

Appendix 1.

Supplementary information including two tables. Table A1.1 giving overview of the data used for the study, Table A1.2 giving details on the park quality indicators.

Table A1.1. List of data used to derive park quality indicators and its characteristics. Acronyms used: MMU = minimum mapping unit (for categorical vector data)

Data denotation	Source	Type	Availability	Spatial resolution (cell size/MMU)	Spatial coverage	Time reference	Quality†	Input for Indicator
Outline of public green spaces	City of Leipzig 2018	spatial, vector (polygon)	Upon request	< 1 m ²	City of Leipzig	2018	high	Area, Shape
Land cover data (incl. trees, shrubs, grass)	Banzhaf and Kollai 2018	spatial, raster	Open (https://doi.pangaea.de/10.1594/PANGAEA.895391)	0.6 m	City + > 1km buffer	2012	high	VegTotal, VegBal, TreeH, VegConf, VegNear
Digital landscape model (Basis-DLM) (=Land use data)	GeoSN 2018b	spatial, vector (polygon, line, point)	Open (https://www.geodate.n.sachsen.de/landschaftsmodelle-3991.html)	1 ha (for polygons)	Federal State of Saxony	2018	high	Water, Stream, WaterNear, SGV, PopDay, Intensity, Urbanity
Digital elevation and surface model	GeoSN 2018a	spatial, raster	Open (https://www.geodate.n.sachsen.de/digitale-hoehenmodelle-3994.html)	2 m	Federal State of Saxony	2012	high	Terrain, TreeH
Tree cadastre data	City of Leipzig 2018	spatial, vector (point)	Upon request, partially open (https://opendata.leipzig.de/dataset/strassenbaumkataster)	Individual tree level	City of Leipzig	2018	medium	TreeDiv

Edible plants (fruit trees and shrubs, herbs)	Terra Concordia 2019	spatial, vector (point)	Upon request (free view under https://mundraub.org/map)	Individual plant or site level	City of Leipzig	2018	medium	Edible
Playgrounds and sports facilities	City of Leipzig 2018	spatial, vector (polygon)	Upon request	Individual playground level	City of Leipzig	2018	high	Play, Sport
Playgrounds and sports facilities	OpenStreetMap contributors 2019 (leisure: pitch, playground)	spatial, vector (polygon, point)	Open (http://overpass-api.de/api/)	Individual playground level	worldwide	2018	high	Play, Sport
Path network	OpenStreetMap contributors 2019 (highway: cycleway, footway, path, pedestrian, track)	spatial, vector (line)	Open (http://overpass-api.de/api/)	Path sections	worldwide	2018	high	Path
Cultural, historic & ornamental elements (artwork, fountain, memorial, tomb, flower beds)	OpenStreetMap contributors 2019 (amenity: fountain; tourism: artwork; historic: archaeological_site, memorial, ruins, tomb; leisure: garden)	spatial, vector (point, polygon)	Open (http://overpass-api.de/api/)	Individual element level	worldwide	2018	low	Cultural, Orna
Sitting facilities & waste bins	OpenStreetMap contributors 2019 (amenity: bench, waste_basket)	spatial, vector (point, line)	Open (http://overpass-api.de/api/)	Individual facility level	worldwide	2018	low	Sit, Waste
Dog parks / free run areas	City of Leipzig 2018	spatial, vector (polygon)	Online view available via ArcGIS online	NA	City of Leipzig	2019	high	Dog

Toilets, food and drink services	OpenStreetMap contributors 2019 (amenity: restaurant, cafe, pub, fast_food waste_basket, toilets)	spatial, vector (point, polygon)	Open (http://overpass-api.de/api/)	NA	worldwide	2018	medium	Food, WC
Bicycle parking racks	OpenStreetMap contributors 2019 (amenity: bicycle_parking)	spatial, vector (point, line)	Open (http://overpass-api.de/api/)	Individual facility level	worldwide	2018	low	Bike
Public transport stations	OpenStreetMap contributors 2019 (highway: bus stop; railway: tram stop, halt, station)	spatial, vector (point, polygon)	Open (http://overpass-api.de/api/)	Individual station level	worldwide	2018	high	PubTrans
Noise data for cars and tram	City of Leipzig 2018	Raster	Upon request	10 m	City of Leipzig	2012	high	Noise
Noise data for railway	BKG 2018	spatial, vector (polygon)	Open (http://laermkartierung1.eisenbahnbundesamt.de/mb3/app.php/application/eb)	Level of constant noise level (Isophones)	Germany	2017	high	Noise
Standard ground value (SGV)	City of Leipzig 2018	spatial, vector (polygon)	Upon request	Properties of constant SGV	City of Leipzig	2016	high	SGV
Traffic emissions (NOx, PM2.5)	City of Leipzig 2018	spatial, vector (line)	Upon request	Road sections	City of Leipzig	2017	high	Pollution
Population data	City of Leipzig 2018	thematic, table	Upon request	Statistical block level	City of Leipzig	2018	high	Pop

Protected areas	LfULG 2018	spatial, vector (polygon)	Open (https://www.natur.sachsen.de/schutzgebiete-in-sachsen-7050.html)	Units of protected areas	Federal State 2018 of Saxony	high	PAI
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† Quality refers to a broad evaluation regarding criteria of thematic reliability as well as spatial accuracy and completeness

Table A1.2. Details on green space indicators. Acronyms used: SD = standard deviation.

Indicator	Acronym	Unit	Input data†	Short description	Data processing workflow‡
Area	Area	ha	Outline of public green spaces	Total area of park (size)	Calculate area (a) of selected parks (min. size 0.25 ha)
Shape index	Shape	-	Outline of public green spaces	Deviation from circle shape (SI = 1)	Calculate perimeter (p) of selected parks, calculate shape index (Forman and Godron 1986): $SI = p / (2 * \sqrt{\pi * a})$
Terrain index	Terrain	-	Digital elevation model	Mean value between normalized SDs for slope and elevation	Create slope raster, calculate standard deviation (SD) of slope within individual green spaces, calculate SD of elevation per hectare of green space, normalize both SD (0 - 1), calculate mean of both normalized SD values (=Terrain index)
Total vegetation cover	VegTotal	-(%)	Land cover data	Proportion covered by vegetation	Sum of proportions of tree, shrub and grass cover within green spaces
Vegetation balance	VegBal	-	Land cover data	SD of proportions for vegetation types (trees, shrubs, grass)	Standard deviation (SD) of proportions of tree, shrub and grass cover (0 = totally balanced, 0.5 = totally unbalanced/only one vegetation type), normalize SD (0-1), reverse values (1-normalized SD)
Mean tree height	TreeH	m	Land cover data, Digital surface model	Mean height of tree coverage	Calculate mean height (surface model) of area under tree cover

Shape index of vegetation	VegConf	-	Land cover data	SI of combined tree and shrub coverage	Merge tree and shrub cover polygons, calculate SI (cf. Shape Index) for these polygons within individual green spaces
Water cover	Water	- (%)	Digital landscape model	Proportion of water bodies (on the ground)	Rasterize landscape model with 1 m cell size, calculate area and proportion of lakes and ponds within each green space
Stream density	Stream	m/ha	Digital landscape model	Stream/ditch length per ha	Calculate total length of streams or ditches per green space and divide by area
Tree diversity	TreeDiv	No/ha	Tree cadaster data	Number of tree species per ha	Calculate total number of (unique) tree species per green space and divide by area
Edible plants	Edible	No/ha	Edible plants (fruit trees and shrubs, herbs)	Number of sites of edible plants per ha	Calculate total number of mapped sites for edible plants per green space and divide by area
Path density	Path	m/ha	Path network data (OSM)	Length of all tracks/paths per ha	Calculate total length of paths per green space and divide by area
Playground density	Play	No/ha	Playground data from administration and OSM	No of playgrounds per ha	Complement data from administration with information from OSM, manually evaluate quality of spatially distinct playgrounds using very-high-resolution aerial images (multiple playground counts had to show sufficient individual quality, e.g. a mere sandbox would be not enough to count as an additional playground), record playground number per green space, divide by area
Sports facilities density	Sport	No/ha	Sports facilities data from administration and OSM	No of sports facilities per ha	Complement data from administration with information from OSM, manually evaluate quality (type of sport) of sports facilities using data descriptors and very-high-resolution aerial images (every possible type of sport counted as a single sport facility, i.e. multi-functional court, e.g. for streetball and football, counted multiple), record sports facility number per green space, divide by area

Sitting facilities density	Sit	No/ha	Sitting facilities data (OSM)	No of benches per ha	Count total number of sitting facilities (benches) per green space and divide by area
Cultural & historic elements density	Cultural	No/ha	Cultural & historic elements (OSM)	Sculptures, monuments, memorials, archaeol. sites, fountains per ha	Count total number of artwork, memorials, tombs, archaeological sites and fountains per green space and divide by area
Ornamental plants/flower beds	Orna	- (%)	Ornamental elements (flower beds) (OSM)	Proportion of flower beds	Calculate proportion of flower beds for respective green spaces
Dog parks	Dog	- (%)	Dog parks / free run areas	Proportion of dog park area	Manually digitize dog parks from online map, calculate proportion of dog parks for respective parks
Waste bin density	Waste	No/ha	Waste baskets (OSM)	Waste bins per ha	Count total number of waste bins per green space and divide by area
Toilets density	WC	No/ha	Toilets (OSM)	No of public toilets (incl. 50m surrounding) per ha	Count total number of toilets within and including a 50-m buffer zone around green spaces, divide number by area
Bicycle parking density	Bike	No/ha	Bicycle parking racks (OSM)	No of bike rack sites (incl. 10m surrounding) per ha	Count total number of bicycle parking sites within and including a 10-m buffer zone around green spaces, divide number by area
Food/drink service density	Food	No/ha	Food and drink services (OSM)	No of food/drinks services (incl. 50m surrounding) per ha	Count total number of restaurants, fast food, bars, cafes and pubs within and including a 50-m buffer zone around green spaces, divide number by area
Distance to public transport	PubTrans	m	Public transport stations (OSM)	Distance to next public transport station	Calculate distance from the edge of green spaces to the nearest public transport station (shortest distance)
Noise	Noise	dB	Noise data for cars, tram and railway	Mean value of max. noise values for cars, tram or railway	Create raster (10 m pixel) with overall maximum noise values (over all three traffic types and for day and night), calculate mean value for individual green spaces

Near water	WaterNear	- (%)	Digital landscape model	Water area within 100 m buffer	Calculate proportion of water bodies within the (external) 100-m buffer zone around green spaces
Standard ground value	SGV	€/m ²	Standard ground value data and digital landscape model	Mean standard ground value for residential area within 500 m buffer	Select SGV data for residential and mixed areas (in digital landscape model) and calculate mean value (spatial mean) within the (external) 500-m buffer zone around green spaces
Traffic/emission exposure	Pollution	g/m ³ *a*ha (gram per meter, year, hectare)	Traffic emissions (NOx, PM2.5)	NOx and PM2.5 emissions within 50 m buffer per ha	Rasterize source data (vector line data) with 1-m pixel size, sum up all pixels that fall within the park area plus 50-m buffer around, divide by area of green space
Surrounding population	Pop	No/ha	Population data on statistical block level	No of residents within 500 m buffer per ha park area	Convert population data per statistical block to a 1-m raster with resident numbers per square meter, count these pixels within 500-m (external) buffer zone around green spaces and divide by area
Surrounding commercial area	PopDay	- (%)	Digital landscape model	Area for commercial use and public amenities in 500 m buffer	Calculate proportion of commercial and mixed areas within the (external) 500-m buffer zone around green spaces
Usage intensity	Intensity	No/ha	Population data on statistical block level, Digital Landscape Model	Pop indicator weighted by available UGS alternatives in 500 m buffer	Calculate proportion of any kind of public green spaces within the 500-m buffer around parks (incl. forest, cemetery, sports areas, shrubland, other parks) (=GS_500mBuf), multiply Pop indicator with reversing value of the green space proportion: Pop*(1- GS_500mBuf)
Surrounding shrubs and trees	VegNear	- (%)	Land cover data	Proportion of trees and shrubs within 500m buffer	Calculate proportion of combined tree and shrub cover within 500-m buffer around parks
Urbanity index	Urbanity	- (m)	Digital landscape model	Distance to edge of built-up area weighted by distance to city center	Calculate distance to built-up area and rescale to positive values only (x + overall max value), calculate distance to city center, normalize distance to city center from 1 to 2, weight (=divide)

Protected Area Index	PAI	- (%)	Protected areas	Weighted (by IUCN cat.) proportion of protected area	rescaled distance to built-up area by normalized distance to city center values, normalize weighted value (0 to 1) Calculate proportion of protected area, weight proportions by IUCN category: $PAI = (Share_IUCN_III*3) + (Share_IUCN_IV*2) + (Share_IUCN_V)$
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† Note: The outline of green spaces data served as input data for every indicator by delineating the target study objects, the green spaces as such

‡ All processing done in ArcGIS Pro, v2.5

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