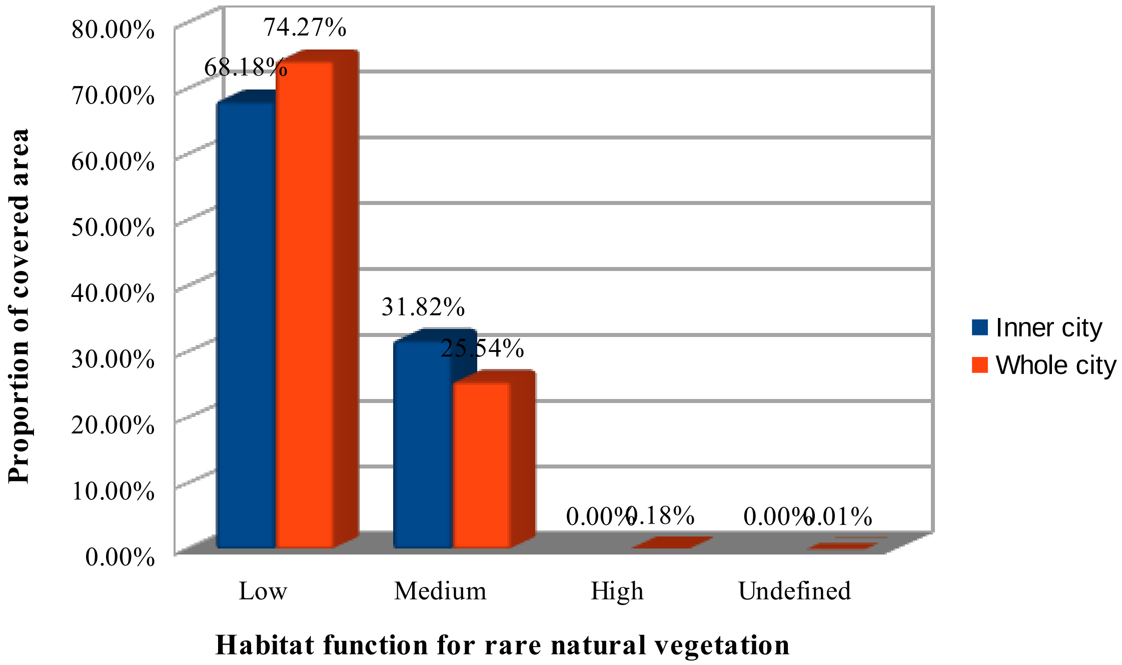


Fig. 172 - Habitat function for rare natural vegetation/indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

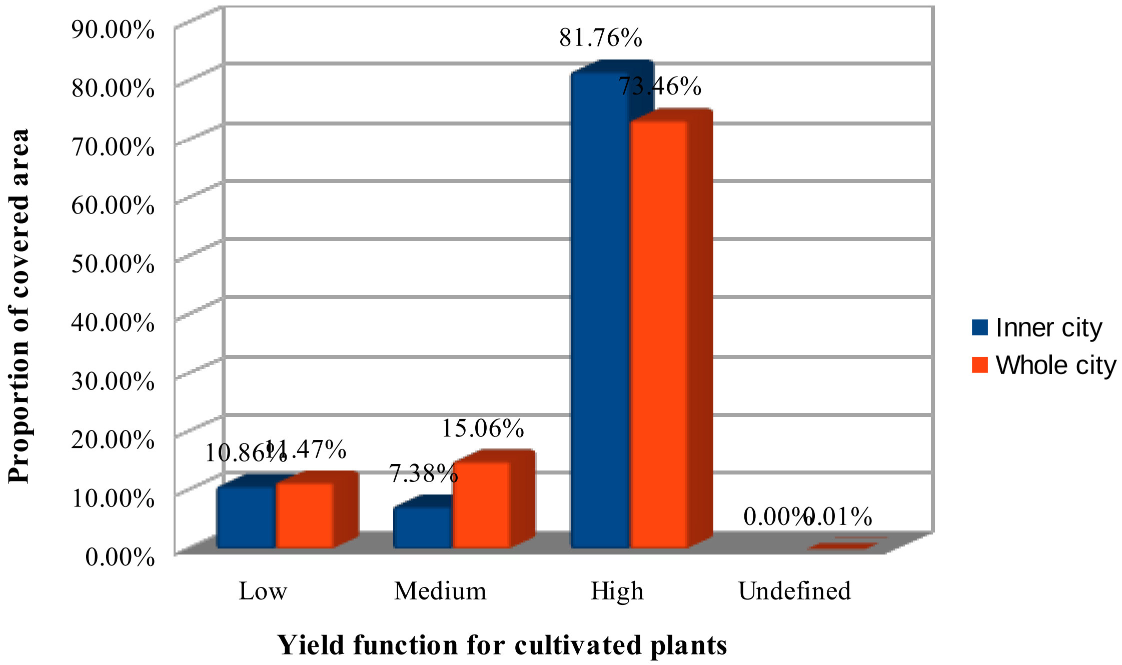


Fig. 173 - Yield function for cultivated plants/sum of water and nutrient supply indicators of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

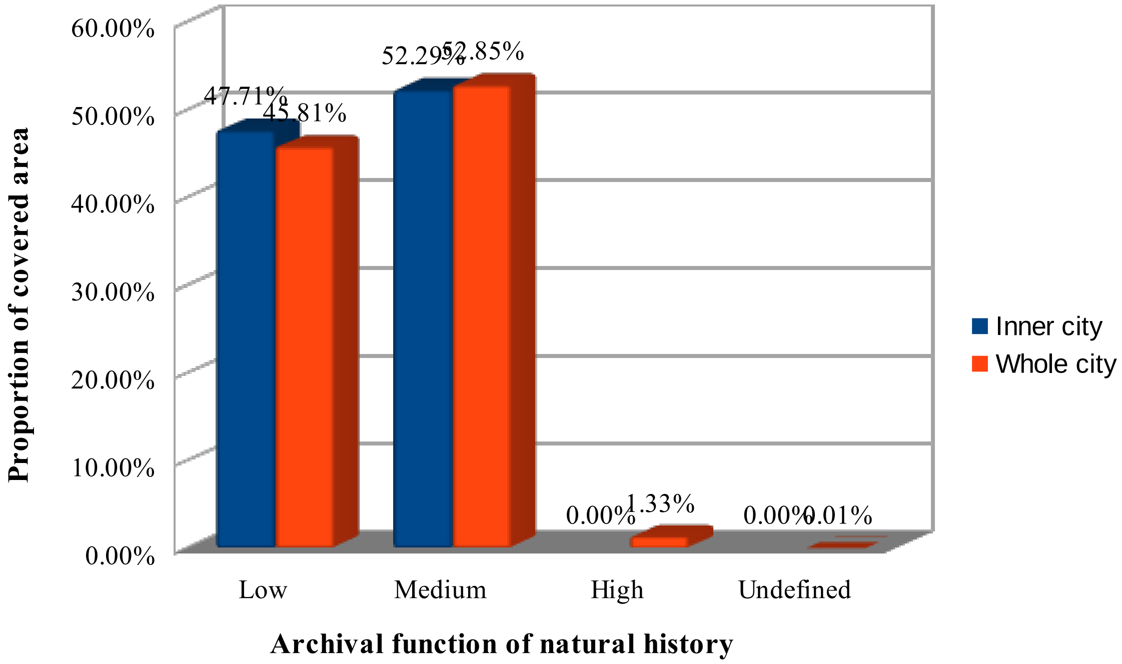


Fig. 174 - Archival function of natural history/rarity of soil associations, and particular soils of the nature region of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

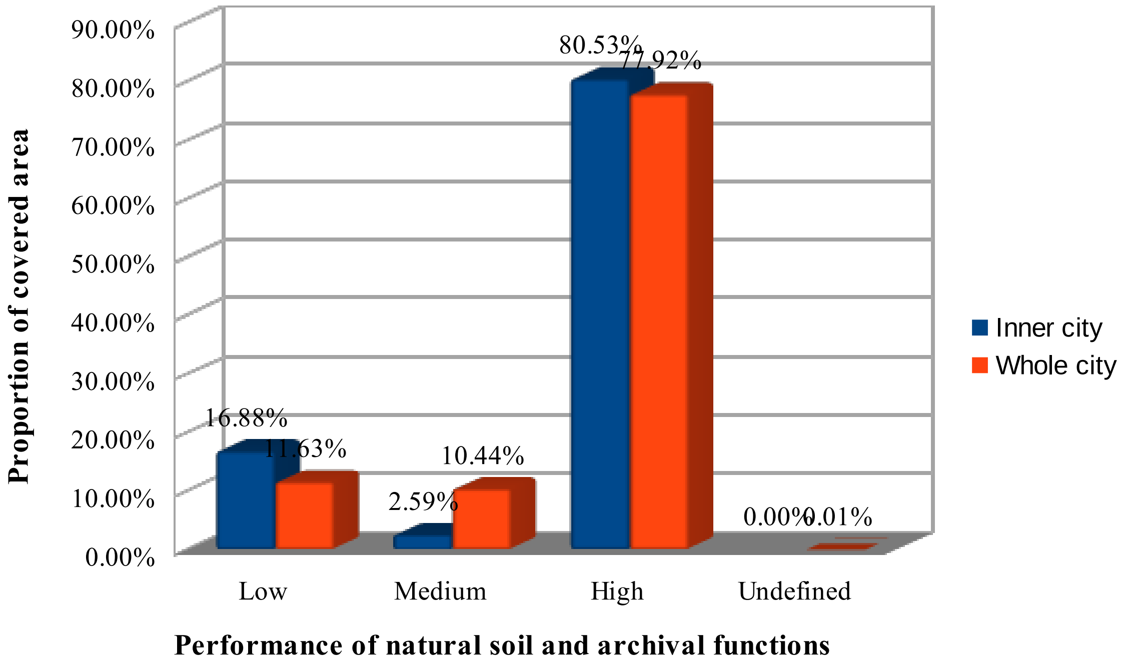


Fig. 175 - Performance of natural soil and archival functions/sum of soil functions of the five analysed soil functions above of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

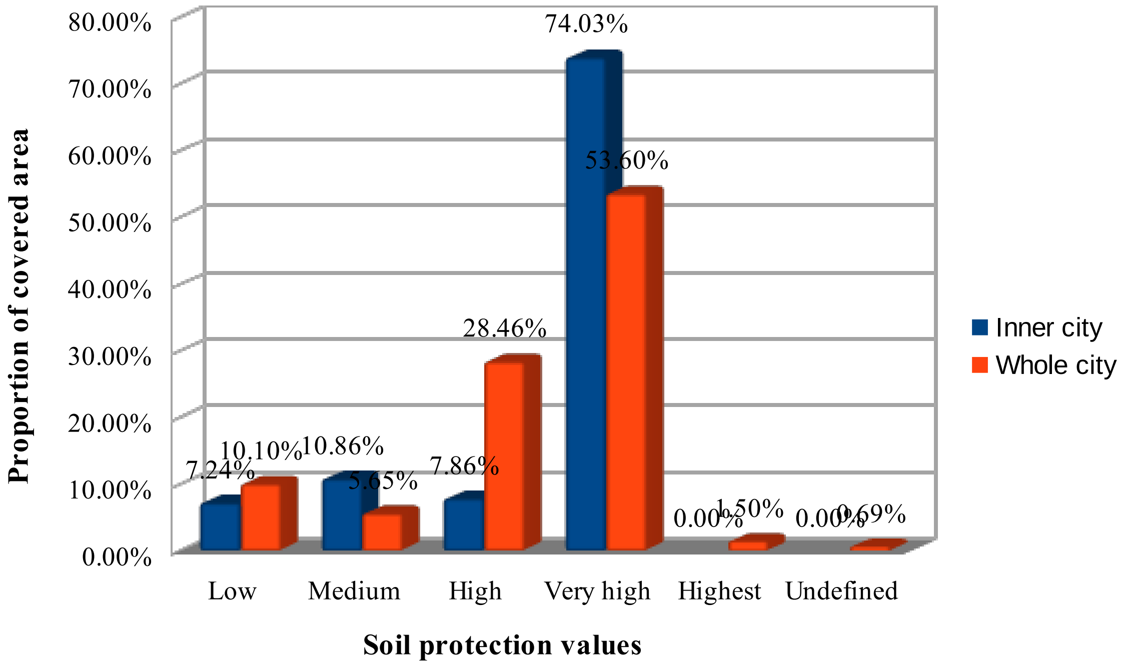


Fig. 176 - Soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance, as well as soil sealing degree of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

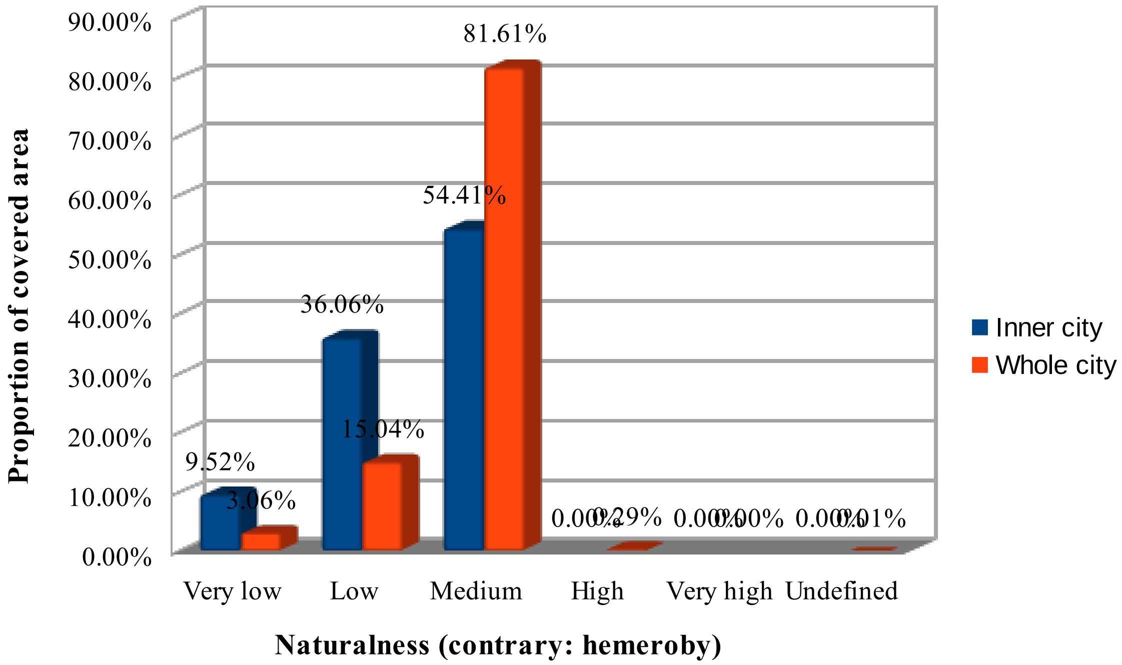


Fig. 177 - Naturalness (contrary: hemeroby) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

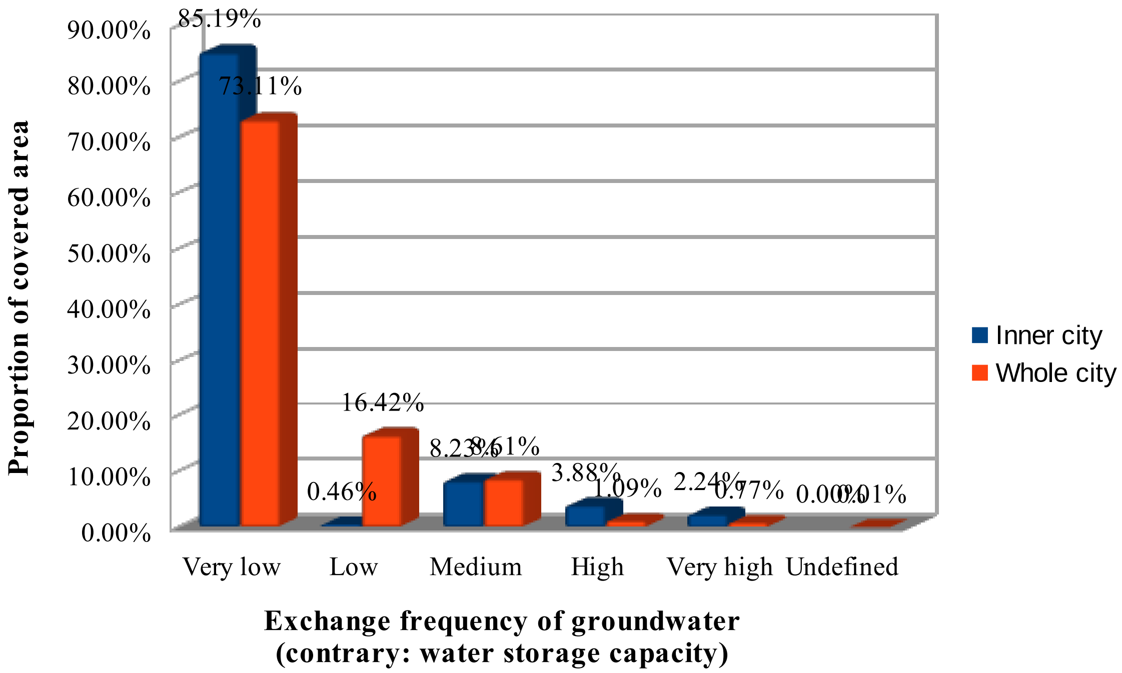


Fig. 178 - Exchange frequency of groundwater (contrary: water storage capacity) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

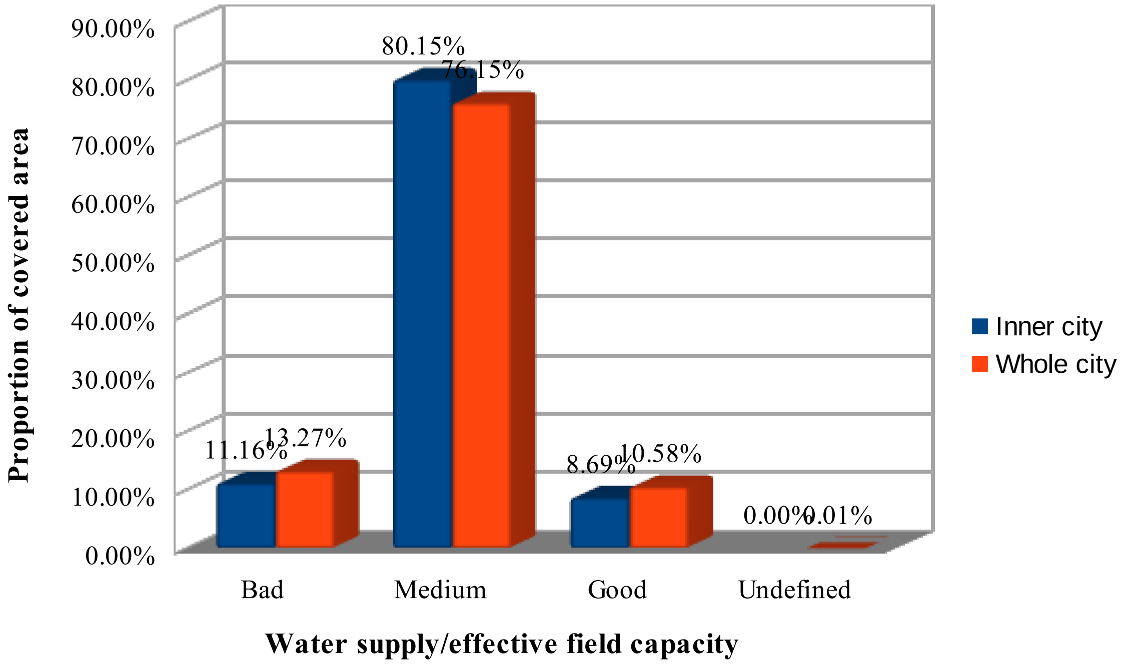


Fig. 179 - Water supply/effective field capacity of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

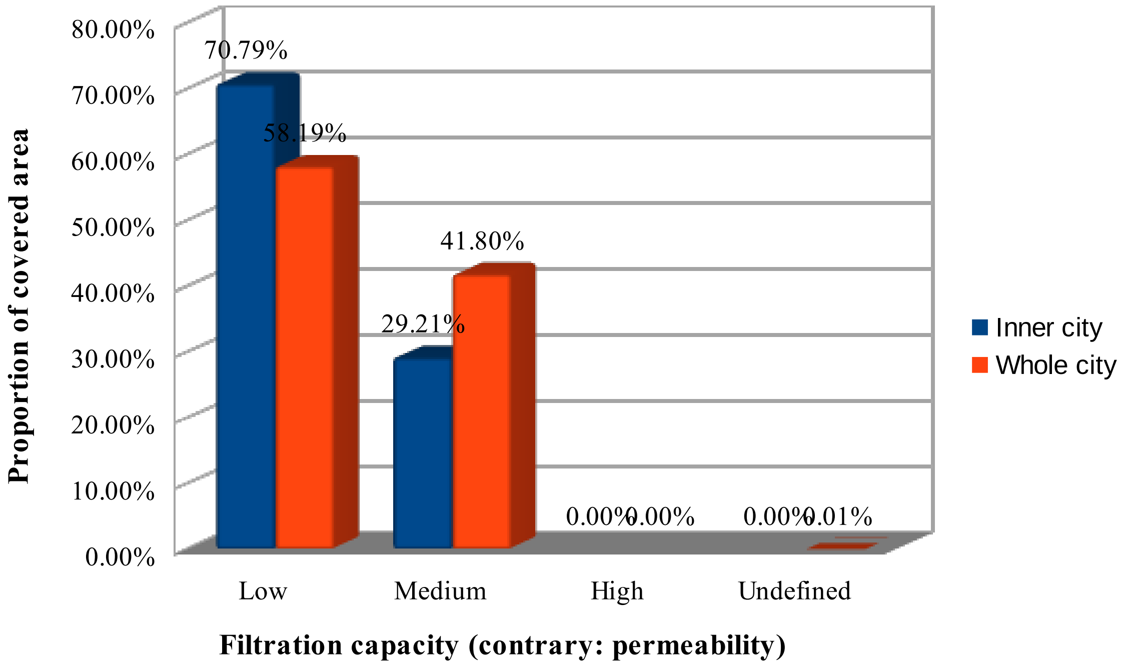


Fig. 180 - Filtration capacity (contrary: permeability) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

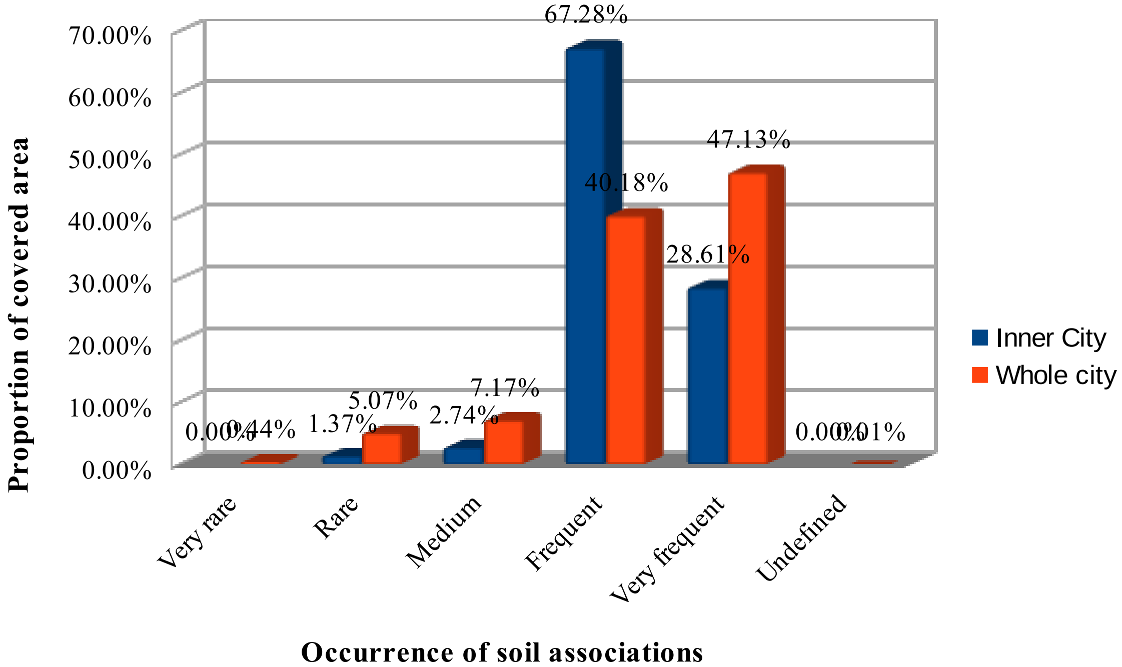


Fig. 181 - Occurrence of soil associations within the area of Berlin of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

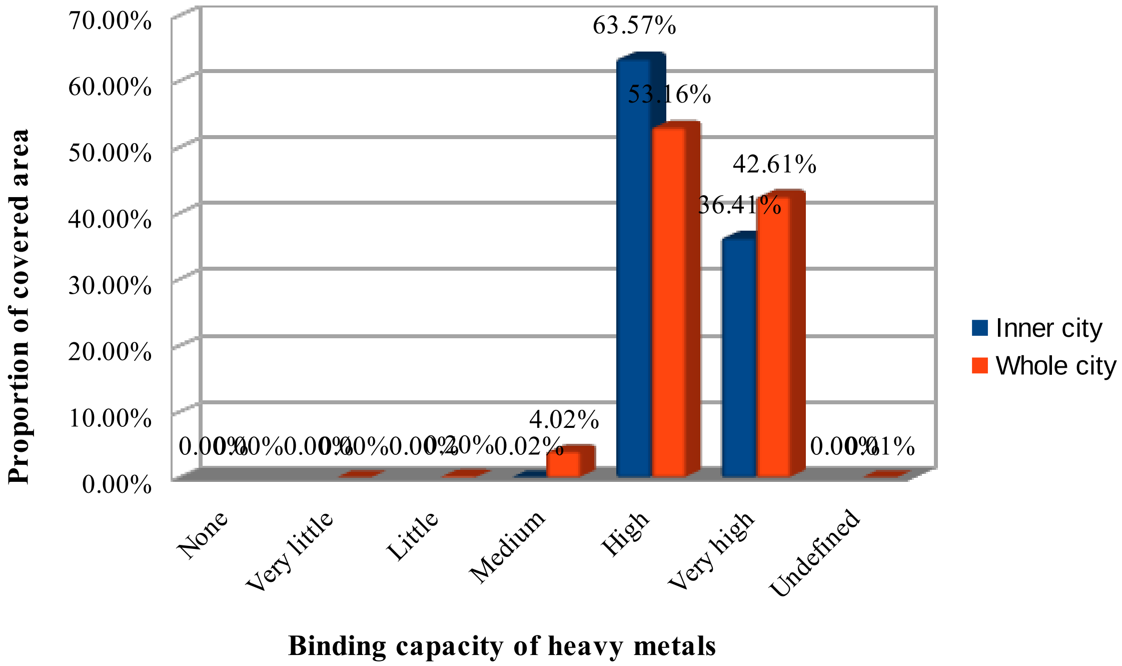


Fig. 182 - Binding capacity of heavy metals of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

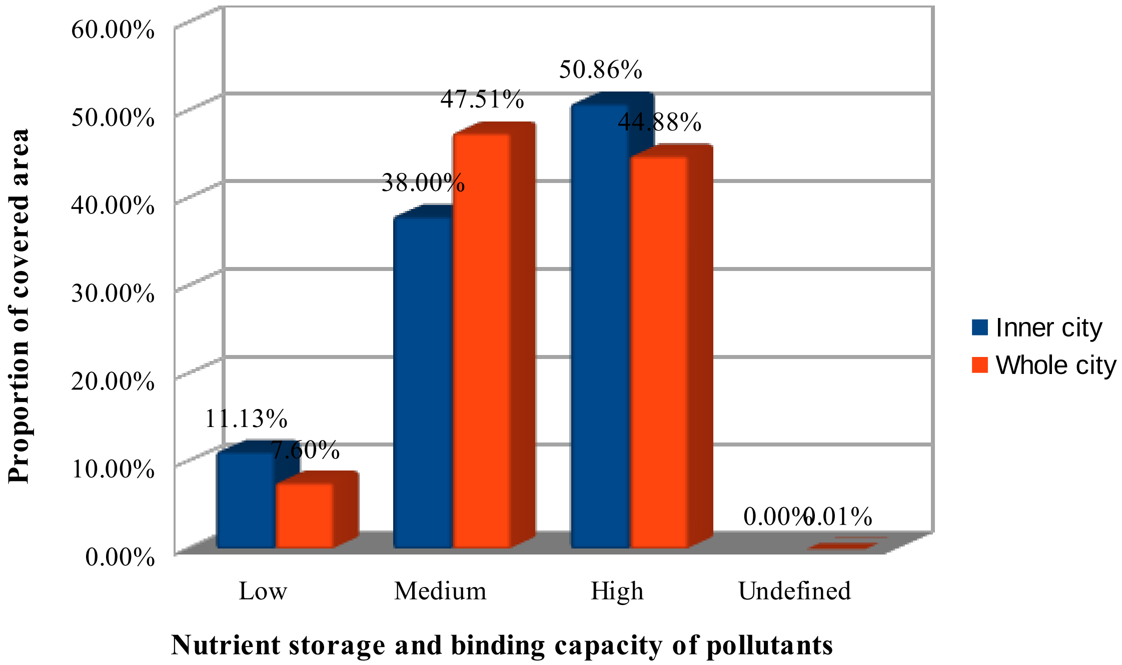


Fig. 183 - Nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

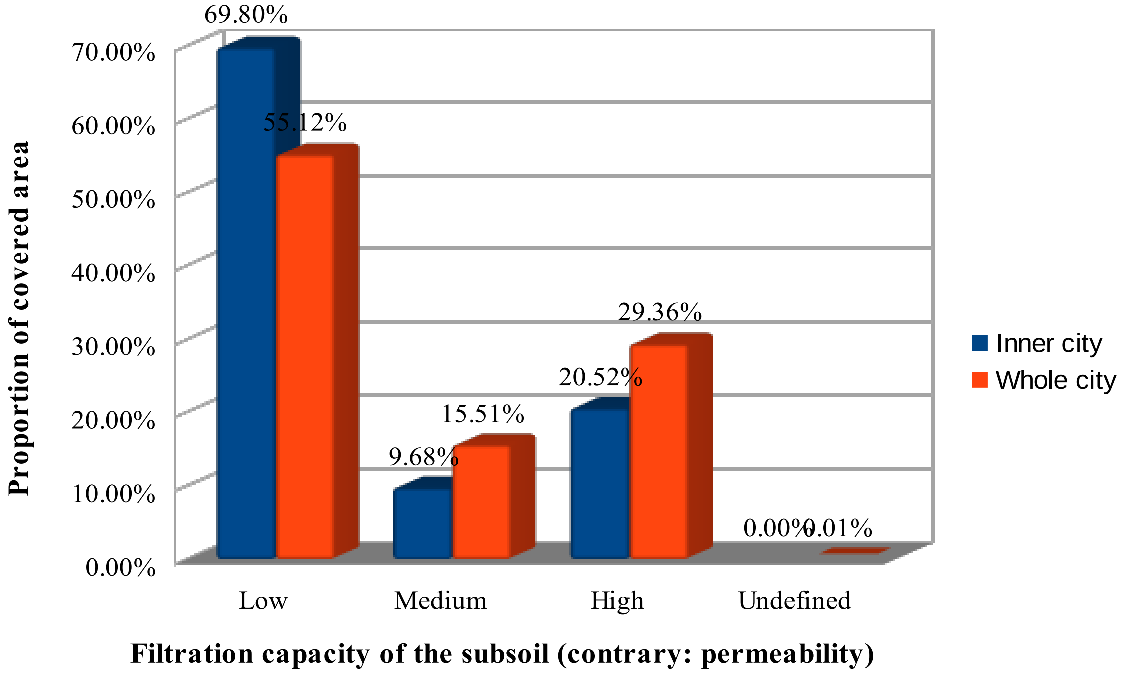


Fig. 184 - Filtration capacity of the subsoil (contrary: permeability) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

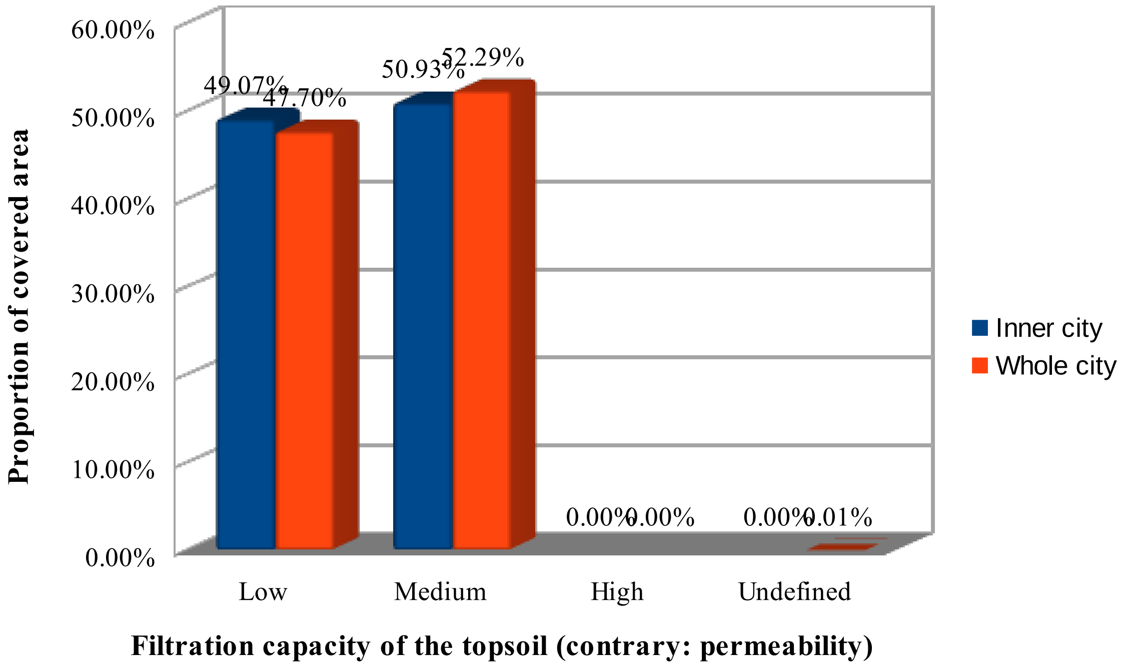


Fig. 185 - Filtration capacity of the topsoil (contrary: permeability) of the proportion of the area of allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

2.2.3. Cemeteries (2010)

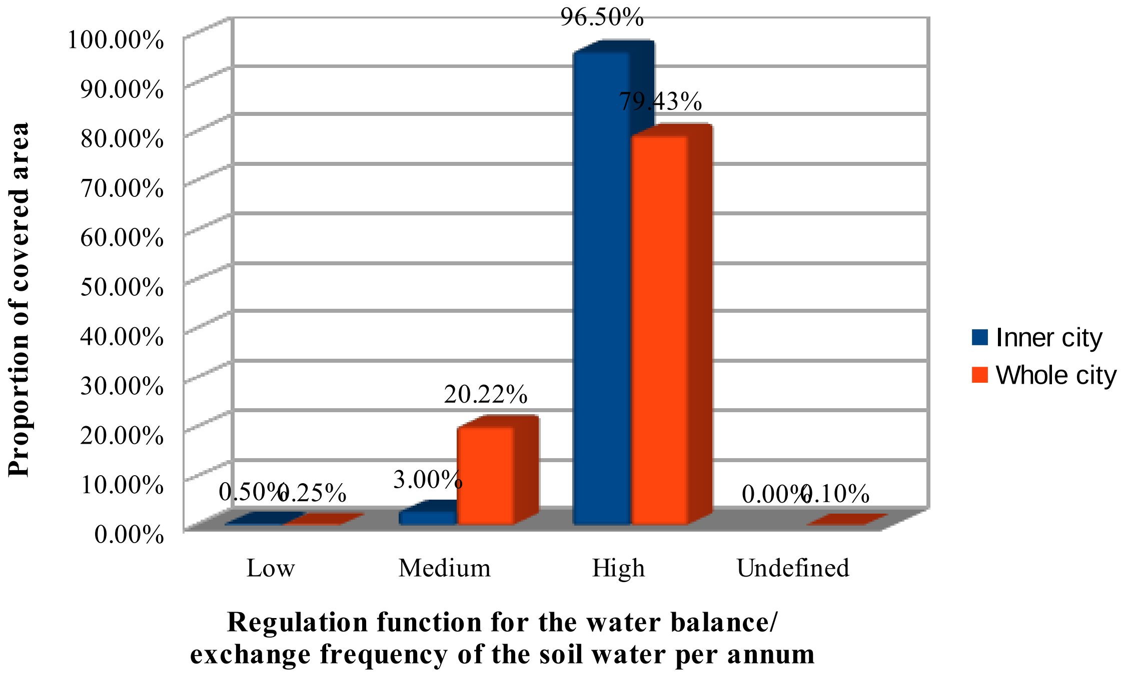


Fig. 186 - Regulation function for the water balance/exchange frequency of the soil water per annum of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

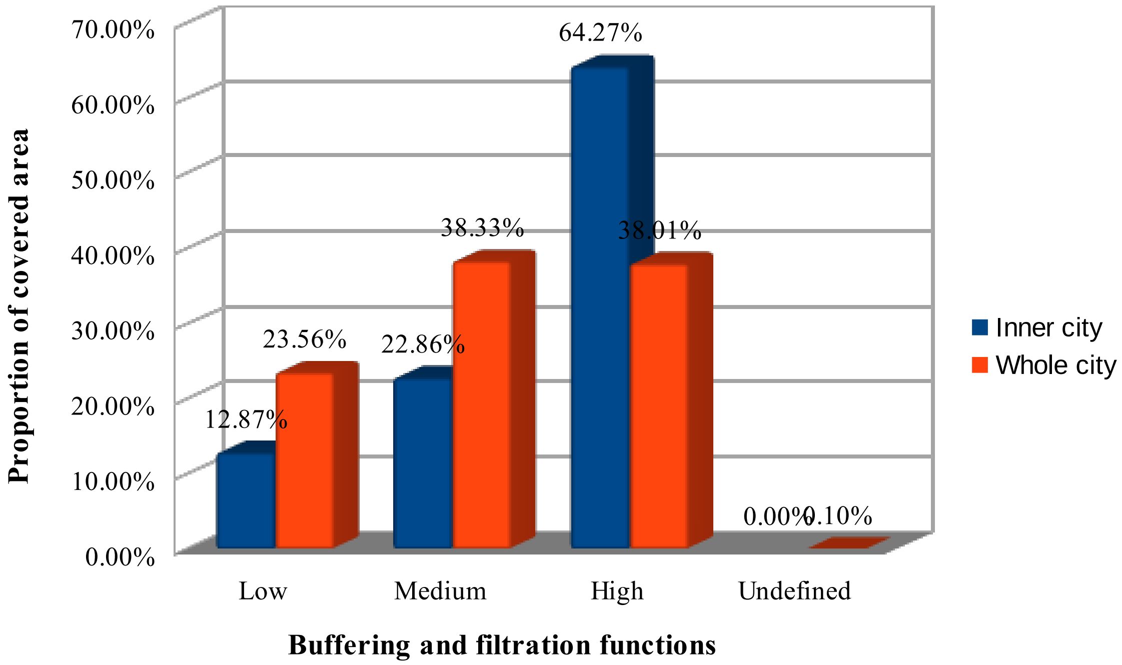


Fig. 187 - Buffering and filtration functions/sum of indicators of filtration capacity (contrary: permeability), nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange capacity, and binding capacity of heavy metals of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

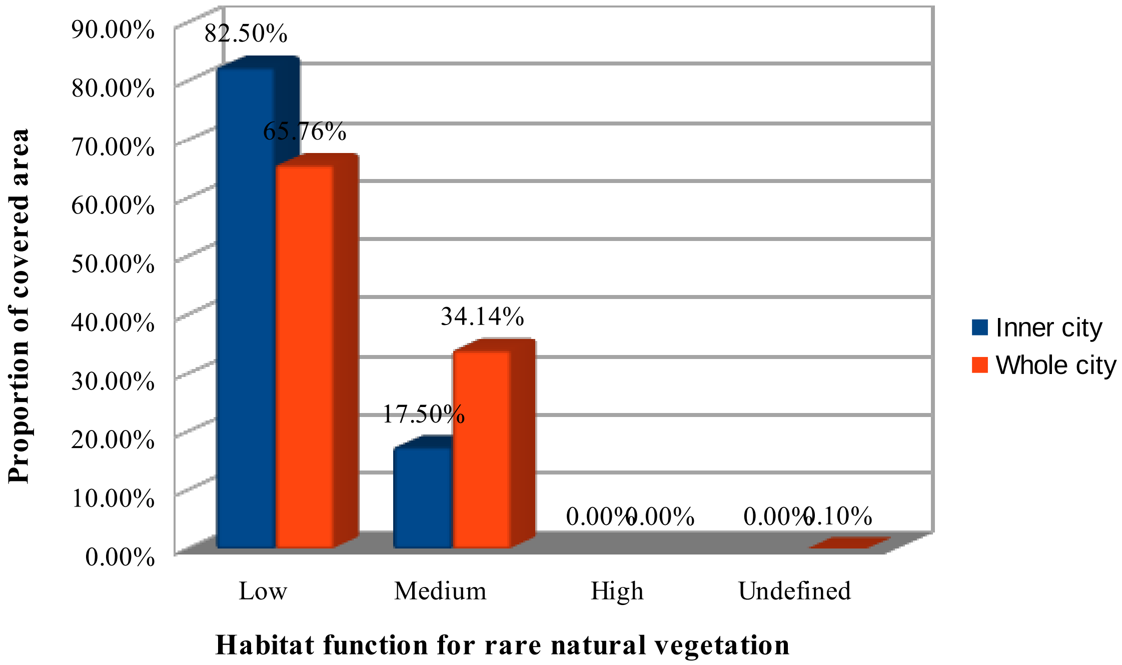


Fig. 188 - Habitat function for rare natural vegetation/indicators of naturalness (contrary: hemeroby), particular soils of the nature region, soil moisture, and nutrient supply of the topsoil/sum of exchangeable alkaline cations in the topsoil (S-Value) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

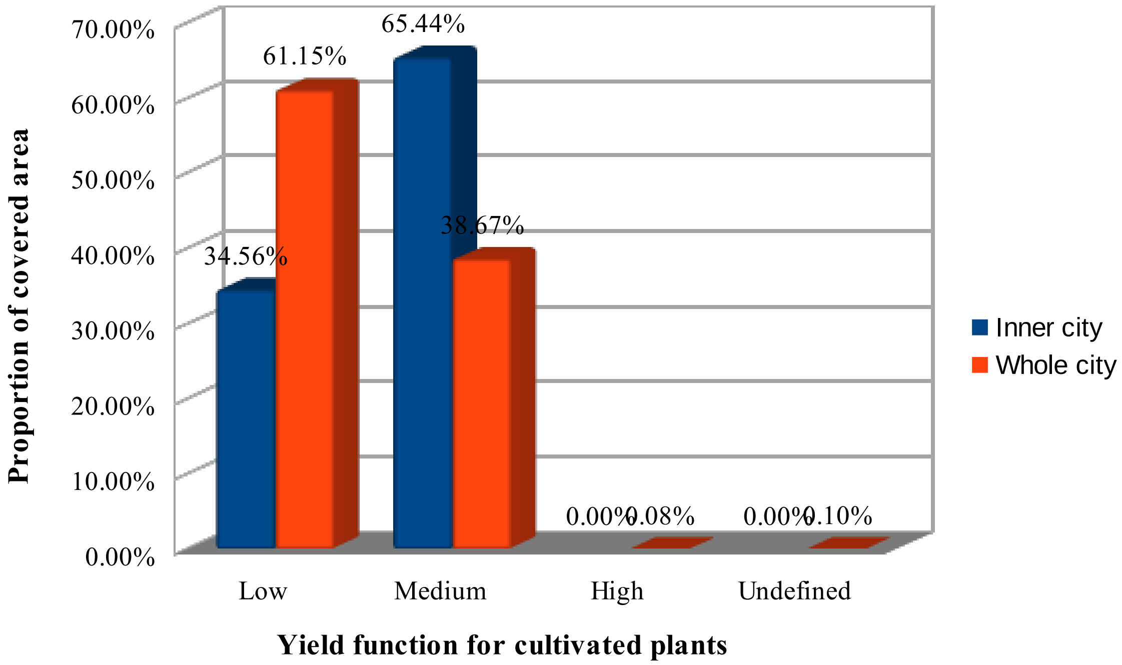


Fig. 189 - Yield function for cultivated plants/sum of water and nutrient supply indicators of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

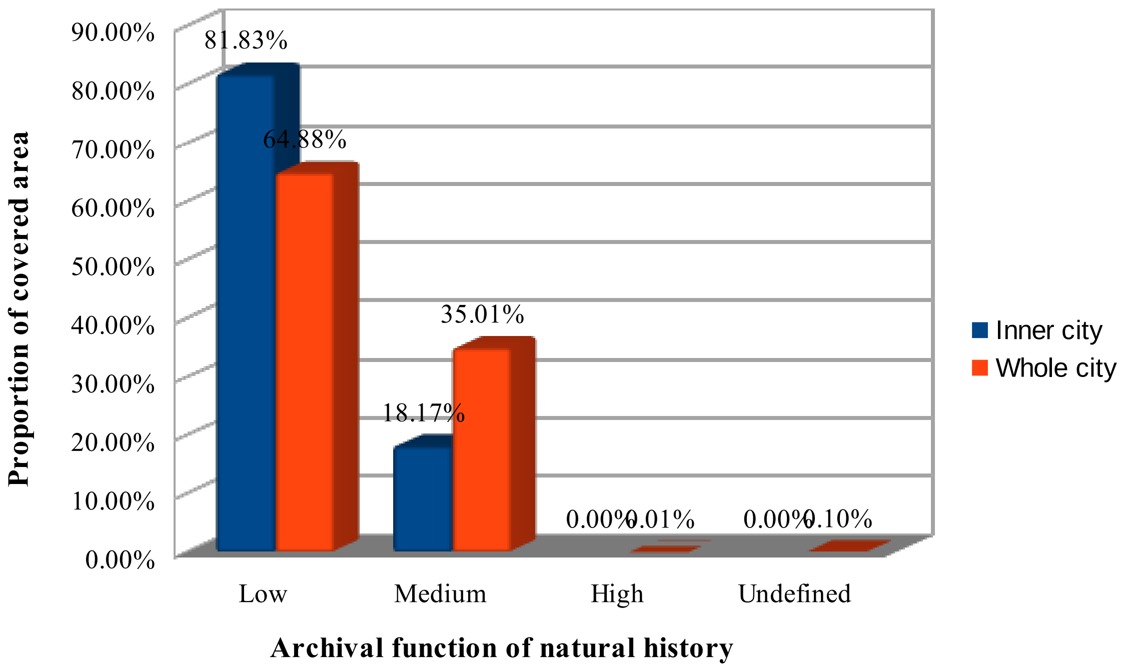


Fig. 190 - Archival function of natural history/rarity of soil associations, and particular soils of the nature region of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

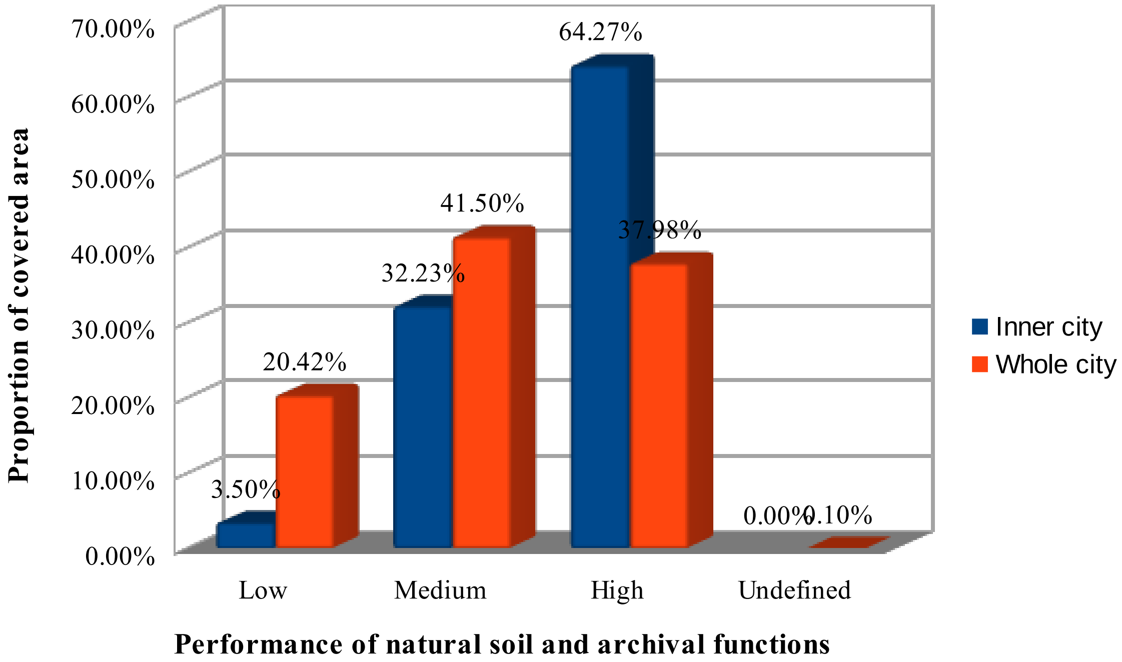


Fig. 191 - Performance of natural soil and archival functions/sum of soil functions of the five analysed soil functions above of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

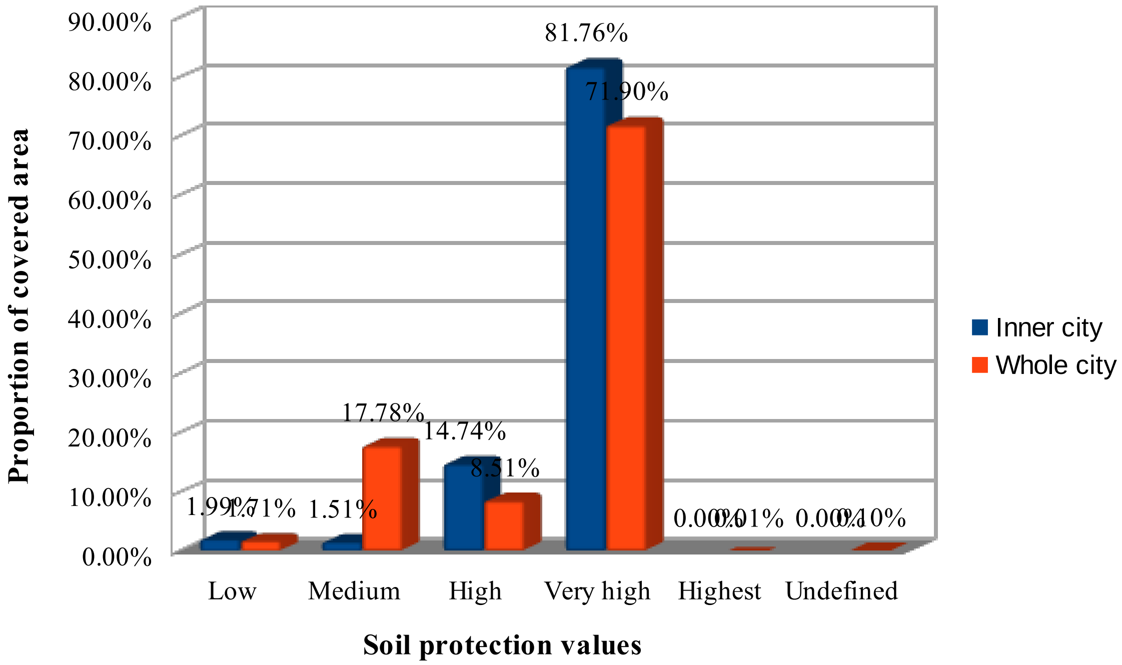


Fig. 192 - Soil protection values/sum of habitat function for rare natural vegetation, archival function of natural history, yield function for cultivated plants, and regulation function for the water balance, as well as soil sealing degree of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

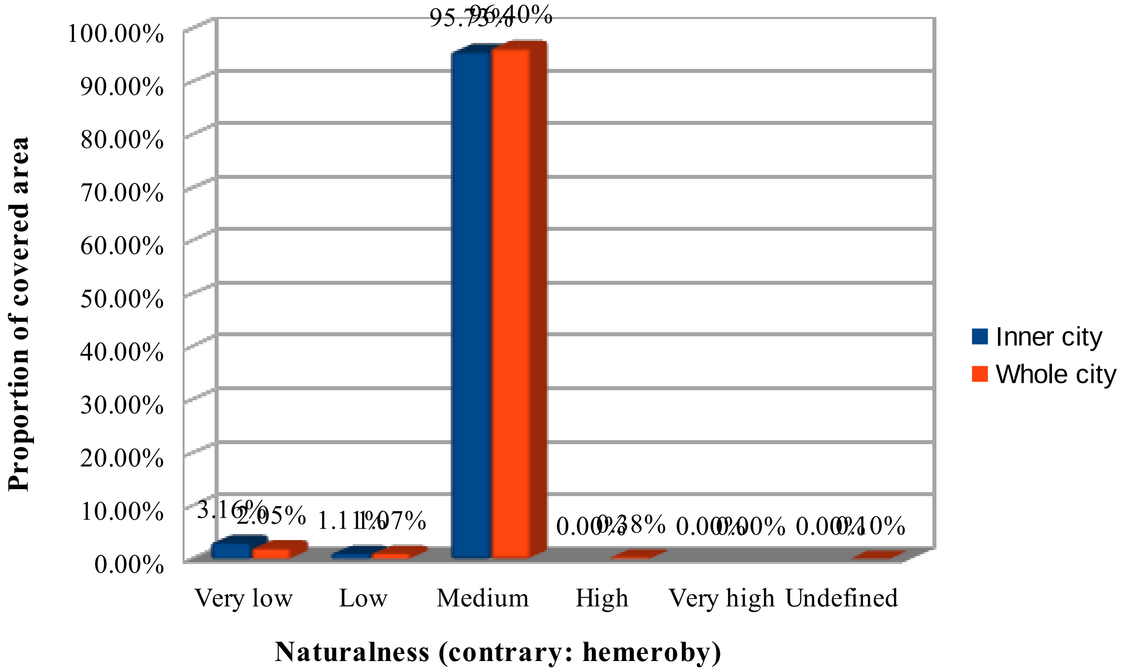


Fig. 193 - Naturalness (contrary: hemeroby) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

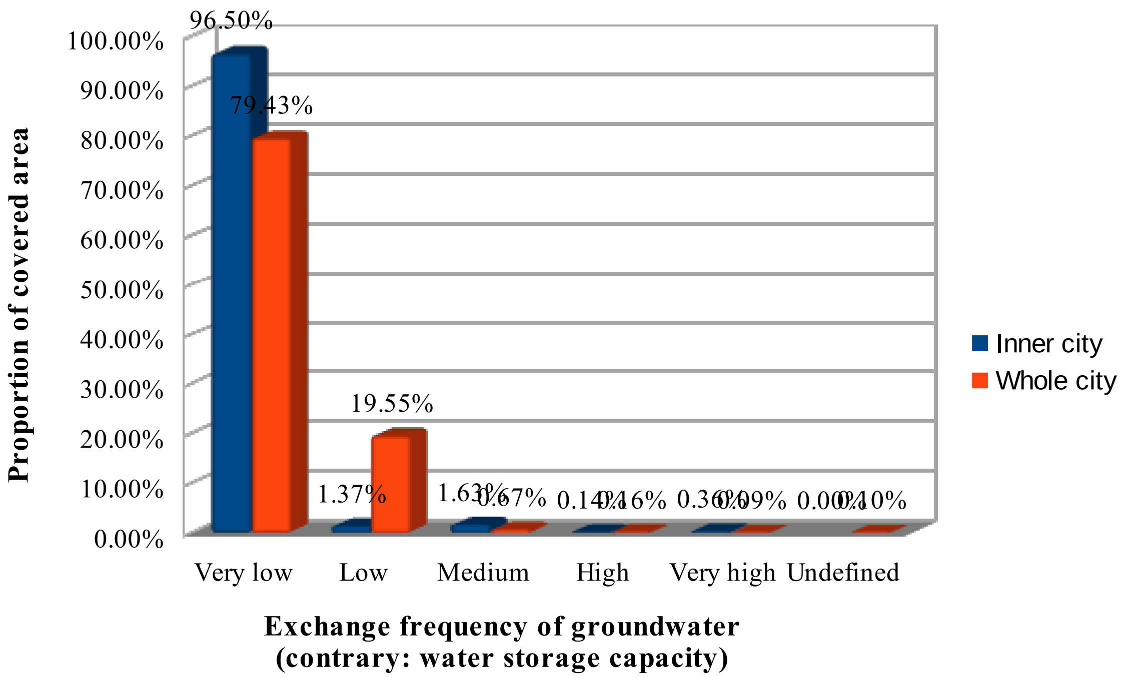


Fig. 194 - Exchange frequency of groundwater (contrary: water storage capacity) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

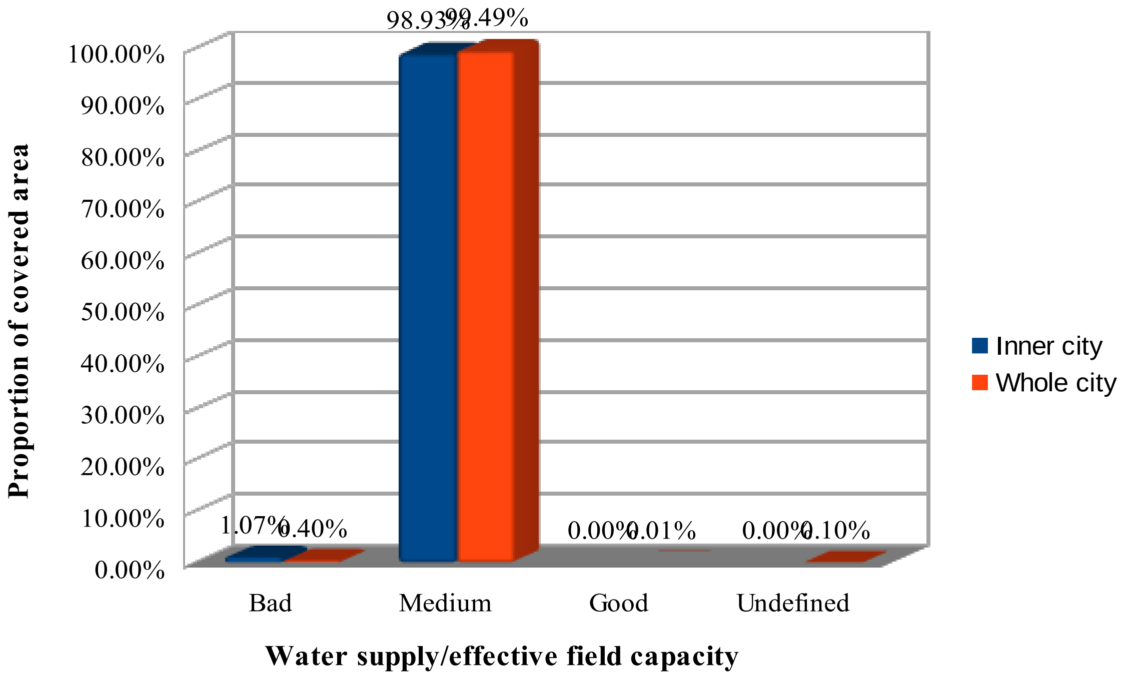


Fig. 195 - Water supply/effective field capacity of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

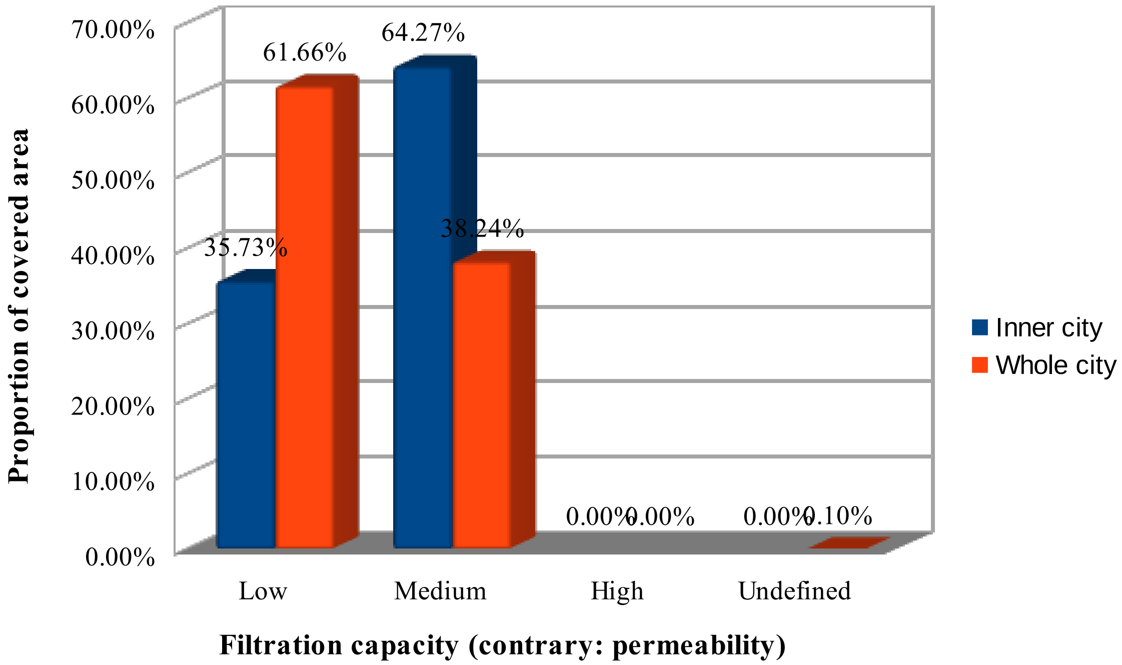


Fig. 196 - Filtration capacity (contrary: permeability) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

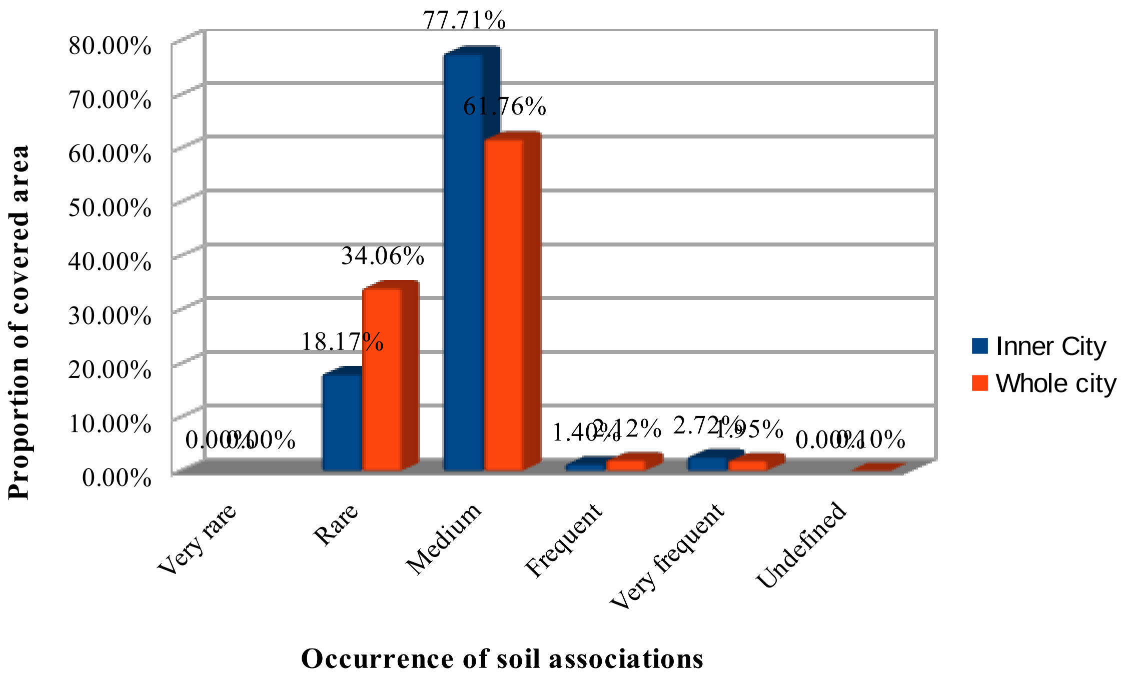


Fig. 197 - Occurrence of soil associations within the area of Berlin of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

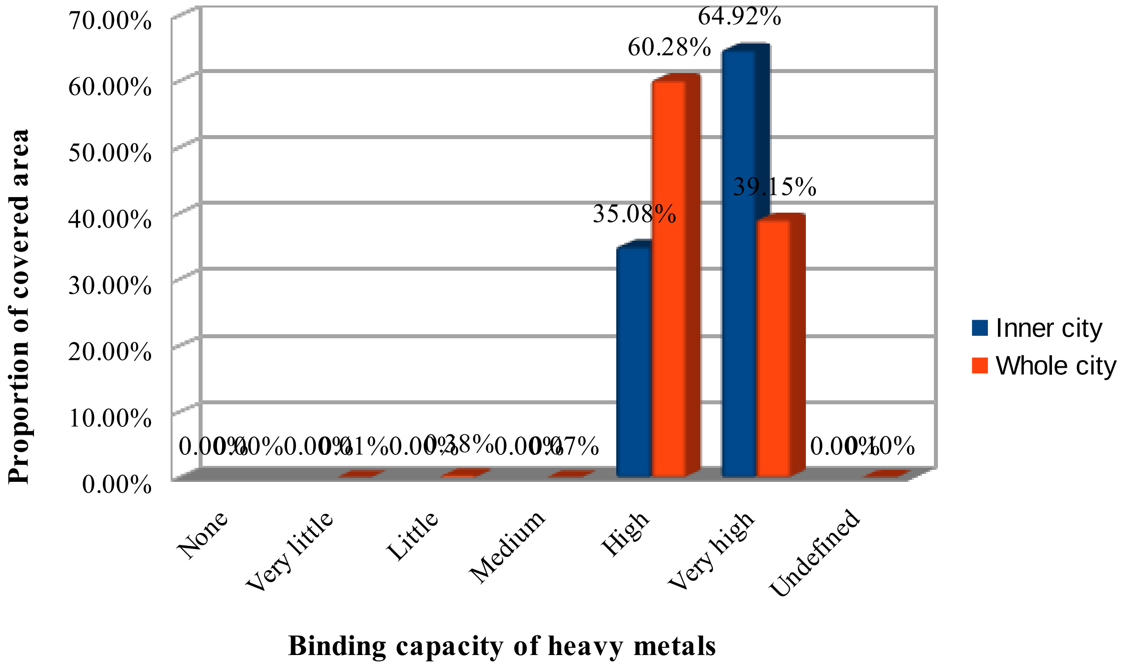


Fig. 198 - Binding capacity of heavy metals of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

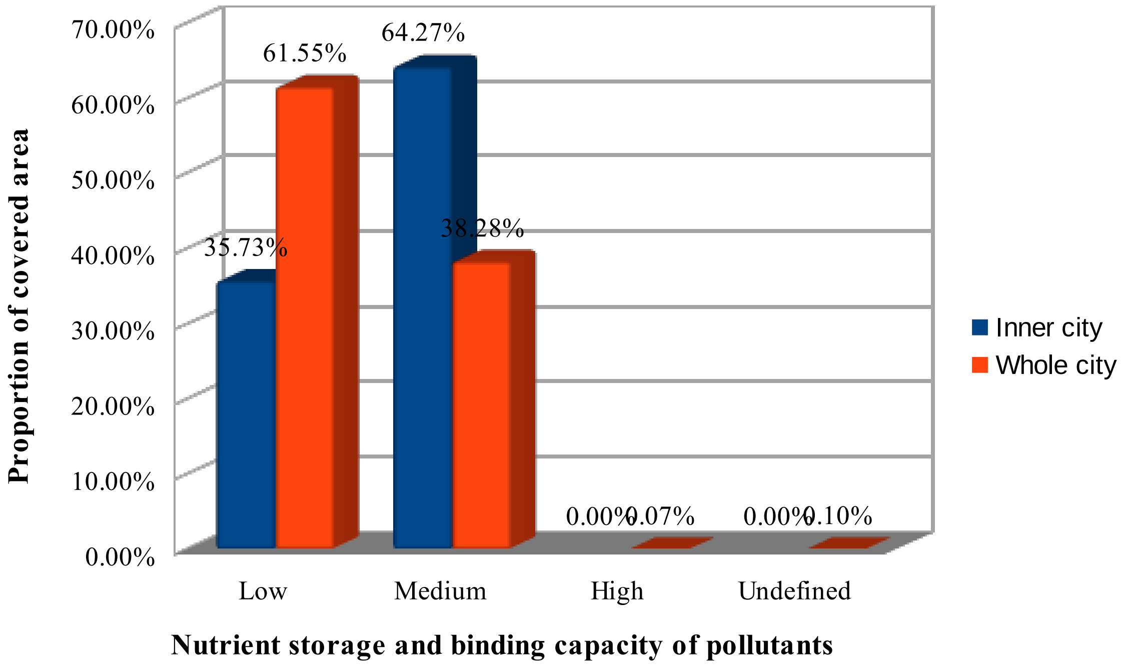


Fig. 199 - Nutrient storage and binding capacity of pollutants/Mean Effective Cation Exchange Capacity of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013).

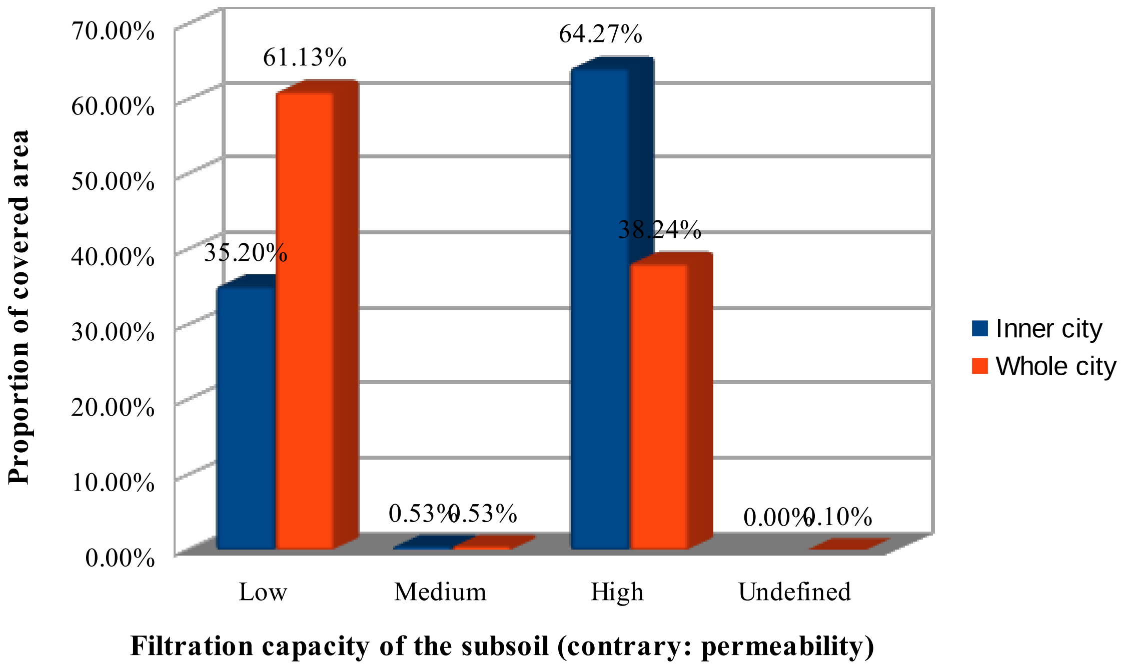


Fig. 200 - Filtration capacity of the subsoil (contrary: permeability) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

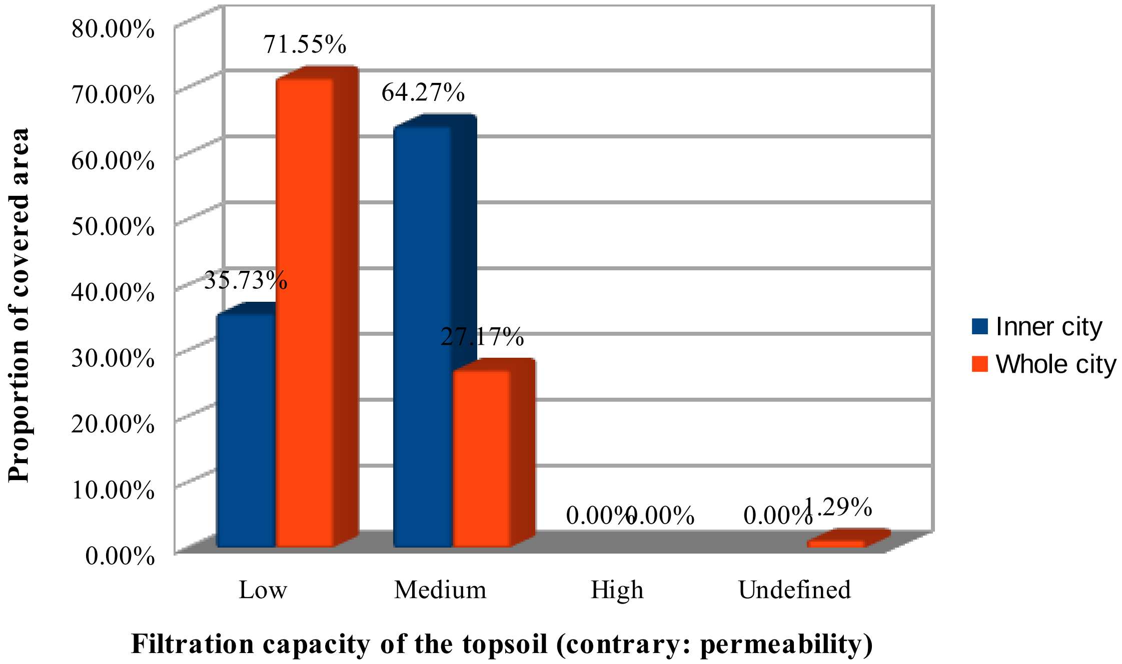


Fig. 201 - Filtration capacity of the topsoil (contrary: permeability) of the proportion of the area of cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2017a; Gerstenberg et al., 2013, 2015).

2.3. Vegetation volume

2.3.1. Public accessible managed green areas/parks (2010)

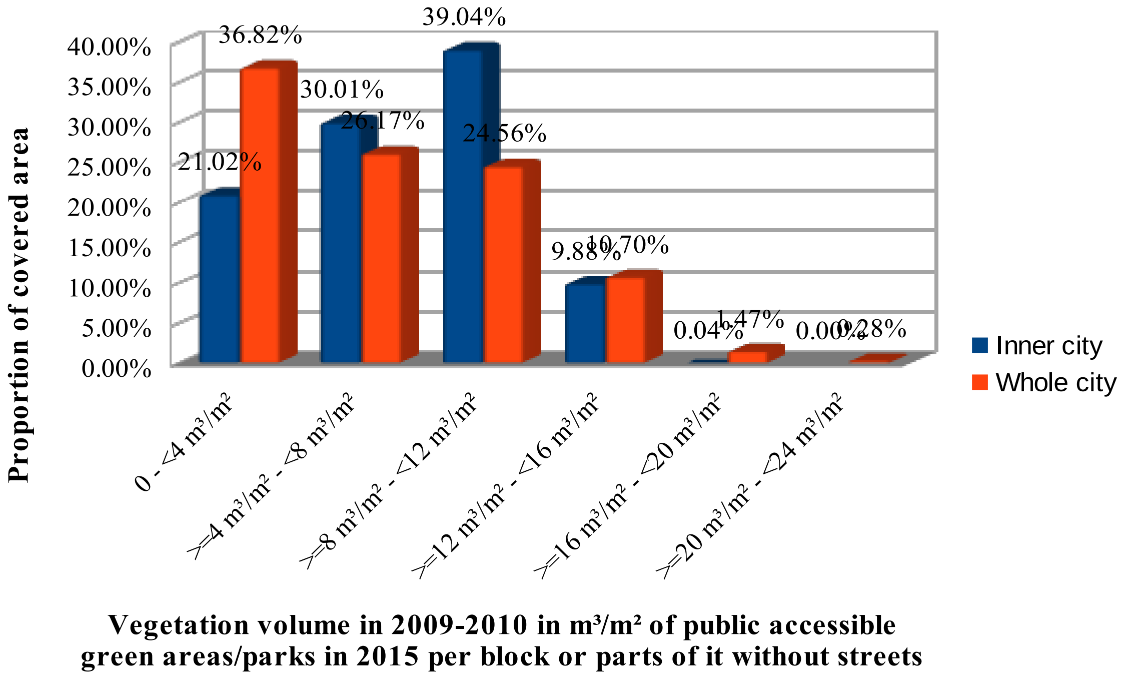


Fig. 202 - Vegetation volume in 2009-2010 in m³/m² of public accessible green areas/parks in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

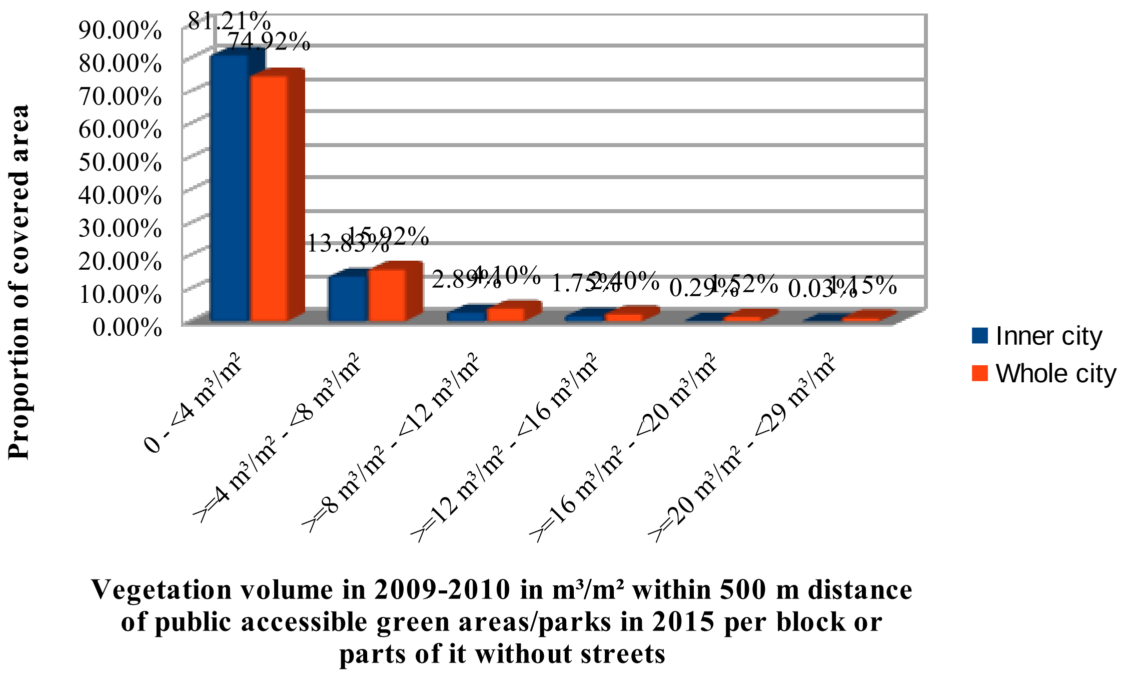


Fig. 203 - Vegetation volume in 2009-2010 in m³/m“ within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

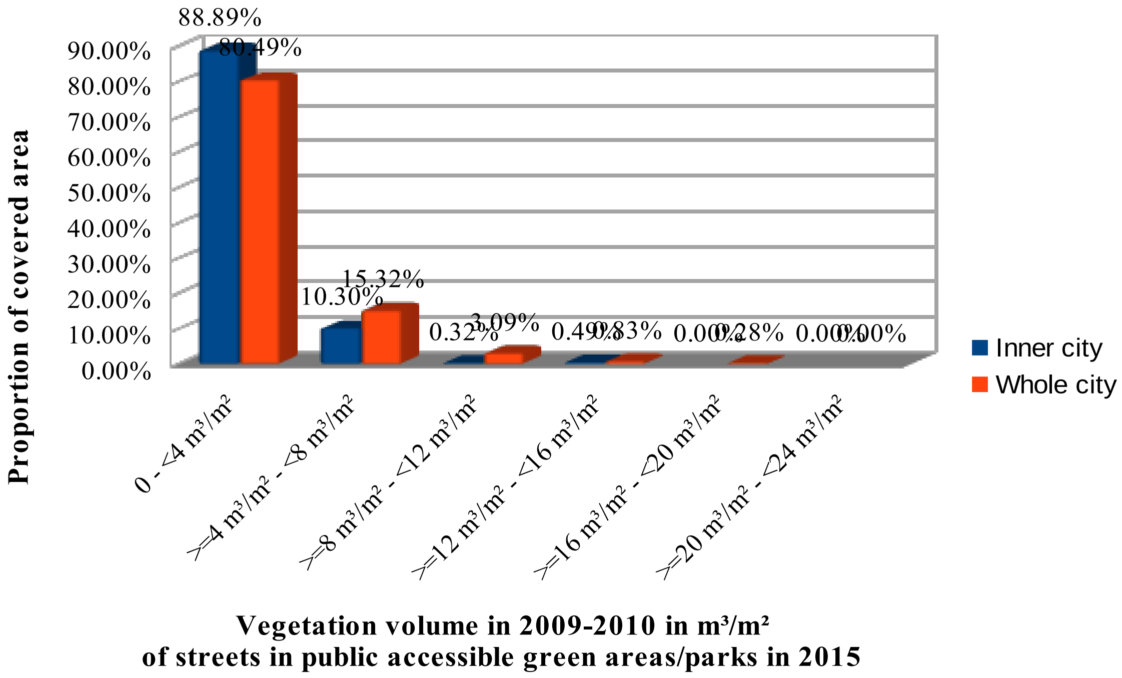


Fig. 204 - Vegetation volume in 2009-2010 in m³/m² of streets in public accessible green areas/parks in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

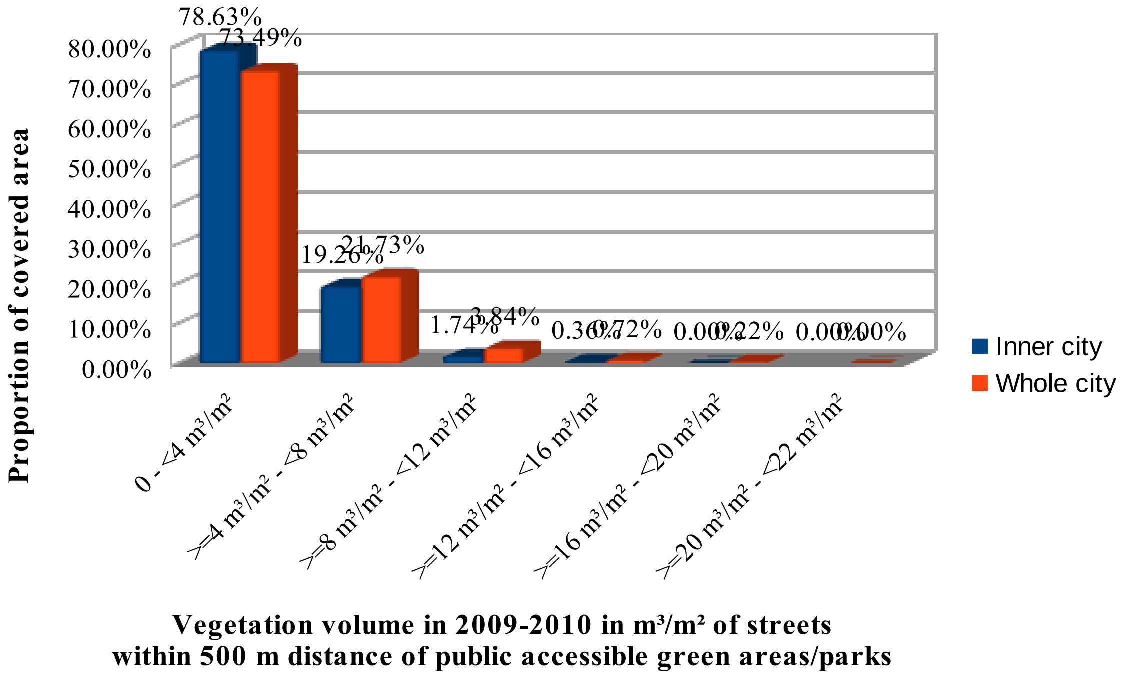


Fig. 205 - Vegetation volume in 2009-2010 in m³/m² of streets within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

2.3.2. Allotments (2015)

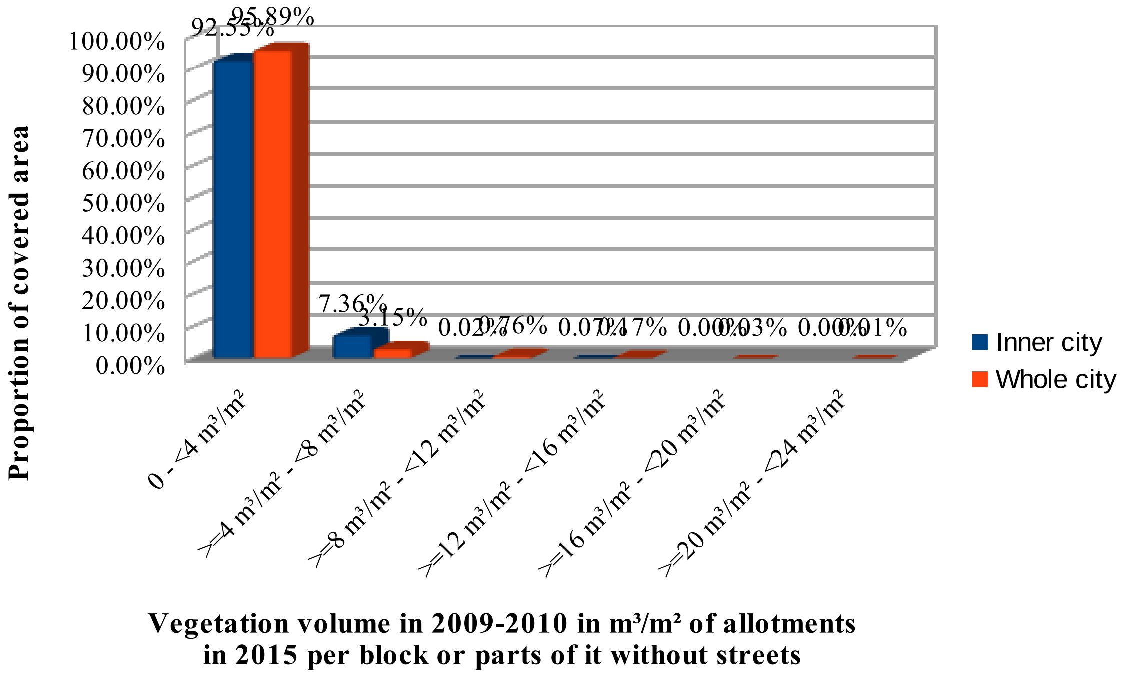


Fig. 206 - Vegetation volume in 2009-2010 in m³/m² of allotments in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

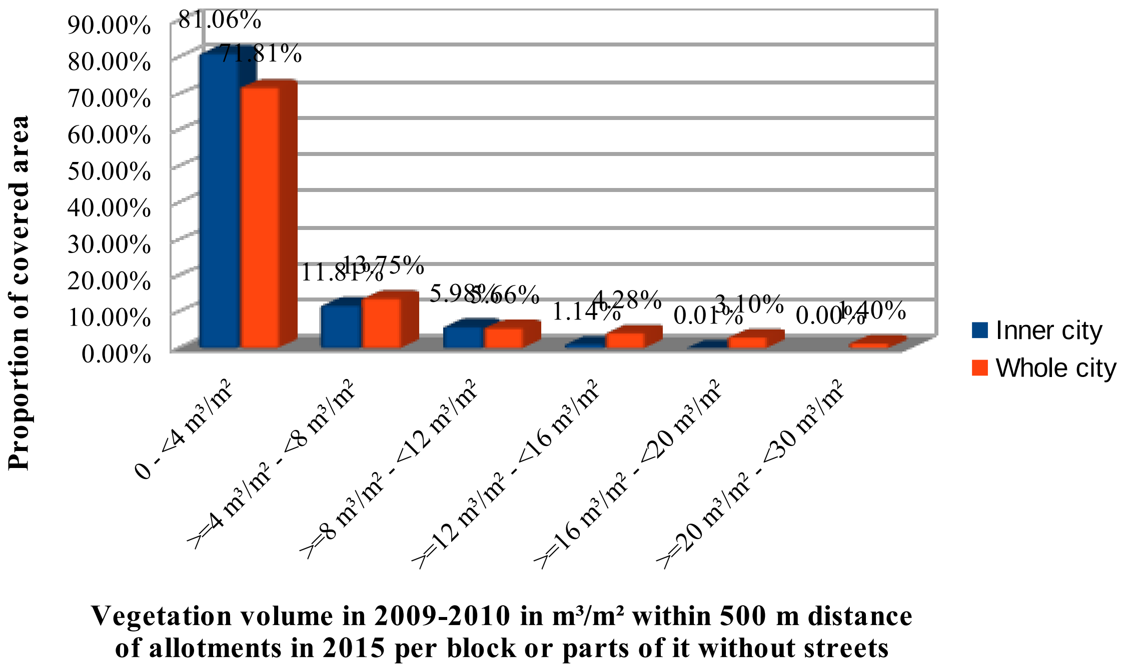


Fig. 207 - Vegetation volume in 2009-2010 in m³/m“ within 500 m distance of allotments of a minimum size of 0.5 ha in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

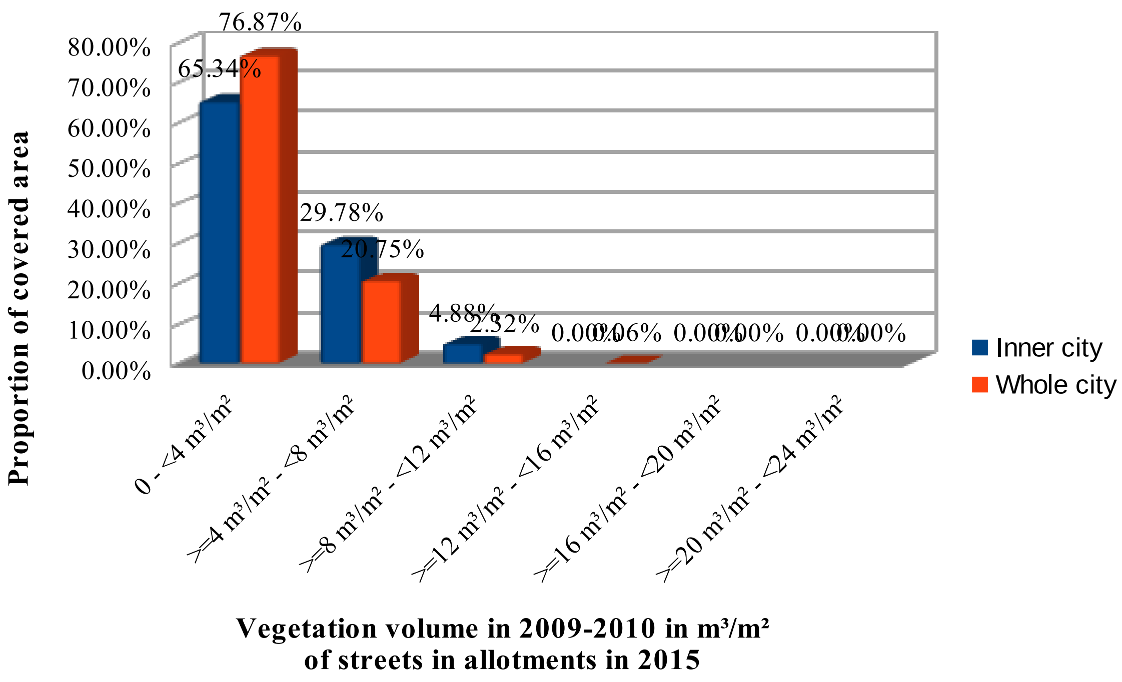


Fig. 208 - Vegetation volume in 2009-2010 in m^3/m^2 of streets in allotments in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

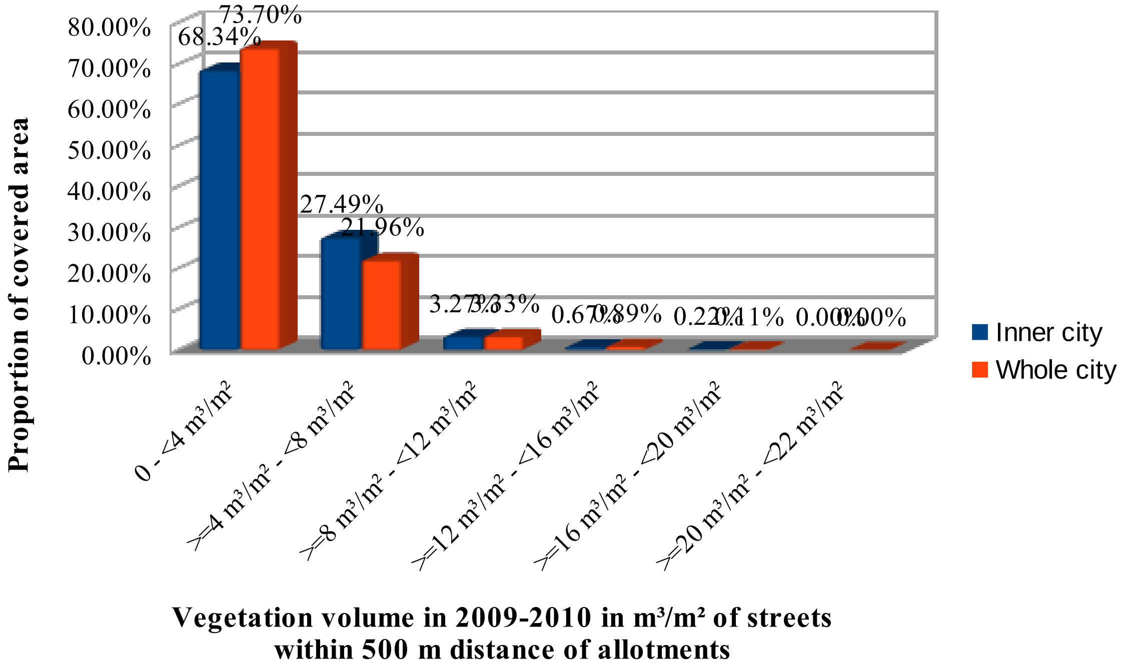
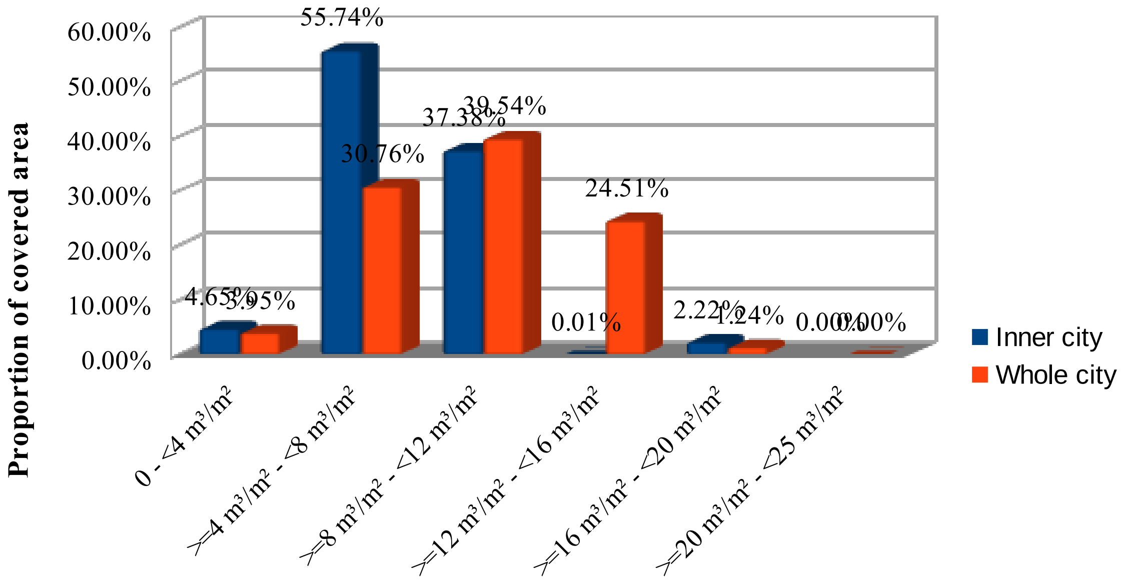


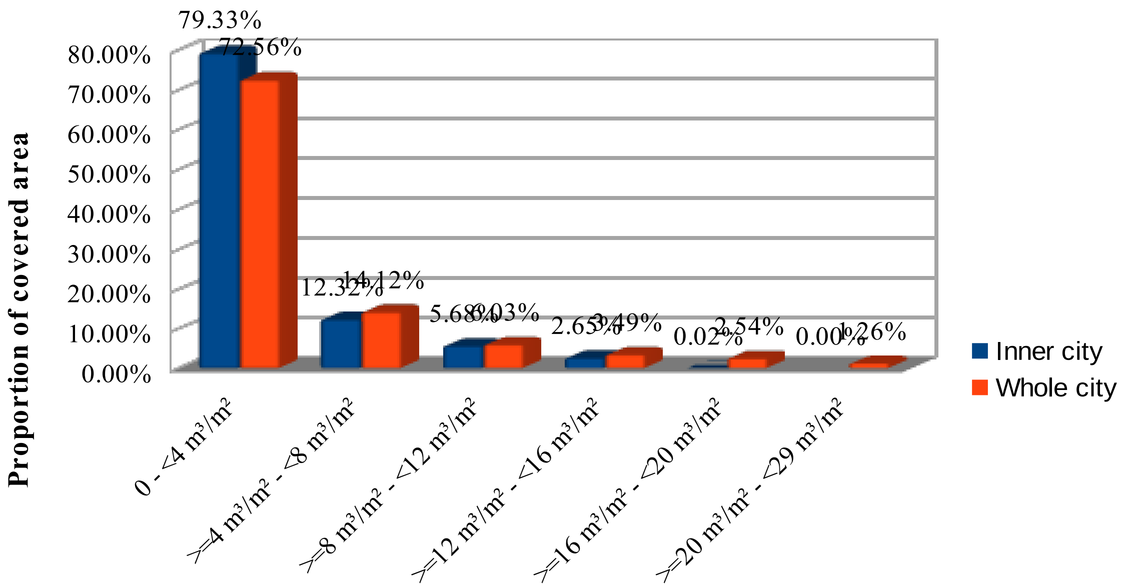
Fig. 209 - Vegetation volume in 2009-2010 in m^3/m^2 of streets within 500 m distance of allotments of a minimum size of 0.5 ha in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

2.3.3. Cemeteries (2010)



Vegetation volume in 2009-2010 in m³/m² of cemeteries in 2015 per block or parts of it without streets

Fig. 210 - Vegetation volume in 2009-2010 in m³/m² of cemeteries in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).



Vegetation volume in 2009-2010 in m³/m² within 500 m distance of cemeteries in 2015 per block or parts of it without streets

Fig. 211 - Vegetation volume in 2009-2010 in m³/m" within 500 m distance of cemeteries of a minimum size of 0.5 ha in 2015 per block or parts of it without streets in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

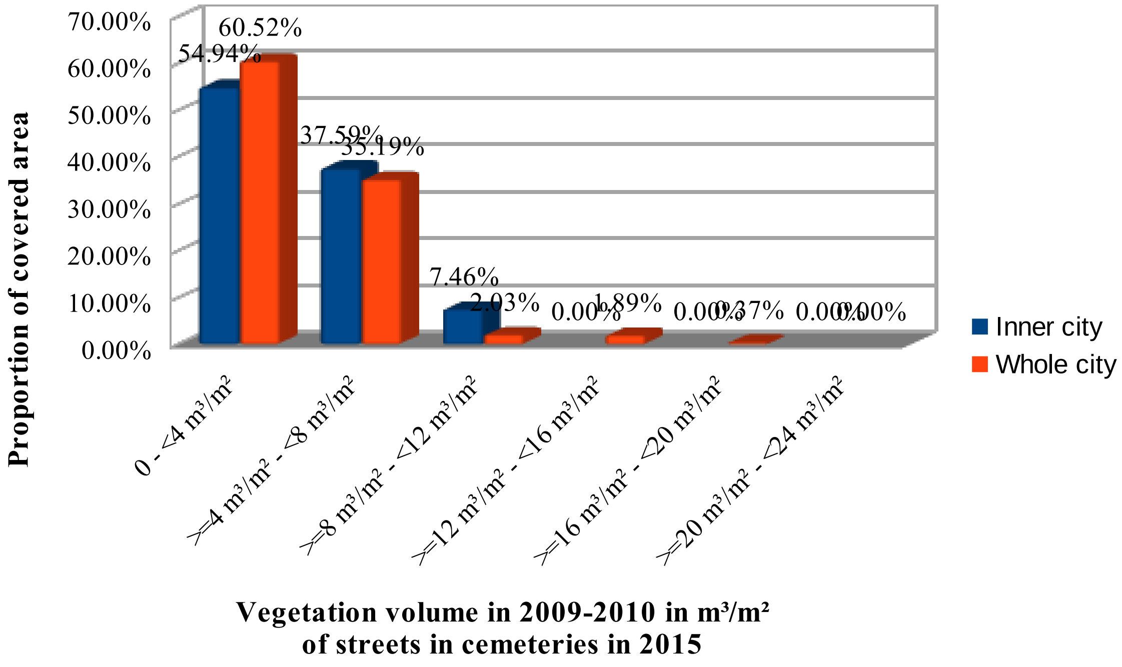


Fig. 212 - Vegetation volume in 2009-2010 in m³/m² of streets in cemeteries in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

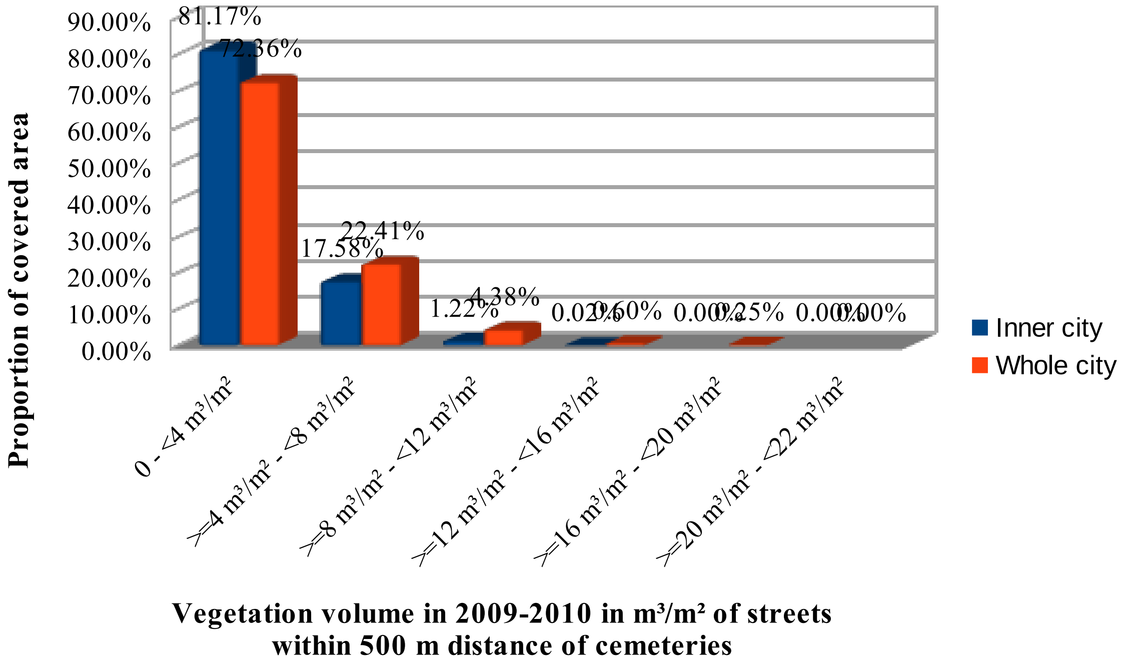


Fig. 213 - Vegetation volume in 2009-2010 in m³/m² of streets within 500 m distance of cemeteries of a minimum size of 0.5 ha in 2015 in the inner and whole city of Berlin (own calculation based on data of the Senate of Berlin, 2017a).

2.4. Hemeroby of biotope types

2.4.1. Public accessible managed green areas/parks (2010)

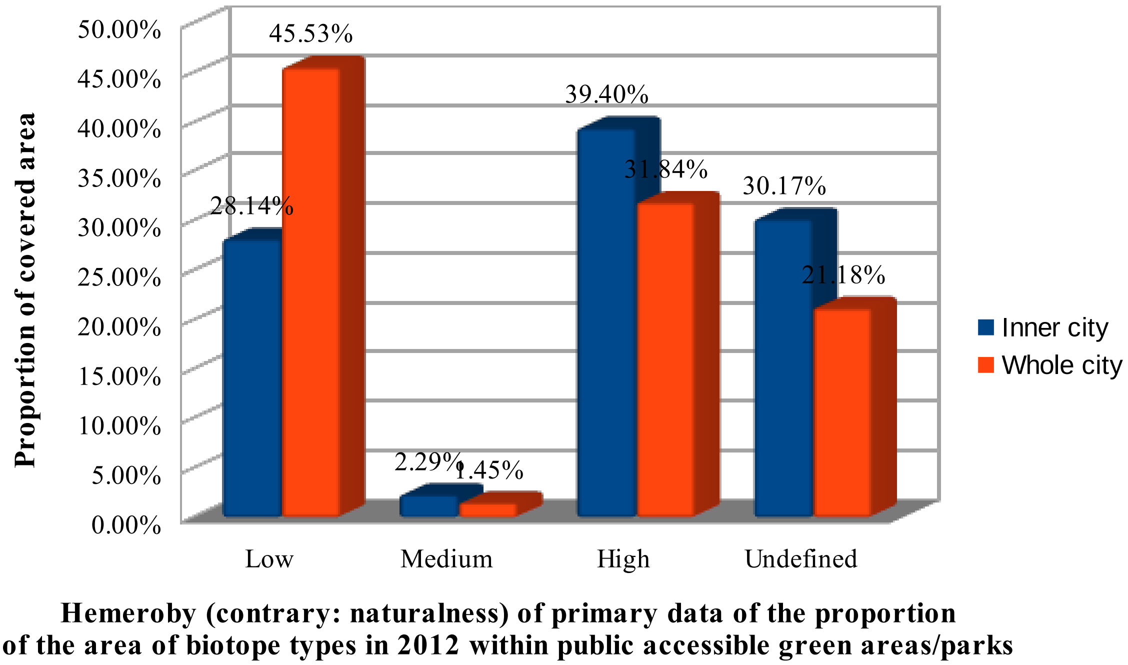


Fig. 214 - Hemeroby (contrary: naturalness) of primary data of the proportion of the area of biotope types in 2012 within public accessible green areas/parks in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2012d; Köstler et al., 2005).

2.4.2. Allotments (2015)

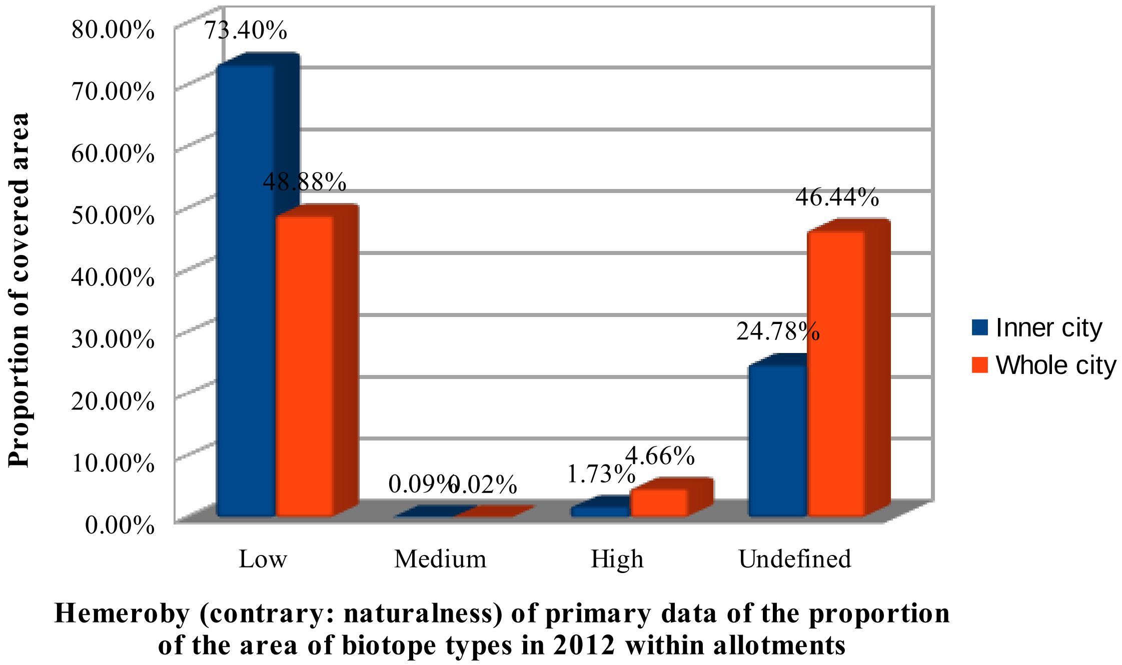


Fig. 215 - Hemeroby (contrary: naturalness) of primary data of the proportion of the area of biotope types in 2012 within allotments in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2012d; Köstler et al., 2005).

2.4.3. Cemeteries (2010)

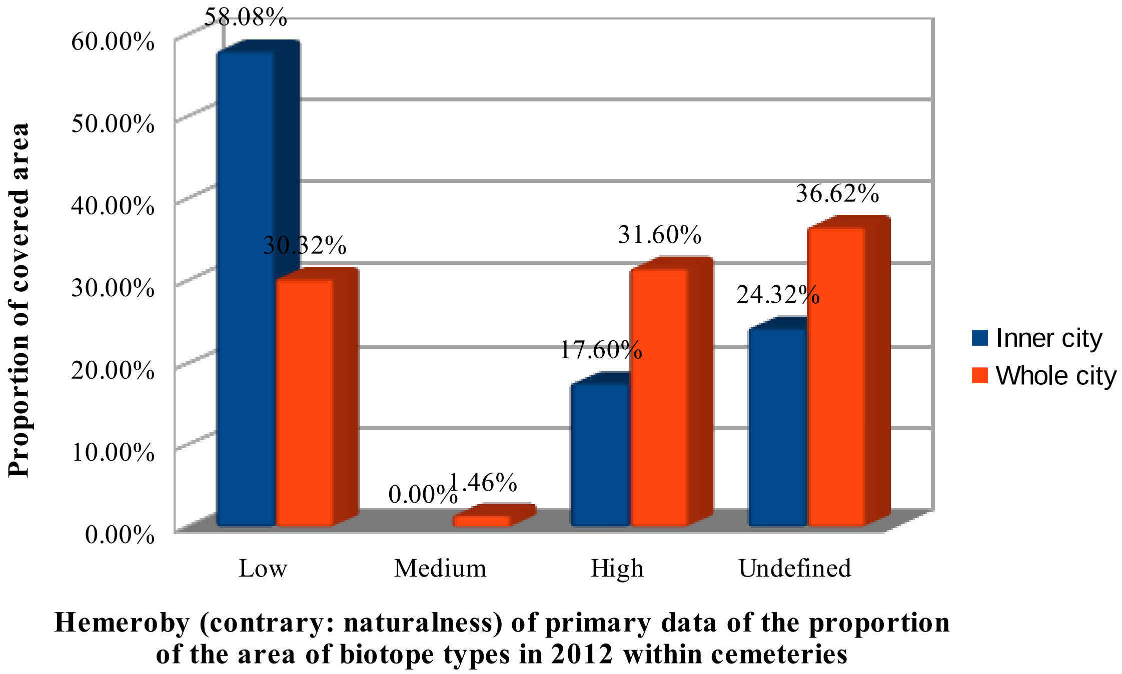


Fig. 216 - Hemeroby (contrary: naturalness) of primary data of the proportion of the area of biotope types in 2012 within cemeteries in the inner and whole city of Berlin in 2010 (own calculation based on data of the Senate of Berlin, 2012d; Köstler et al., 2005).

2.5. Social and economic data of inhabitants

2.5.1. Public accessible managed green areas/parks (2010)

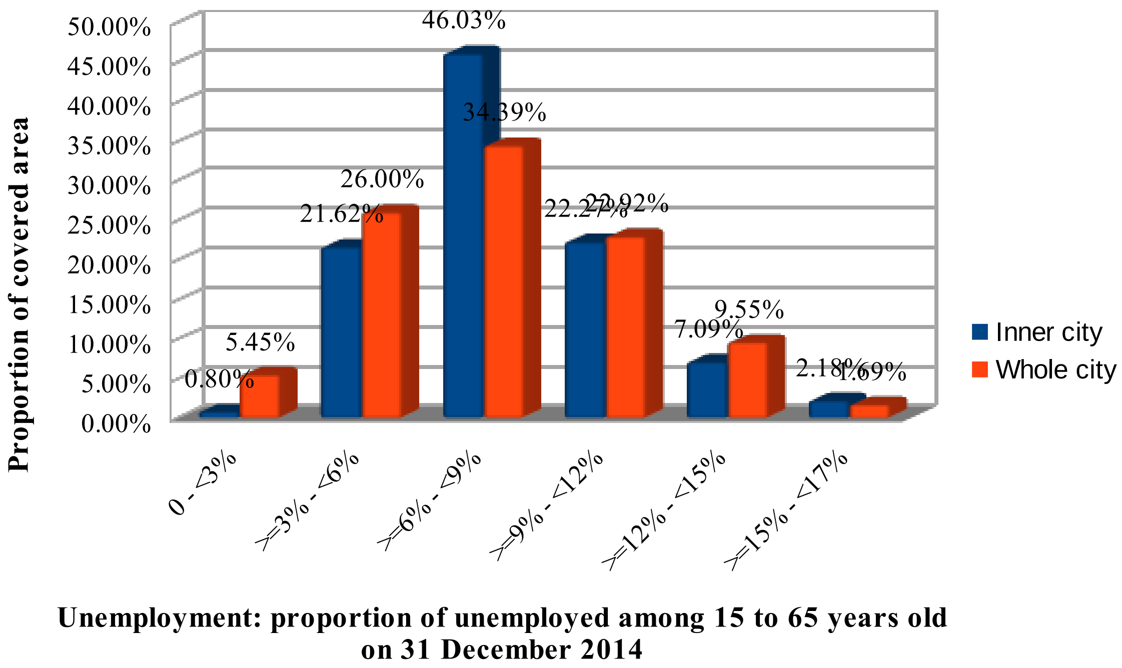
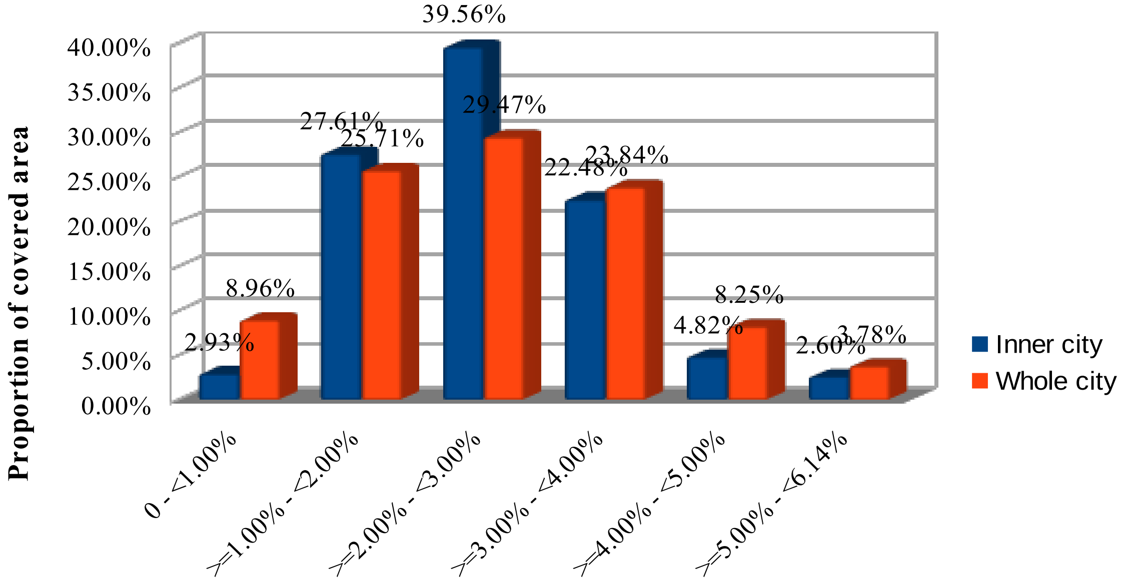


Fig. 217 - Unemployment: proportion of unemployed among 15 to 65 years old on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Long-term unemployment: proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year on 31 December 2014

Fig. 218 - Long-term unemployment: proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

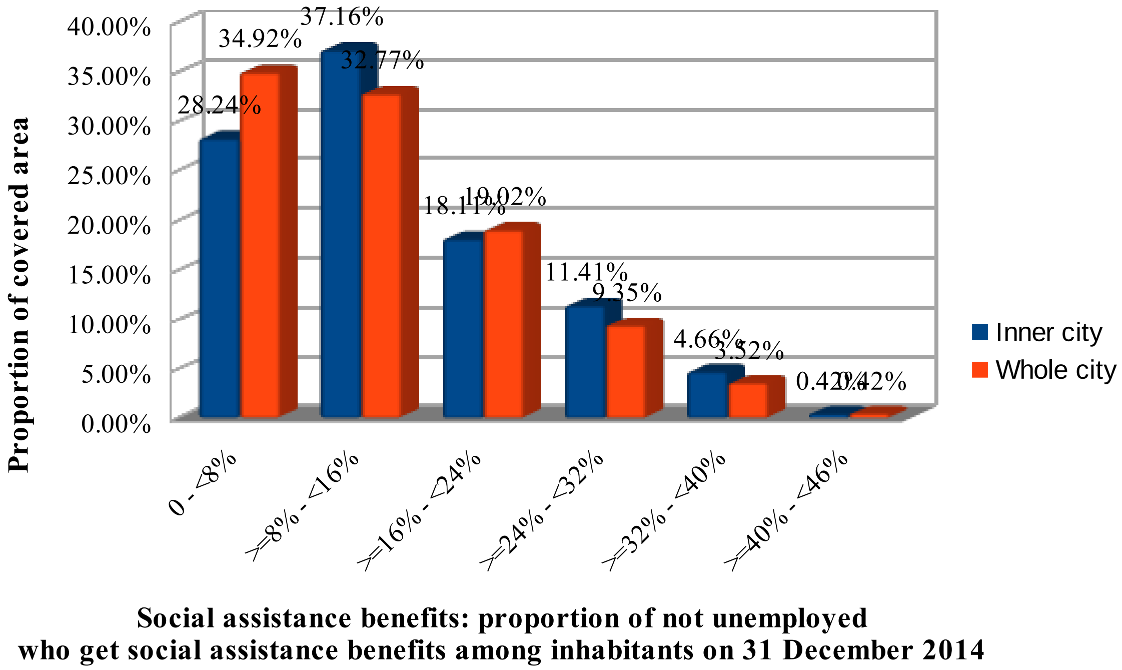


Fig. 219 - Social assistance benefits: proportion of not unemployed who get social assistance benefits among inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

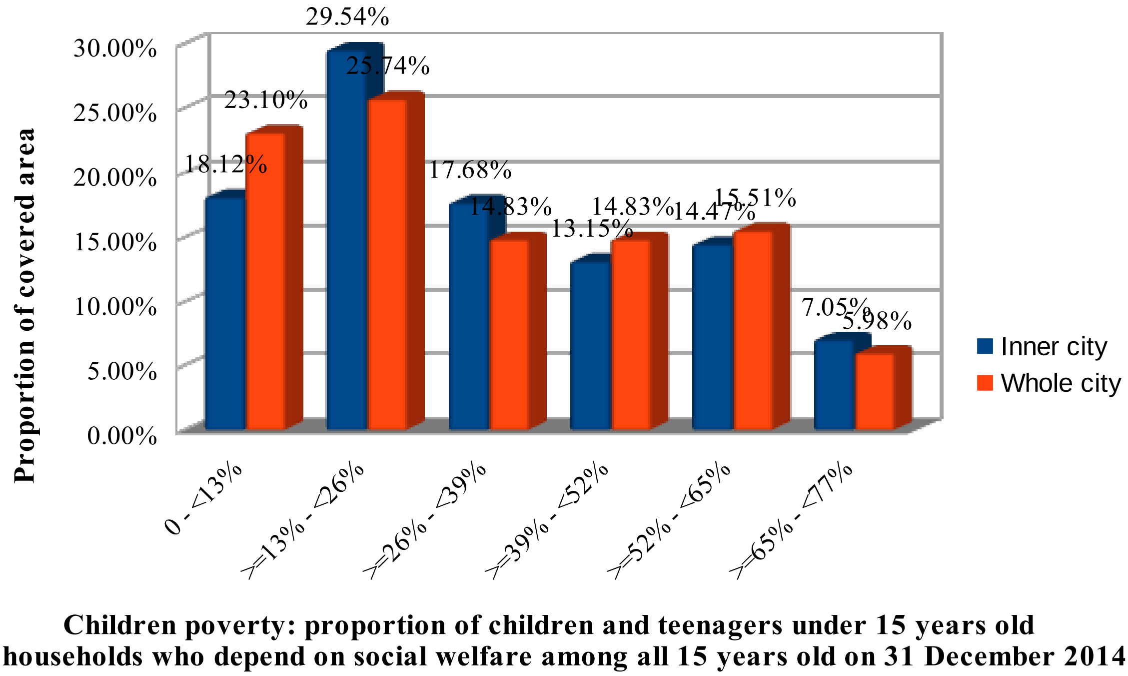


Fig. 220 - Children poverty: proportion of children and teenagers under 15 years old in households who depend on social welfare among all 15 years old on 31 December 2014 within 500 m distance of public accessible green spaces/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

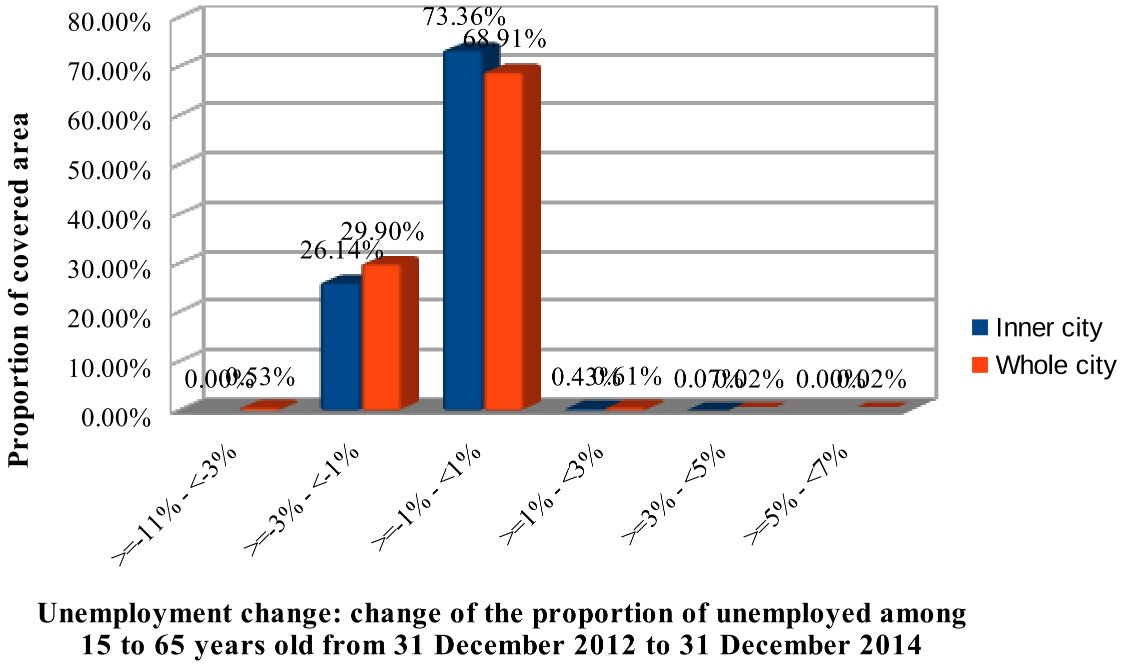


Fig. 221 - Unemployment change: change of the proportion of unemployed among 15 to 65 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

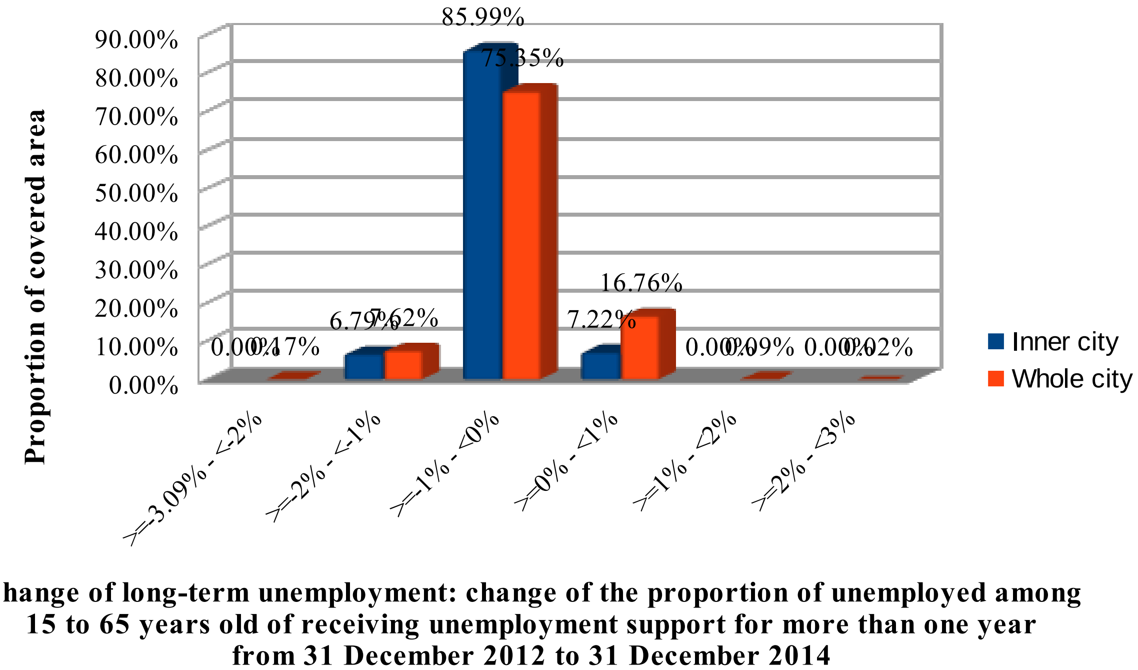


Fig. 222 - Change of long-term unemployment: change of the proportion of unemployed among 15 to 65 years old of receiving unemployment support for more than one year from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

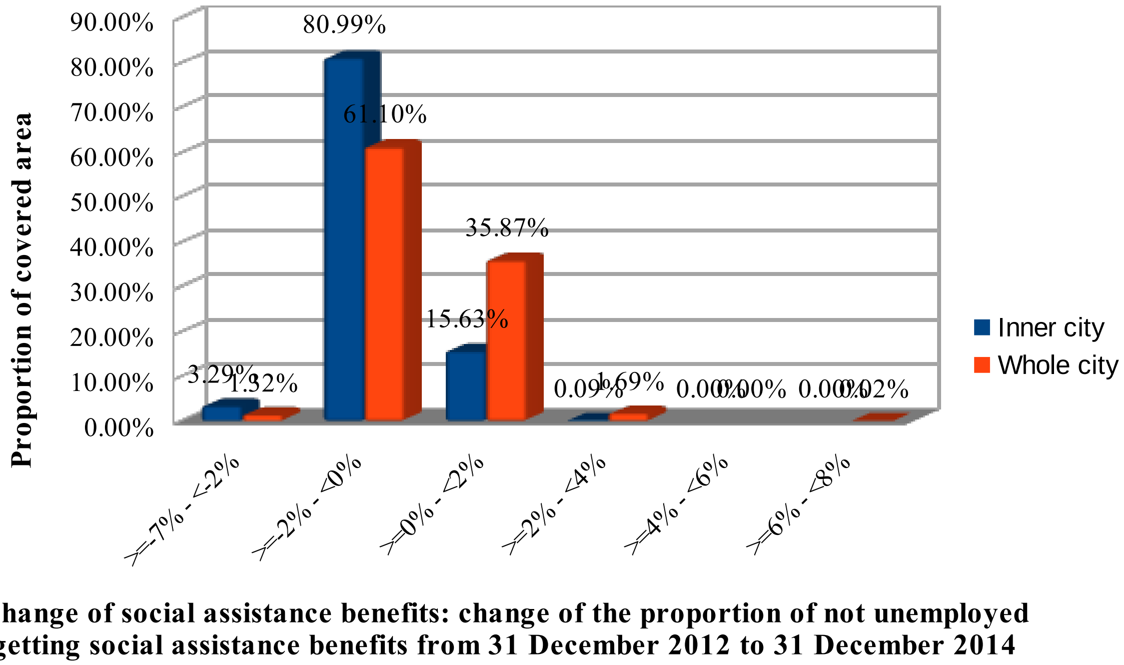
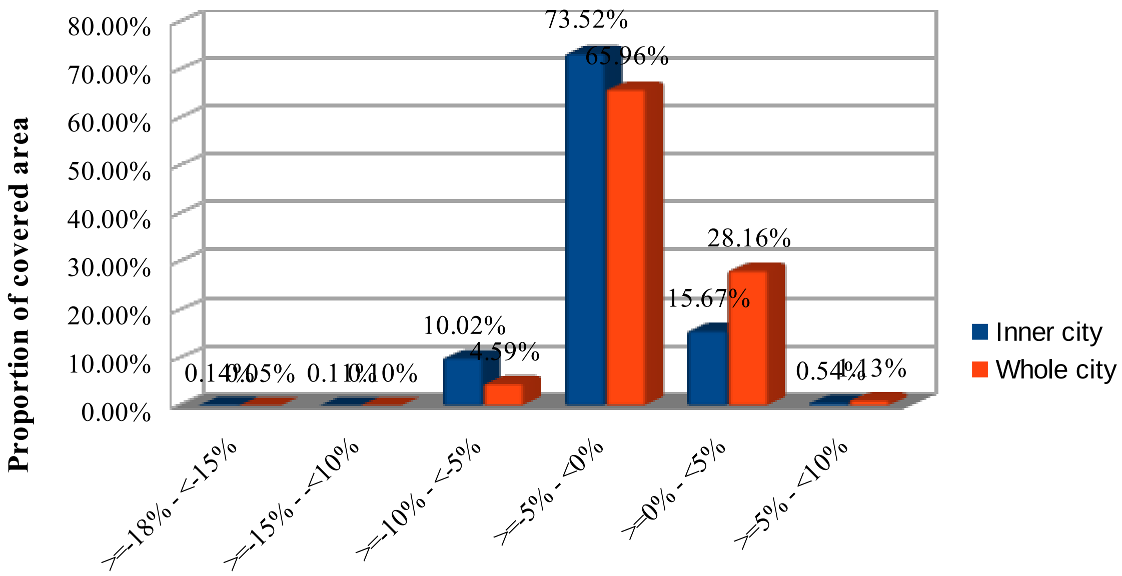


Fig. 223 - Change of social assistance benefits: change of the proportion of not unemployed getting social assistance benefits from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Change of children poverty: change of the proportion of children and teenagers below 15 years old in households who depend on social welfare among all 15 years old

Fig. 224 - Change of children poverty: change of the proportion of children and teenagers of less than 15 years old in households who depend on social welfare among all 15 years old from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

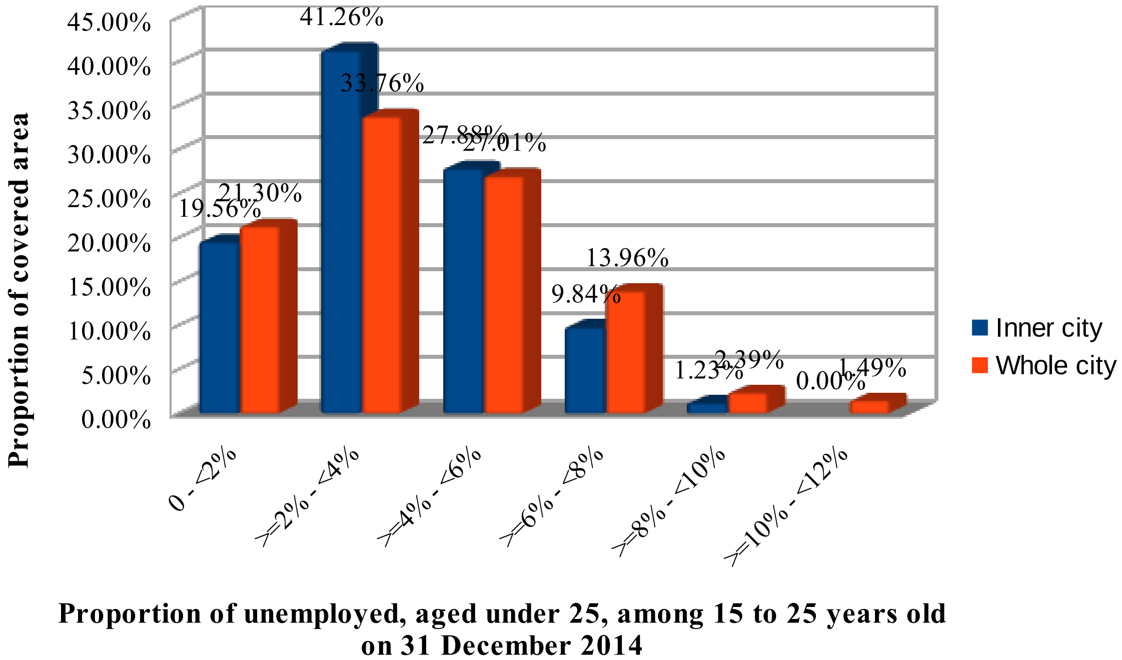


Fig. 225 - Proportion of unemployed, aged under 25, among 15 to 25 years old on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

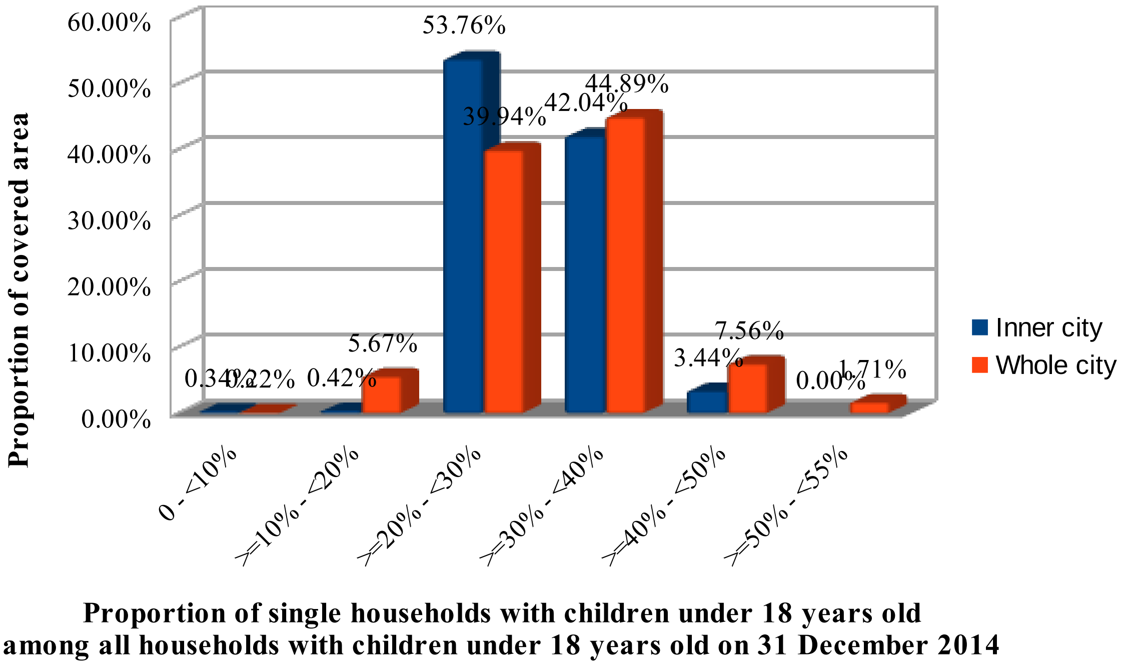
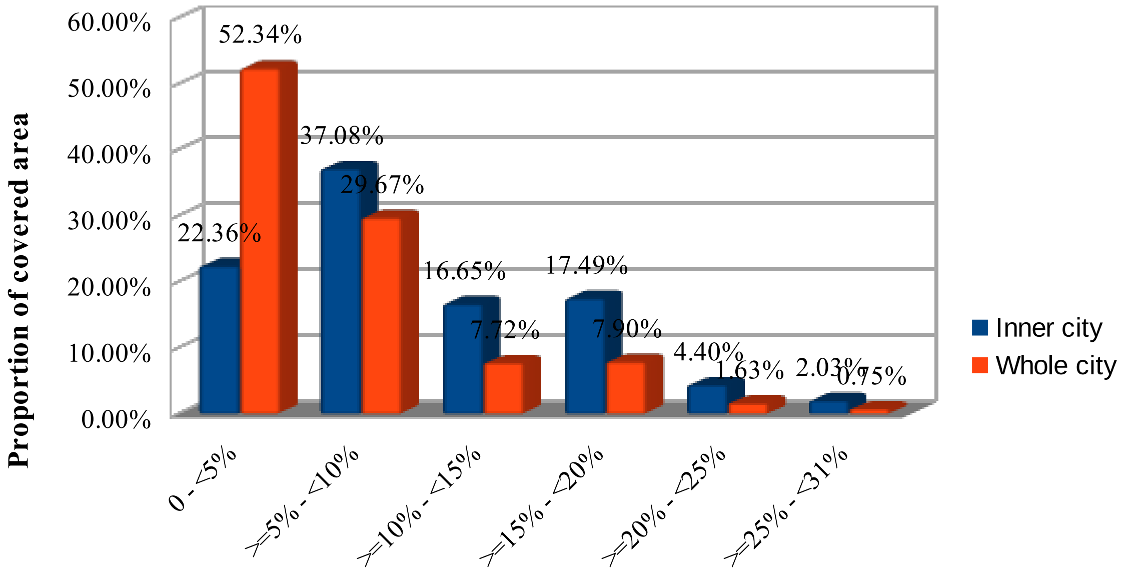
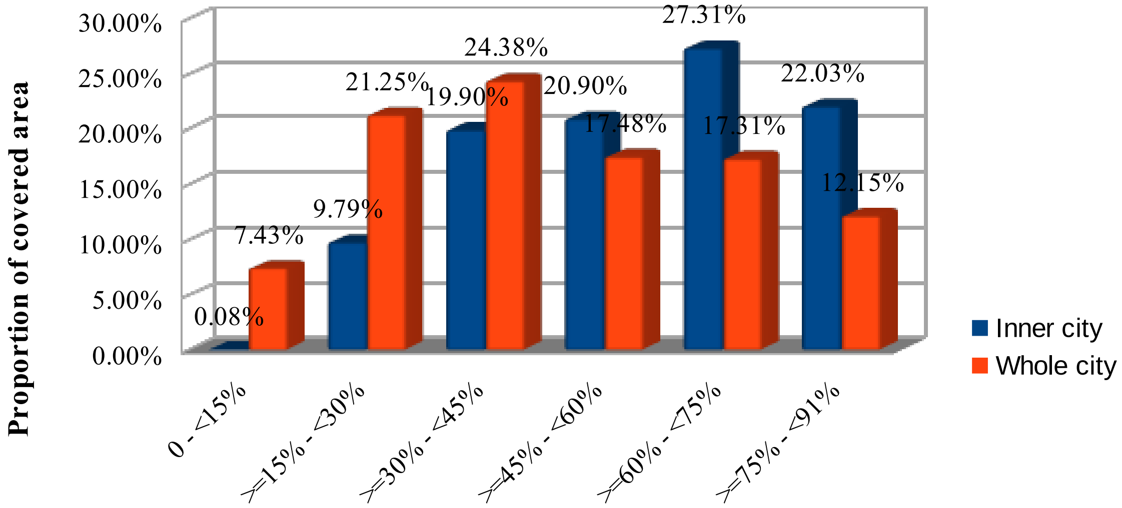


Fig. 226 - Proportion of single households with children under 18 years old among all households with children under 18 years old on 31 December 2014 within 500 m distance of public accessible green spaces/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of inhabitants who depend on social welfare (not living in institutions) of 65 years and older among all inhabitants of this age class on 31 December 2014

Fig. 227 - Proportion of inhabitants who depend on social welfare (not living in institutions) of 65 years and older among all inhabitants of this age class on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of children and youngsters of migration background (foreigners, citizens with a second nationality, and Germans born abroad or with at least one parent born in another country) under 18 years old among all inhabitants of this age class on 31 December 2014

Fig. 228 - Proportion of children and youngsters of migration background (foreigners, citizens with a second nationality, and Germans born abroad or with at least one parent born in another country) under 18 years old among all inhabitants of this age class on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

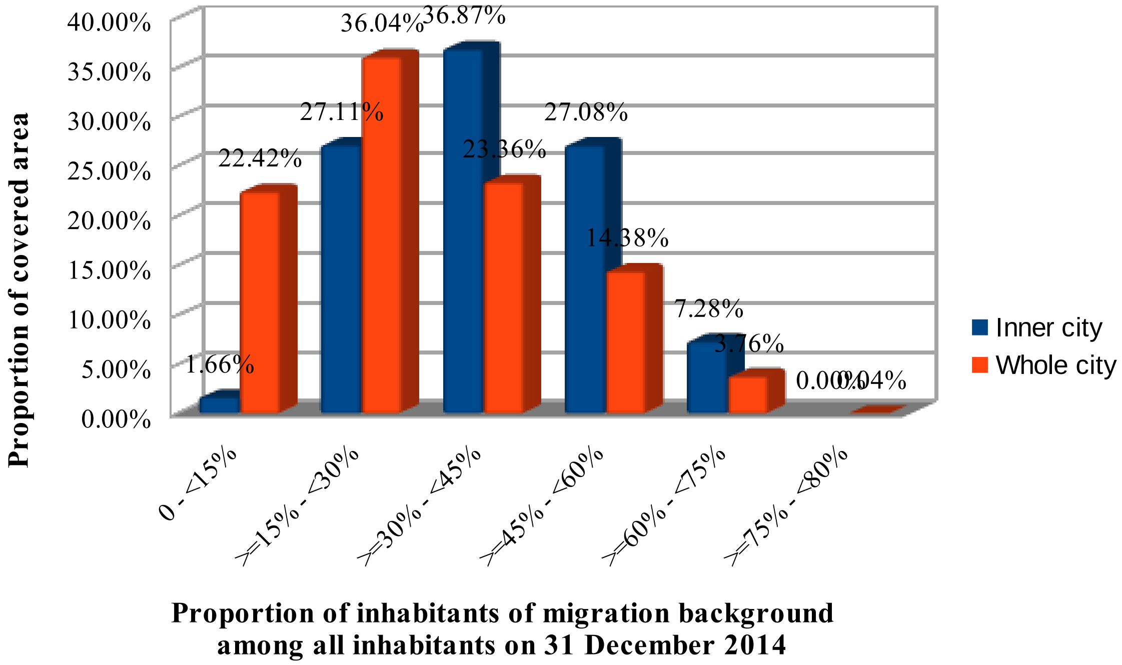


Fig. 229 - Proportion of inhabitants of migration background among all inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

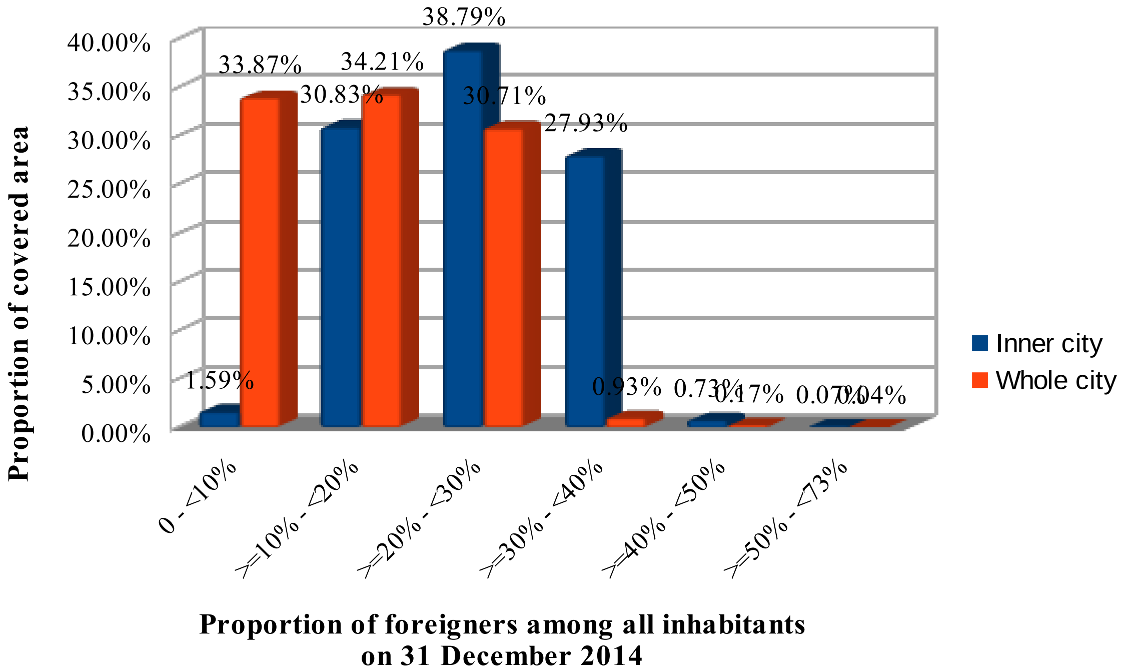


Fig. 230 - Proportion of foreigners among all inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

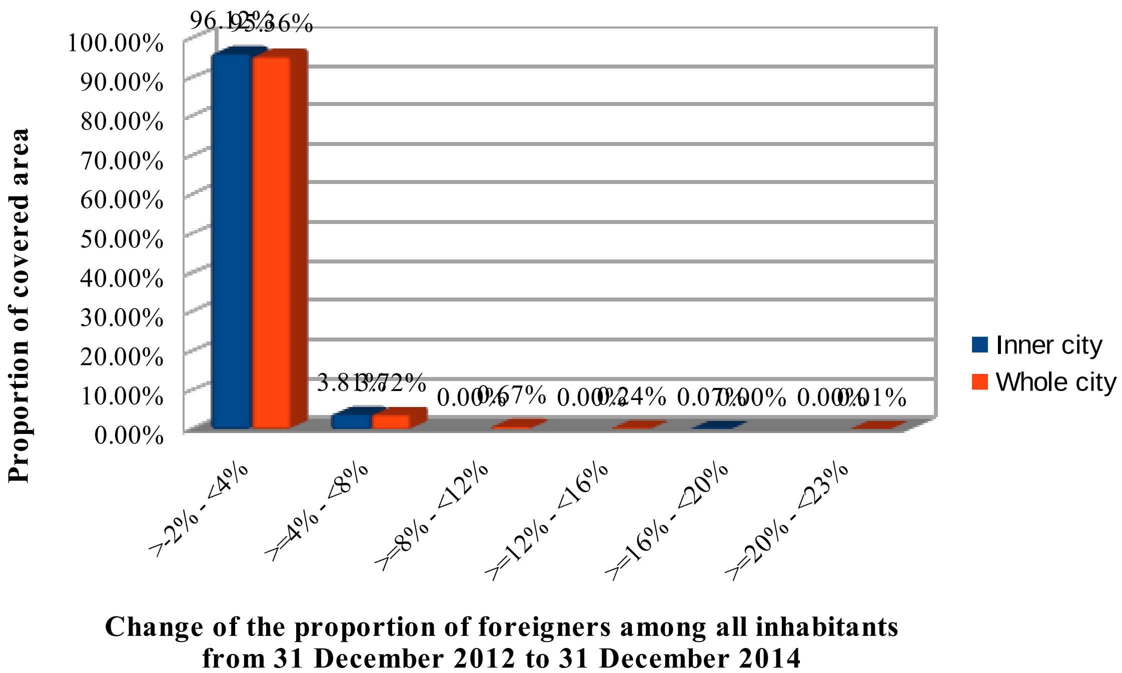


Fig. 231 - Change of the proportion of foreigners among all inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

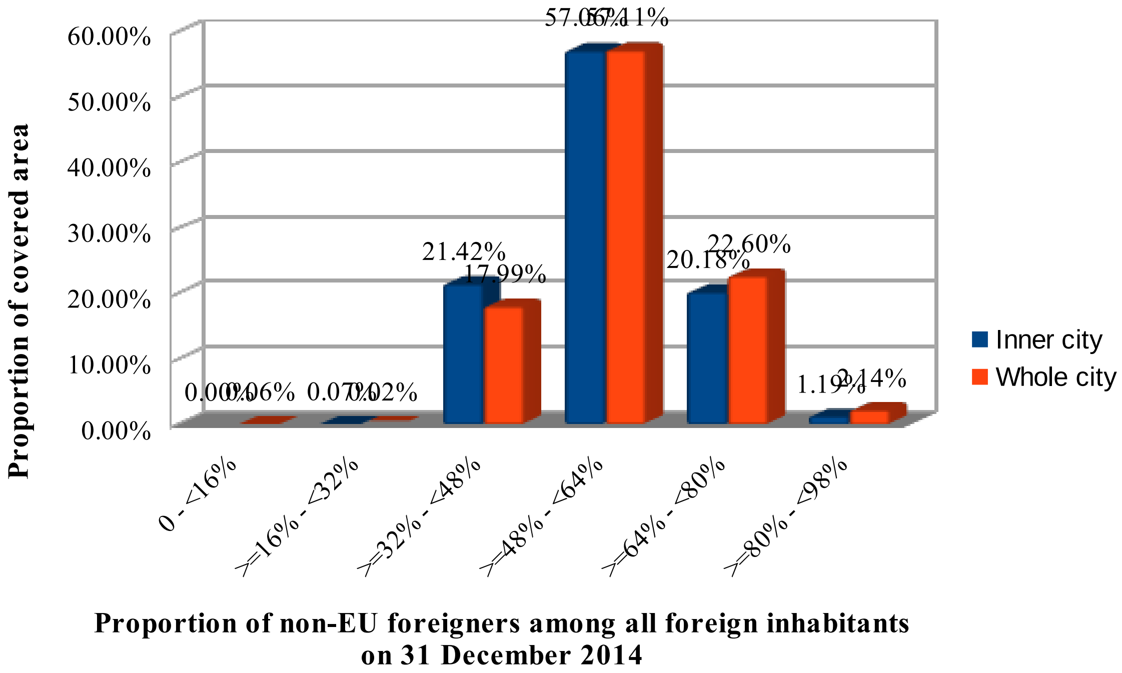


Fig. 232 - Proportion of non-EU foreigners among all foreign inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

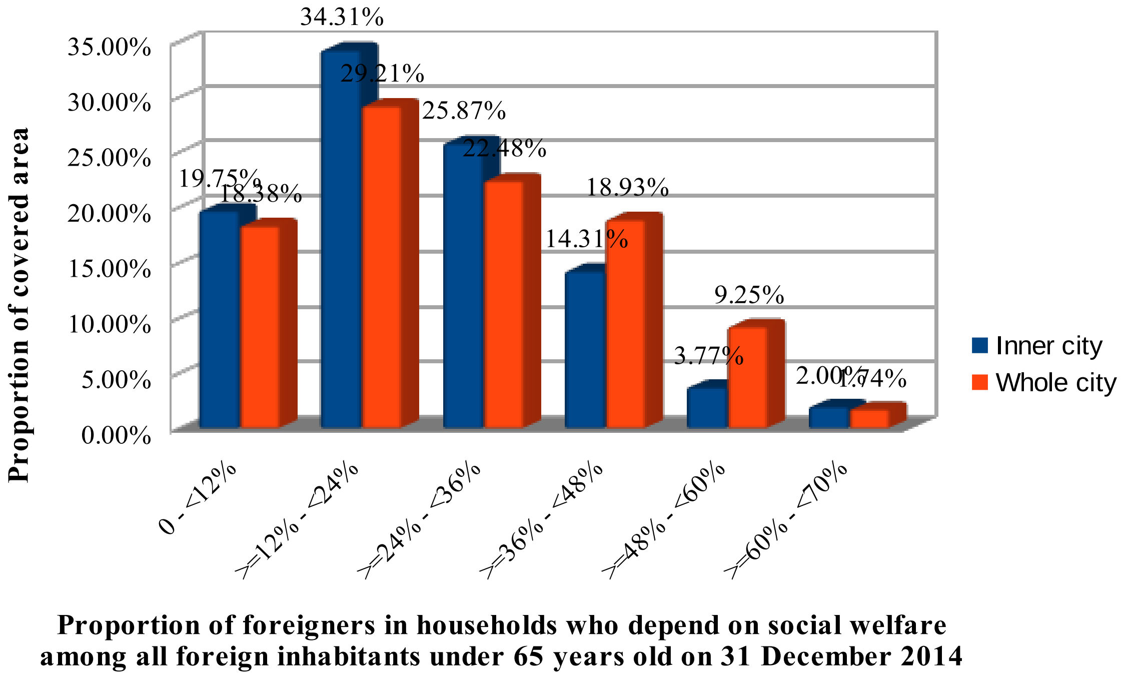


Fig. 233 - Proportion of foreigners in households who depend on social welfare among all foreign inhabitants under 65 years old on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

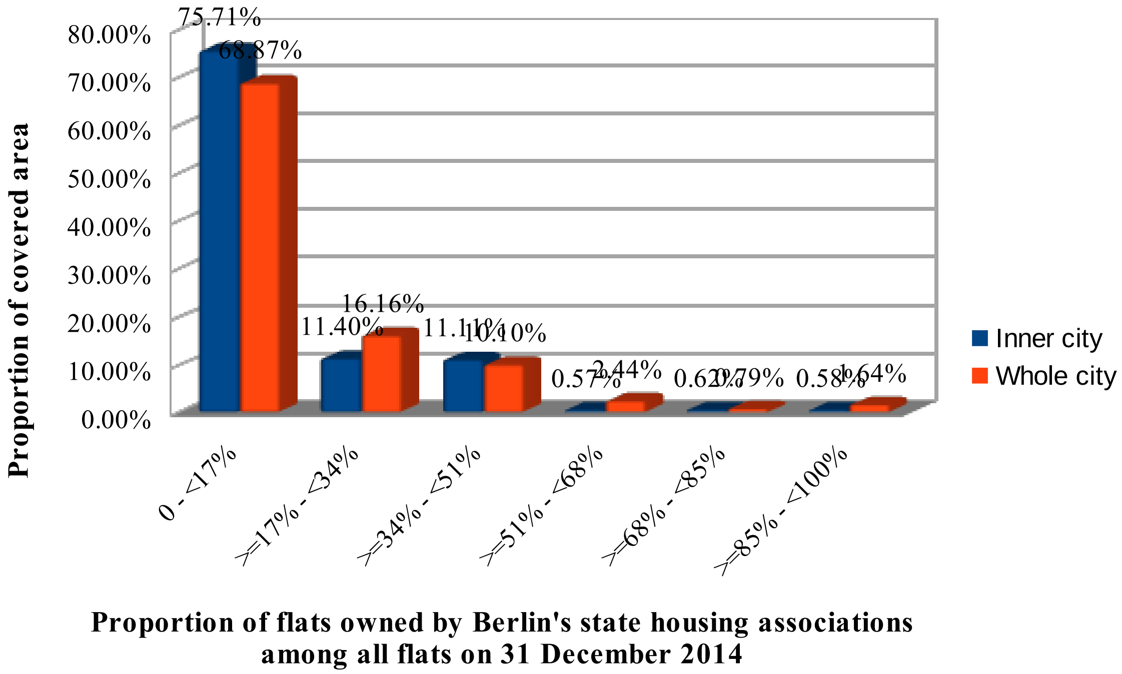


Fig. 234 - Proportion of flats owned by Berlin's state housing associations among all flats on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

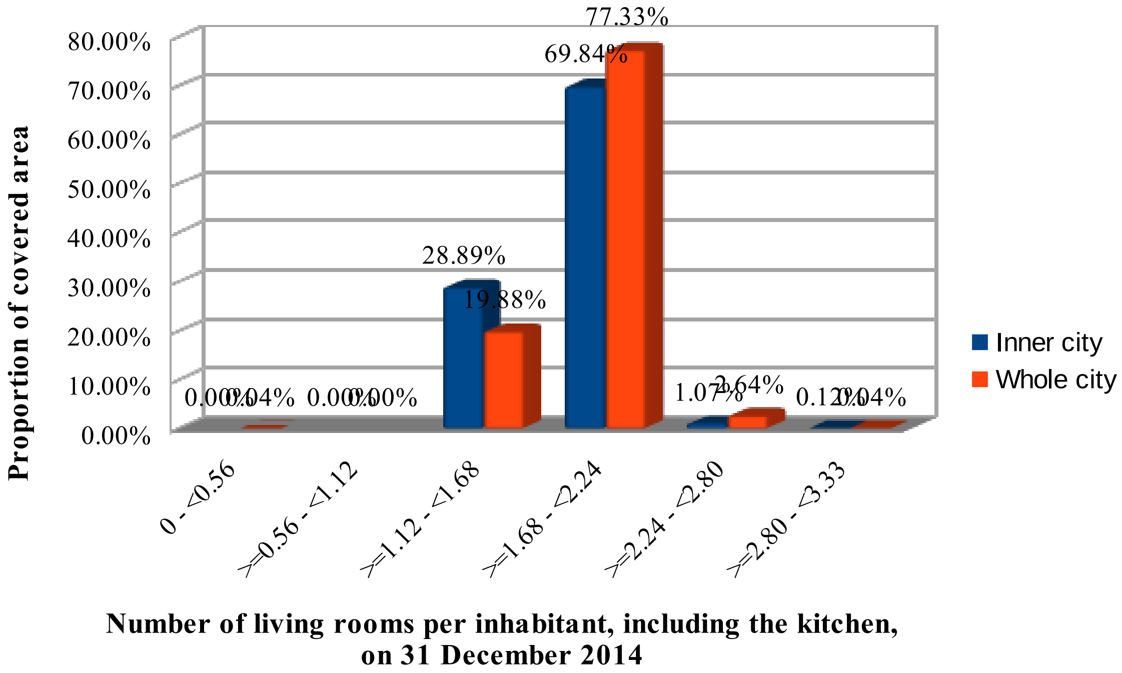


Fig. 235 - Number of living rooms per inhabitant, including the kitchen, on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

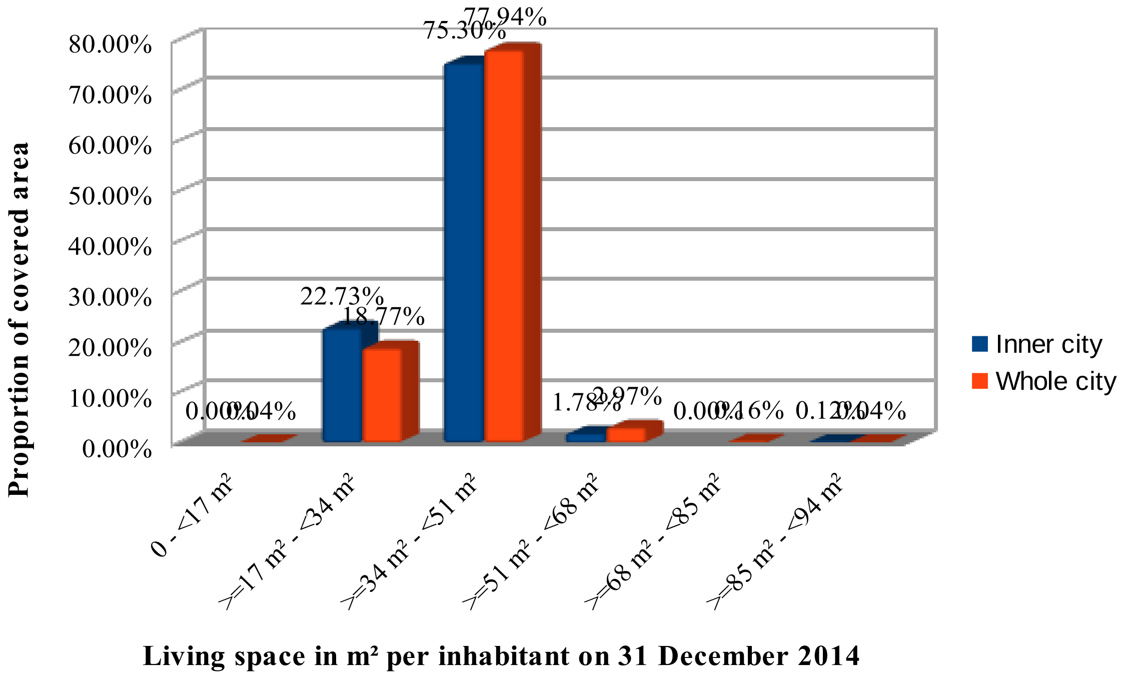
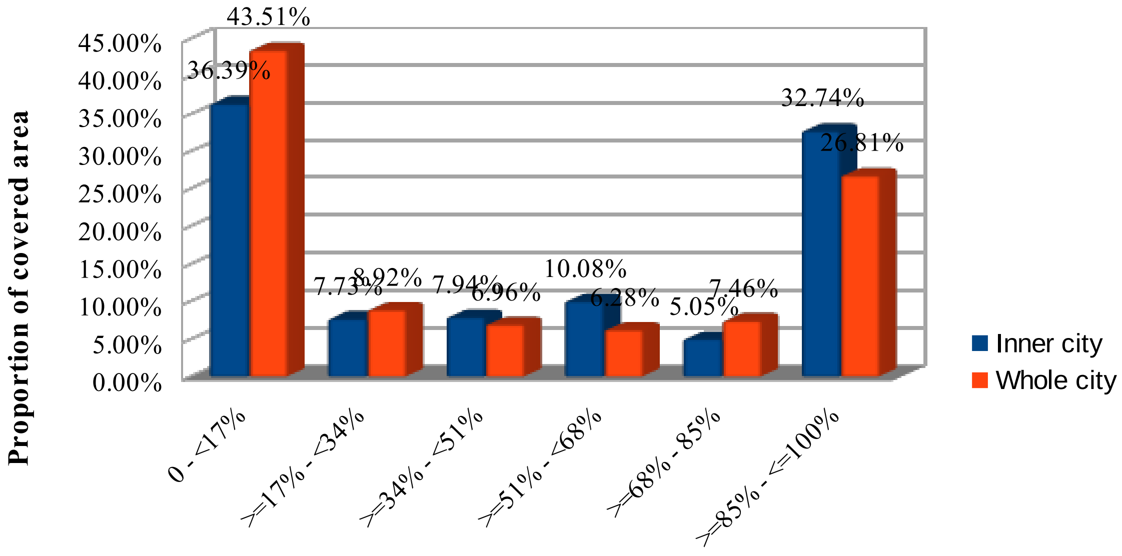


Fig. 236 - Living space in m² per inhabitant on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Proportion of inhabitants of simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) among all inhabitant on 31 December 2014

Fig. 237 - Proportion of inhabitants of simple housing areas according to the rent index (housing area of recognized noise exposure to road traffic) among all inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

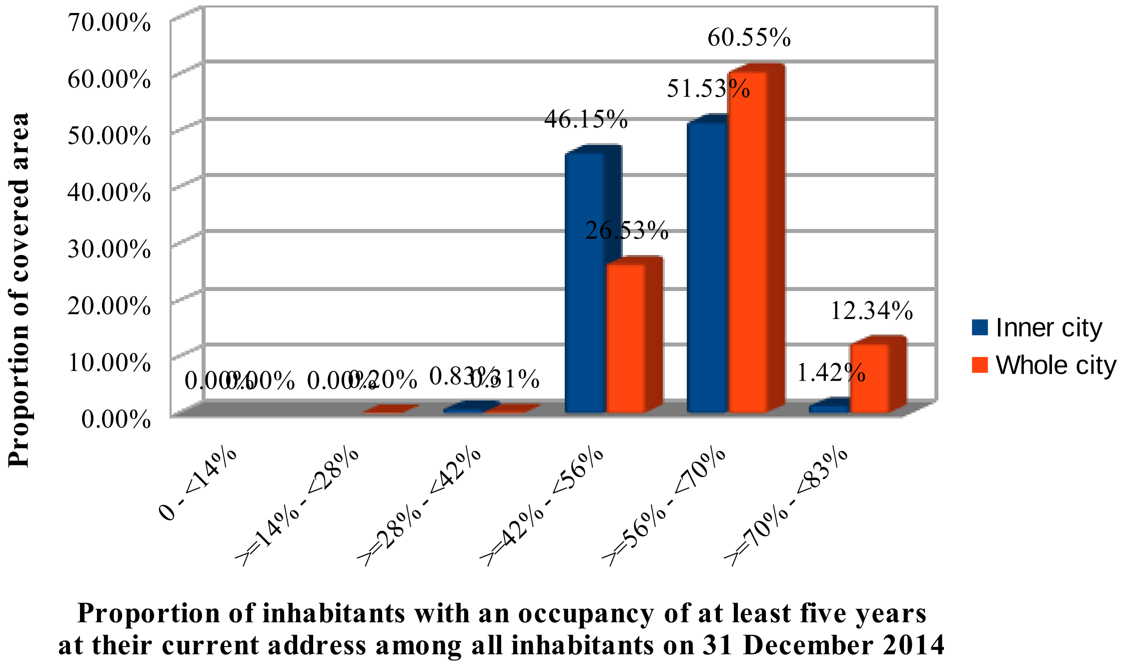


Fig. 238 - Proportion of inhabitants with an occupancy of at least five years at their current address among all inhabitants on 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).

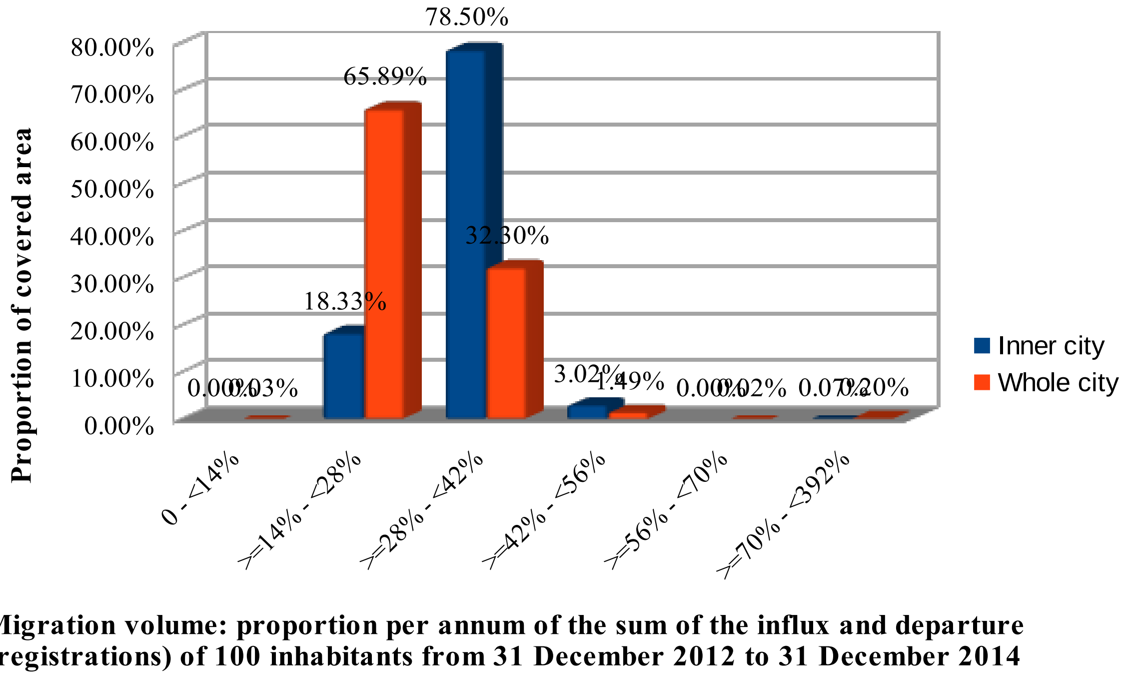
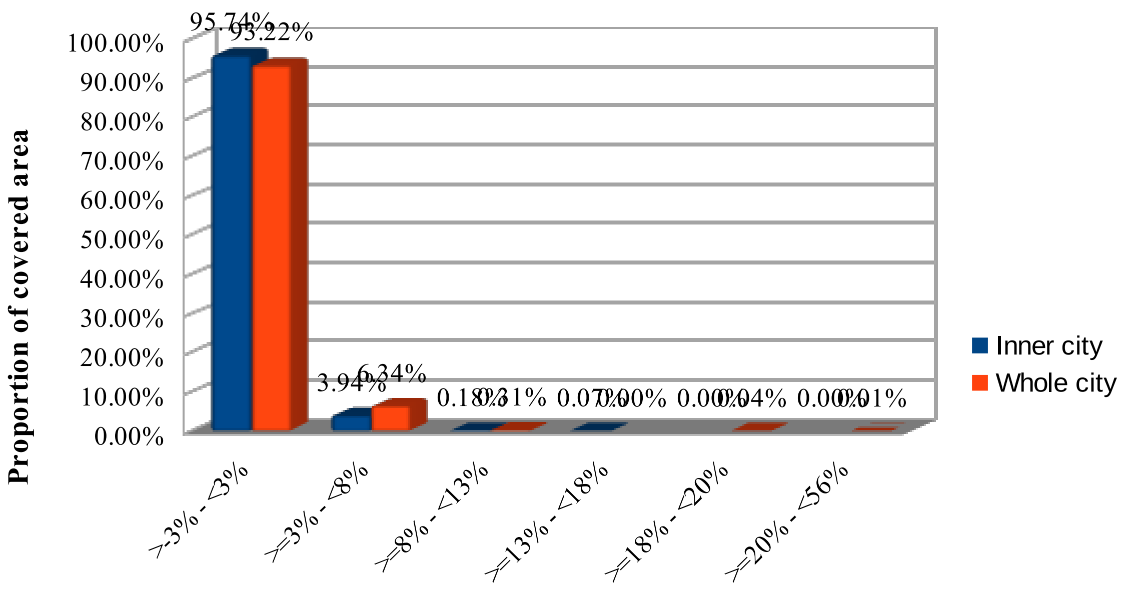
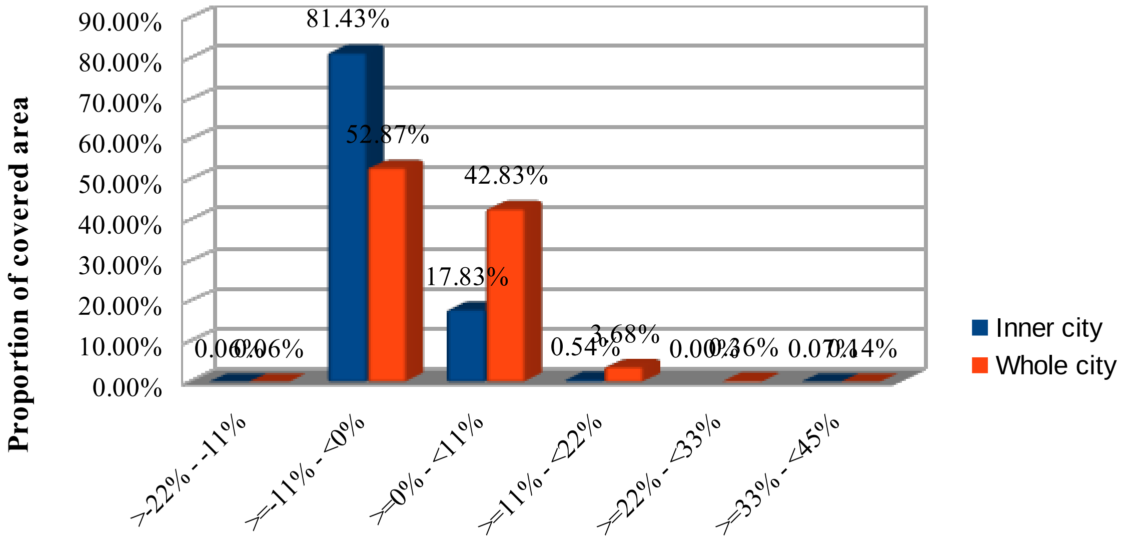


Fig. 239 - Migration volume: proportion per annum of the sum of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Net migration: proportion per annum of the difference of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014

Fig. 240 - Net migration: proportion per annum of the difference of the influx and departure (registrations) of 100 inhabitants from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).



Net migration of children of an age less than six years: proportion per annum of the difference of the influx and departure (registrations) of children less than six years old of 100 children of this age class from 31 December 2012 to 31 December 2014

Fig. 241 - Net migration of children of an age less than six years: proportion per annum of the difference of the influx and departure (registrations) of children less than six years old of 100 children of this age class from 31 December 2012 to 31 December 2014 within 500 m distance of public accessible green areas/parks of a minimum size of 0.5 ha in the inner and whole city of Berlin in 2016 (own calculation based on data of the Senate of Berlin, 2017a).