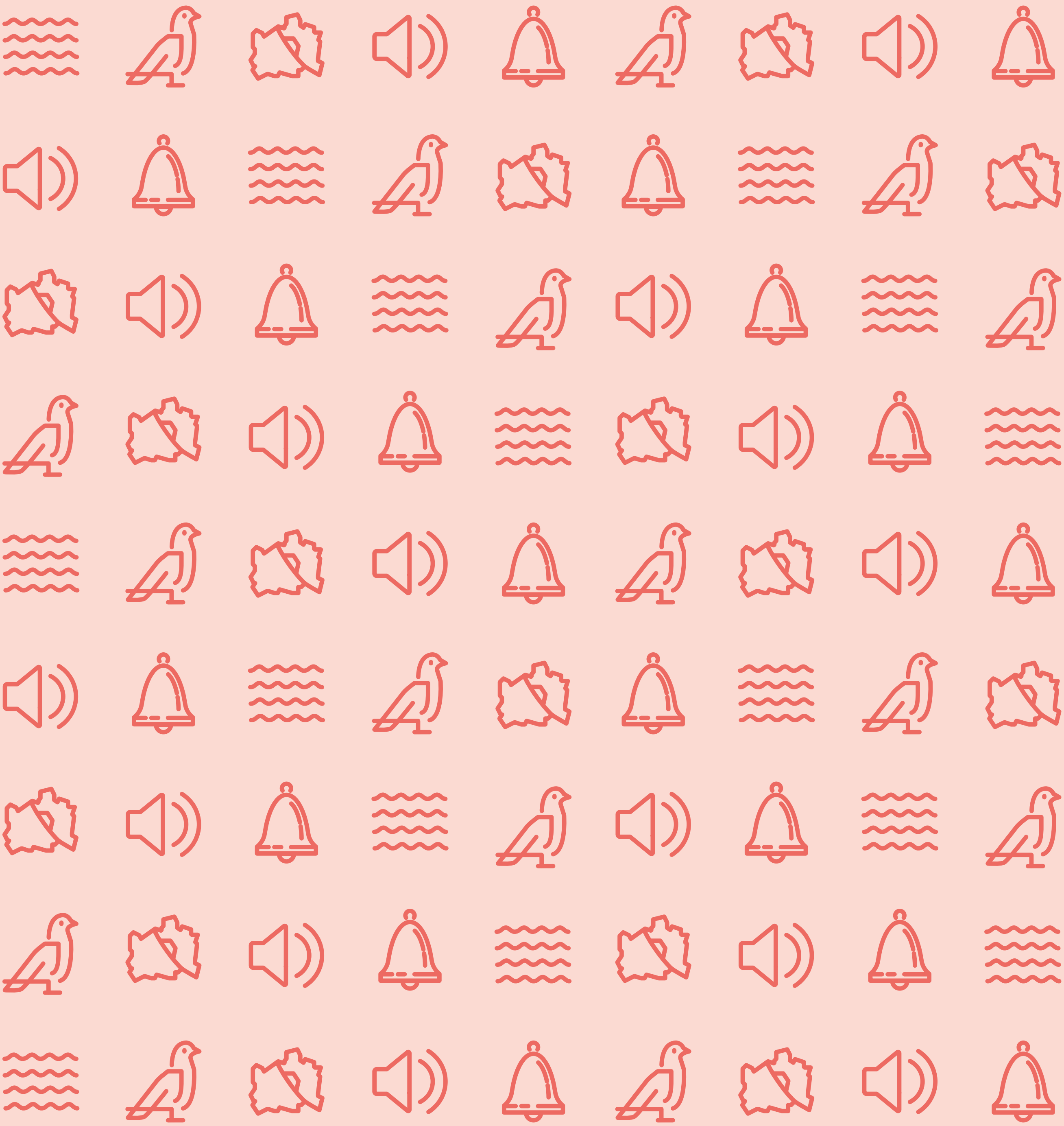
Vienna Sounds

Music of the Future for an Environmentally Friendly City



City of Vienna | Environmental Protection

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Abbreviations used in the text:

END2022
Environmental Noise Directive 2022

$L_{A,eq}$
Energy-equivalent continuous sound level in dB

L_{den}
Energy-equivalent continuous sound level over time periods day (**d**), evening (**e**) and night (**n**) energetically summed up

UHVI
Urban Heat Vulnerability Index

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1. Introduction and objectives

Vienna is growing - very dynamically at that (City of Vienna, undated). Growth means more people, and more people mean more resources, more creativity, but also more potential for conflict. This makes the role which noise protection and abatement can play all the more important: If used properly, these are instruments which many of Vienna's residents will benefit from thanks to improved recreation, e.g. through noise protection measures in perimeter development. And if noise protection and abatement are used in the design of public spaces, better quality of life can be achieved for an entire neighbourhood.

For this reason, various factors relevant to the amenity value of an area are to be analysed and combined: Quiet places are juxtaposed with publicly accessible green spaces, the Urban Heat Vulnerability Index (UHVI) (Ecoten 2019) is included in our considerations, as are the multi-temporal temperature classification (SPACETEC 2003) and the social status of the Viennese population (Molina et al. 2020).

Combining these environmentally relevant factors results in an action matrix. Ideally, the implementation of noise-reducing measures should cover several areas in order to achieve the most holistic improvement possible in the living conditions of Vienna's residents.

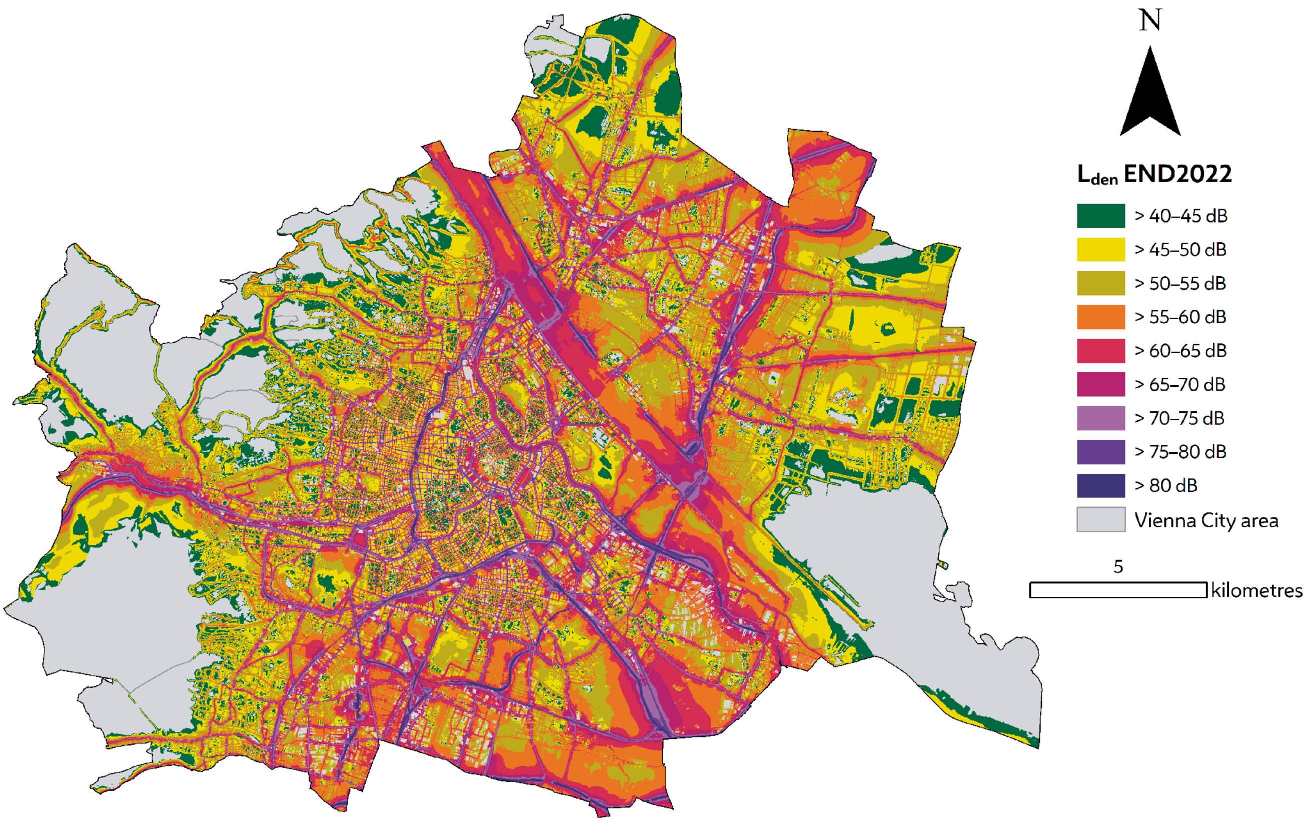

Figure 1: Strategic noise map of Vienna. Data source: MA 22 (2022); in-house illustration.

2. Basic data

In order to identify potential fields of action, the first step is to present and explain the raw data available. Various statistical procedures are then used to make such data comparable with each other in order to enable the subsequent combination of information levels.

2.1 STARTING POINT

The starting point for each study is Vienna's current **strategic noise map** (MA 22, 2022), which is based on the EU Environmental Noise Directive (END) of 2022. Traffic count data from road and rail are used to create the map, which is then fed into a traffic model. Typically, buildings, other structures or the topographical location shield us from traffic. The energy-equivalent continuous sound levels $L_{A,equ}$ for the individual time periods of **d**ay, **e**vening and **n**ight are energetically summed to form the so-called L_{den}.

The strategic noise map of Vienna dating from 2022 (Figure 1) shows that **main traffic axes** such as the Ring, the Gürtel and freeways have a **high** L_{den}. The further away you are from the road or mode of transport or the better you are shielded from it, the lower the sound pressure level.

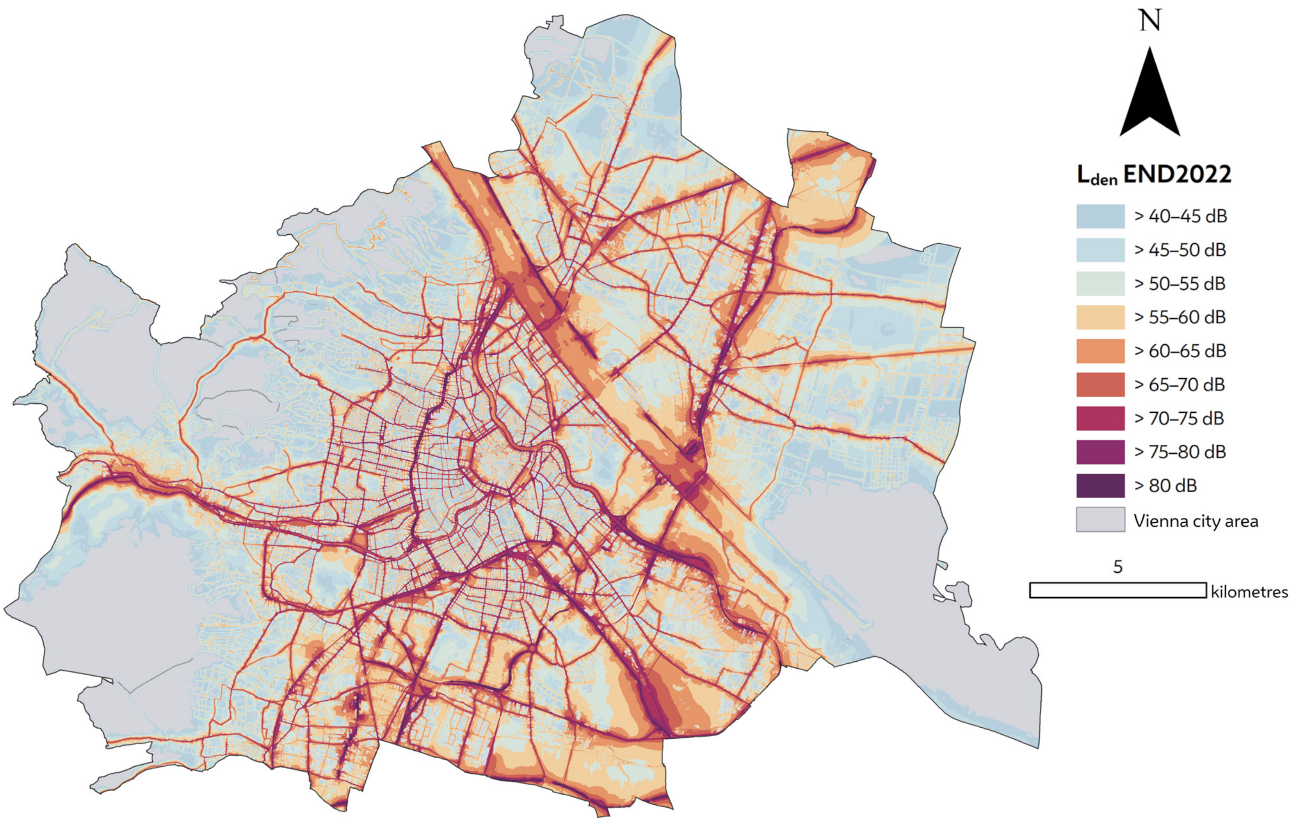

Figure 2: Strategic noise map of Vienna, based on END2022 (MA 22, 2022), using the colour scheme devised by Beate Weninger (2015); in-house illustration.

In her dissertation, **Beate Weninger** (2015) identified **a need for improvement with regard to the colour scheme** of strategic noise maps which became established at EU level. She criticised the fact that red is a signal colour, which is thus often associated with the maximum value of a component. Accordingly, Weninger developed a new colour scheme which is better adapted to the requirements of clarity and legibility in a strategic noise map in terms of **brightness, colour intensity and warmth**. She also took into account various forms of colour vision deficiencies such as deuteranopia (green colour blindness), protanopia (red colour blindness) and tritanopia (blue colour blindness).

Thus, the application of Weninger's colour scheme to the strategic noise map of 2022 for Vienna results in the map in Figure 2. In contrast to the old EU colour scheme, as used in Figure 1, Weninger's colour scheme is impressive due to its clear and above all **intuitive attributability** of sound pressure levels to colours. As this colour scheme ensures **very good legibility**, it will subsequently be used in various analyses.

2.2 QUIET PLACES

To be designated as **"quiet places"**, areas identified in the END2022-24h map (MA 22, 2022) had to show L_{den} values **below 50 dB** (see Figure 3).

Quiet places in Vienna are mainly found on the **outskirts of the city**, often in the vicinity of recreational areas such as the Vienna Woods, Lobau or Lainzer Tiergarten. As we move closer to the city centre, quiet places are mainly found in **inner courtyards**, which are shielded from traffic due to their location. Areas generally further **removed from main traffic routes** can also be defined as "quiet places".

However, it makes a difference whether the quiet places are located in the central areas of the city, where open space is already in short supply, or whether they are on the outskirts of the city, where the recreational areas of Vienna are located and the population density is lower. Furthermore, we must not forget that large districts can accommodate larger quiet areas than small districts.

In order to ensure better comparability within Vienna, the share of quiet places in the registration district areas was calculated (see Figure 4). As this is very low in many registration districts and the distribution shows an exponential tendency in this respect, the class boundaries were formed on the basis of quantiles (cf. Georgii 2015). Three classes

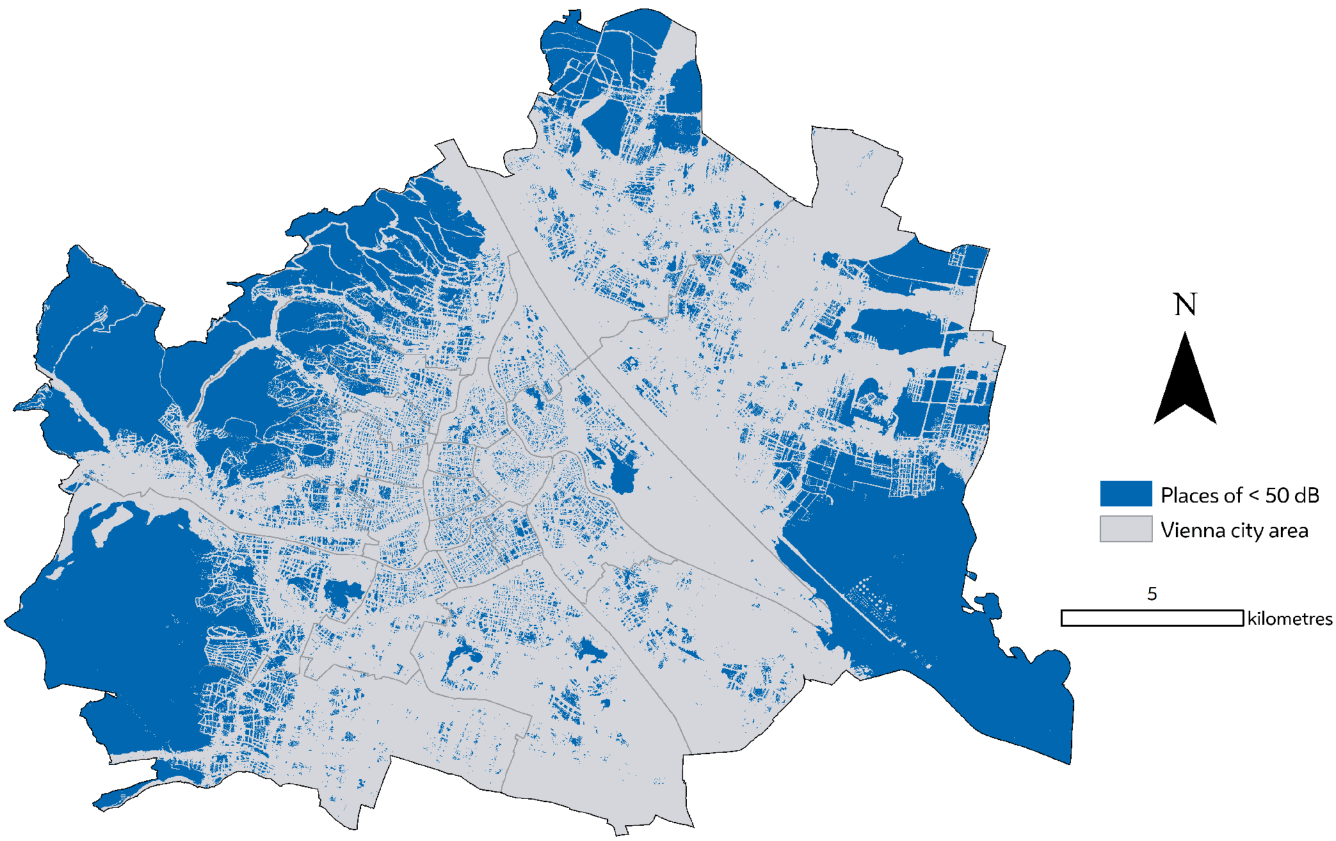

Figure 3: Quiet places of < 50 dB in Vienna. Data source: MA 22 (2022); in-house illustration.

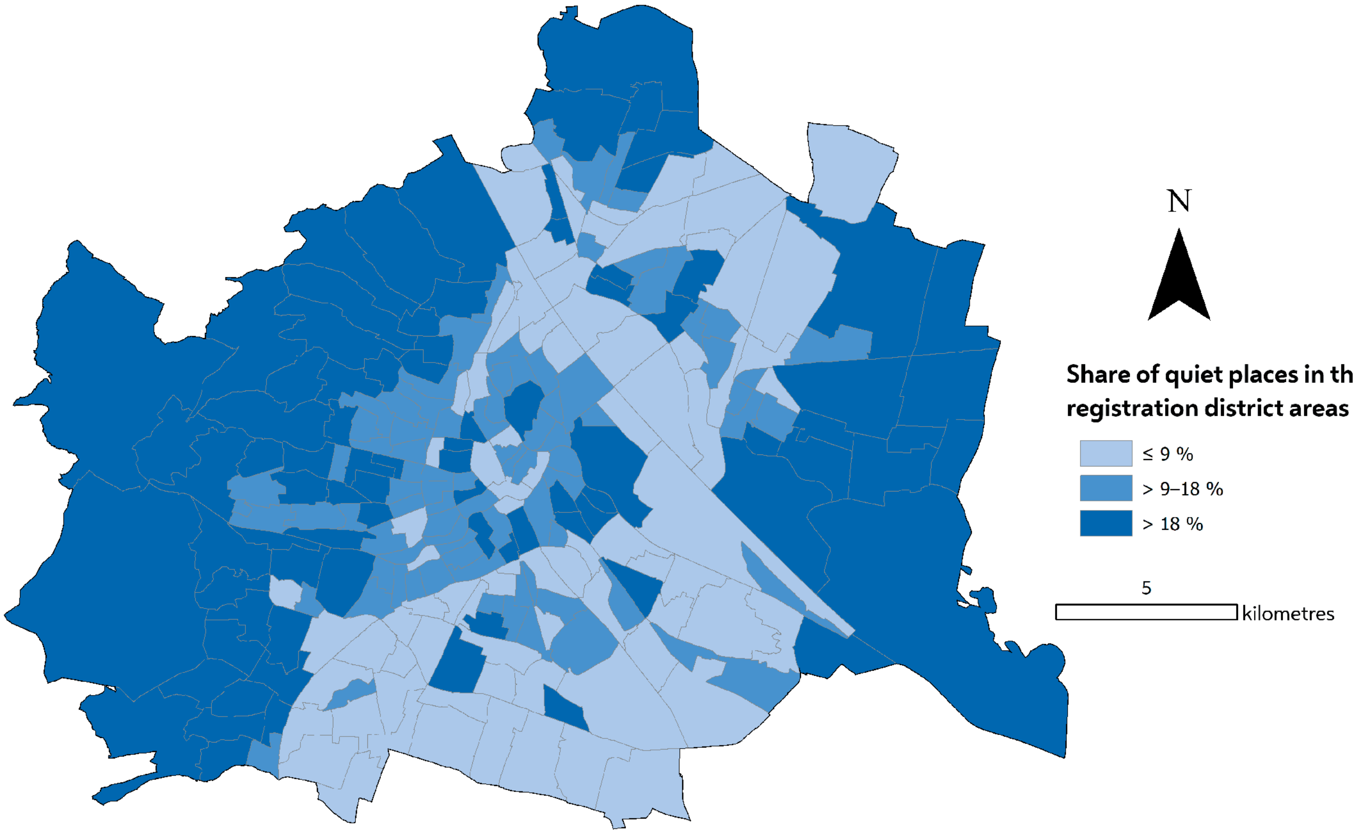

Figure 4: Share of quiet places in the registration district areas, broken down by quantiles. Data source: MA 22 (2022); in-house illustration.

were formed, corresponding to a breakdown into "above average", "average" and "below average". The division into three classes represents a major simplification, but subsequently facilitates comparability with the other data.

2.3 PUBLICLY ACCESSIBLE GREEN SPACES OF HIGH AMENITY VALUE

Publicly accessible green spaces are of great importance for biodiversity, microclimate and recreation, especially in large cities, where a lot of surface soil is otherwise sealed (see Barbosa et al. 2007, Pincetl and Gearin 2013, Richter et al. 2016). Due to their public accessibility, such green spaces can have an inclusive effect. They offer people who do not have private green spaces a piece of nature in the middle of the city.

However, not every public green space automatically invites people to linger, not all green spaces are perceived as quiet, and not every green space is equally close to nature. In short, not every publicly accessible green space necessarily offers high amenity value.

In the specific case of Vienna, the greenest city among the 50 most visited cities in the world (Wien Info, undated), the next question is: Which green spaces offer a higher amenity value?

Various **criteria** were established for this purpose:

- publicly accessible green space according to the environmental inventory maps of the City of Vienna (undated)
- contiguous areas
- cemeteries

The aim of drawing up this list of criteria was to assess an amenity value which is otherwise difficult to define. The requirement for green spaces to be publicly accessible is based on the fact that private green spaces cannot be used by the general public and therefore cannot contribute to recreation and to improving the amenity value of Vienna. For this purpose, only the green spaces designated as "publicly accessible" in the City of Vienna's environmental inventory (undated) are included. Moreover, all cemeteries are part of this classification because they are perceived as places of recreation in the everyday experience of many Vienna residents. Take, for example, the Central Cemetery, where a visit is like a trip to the countryside.

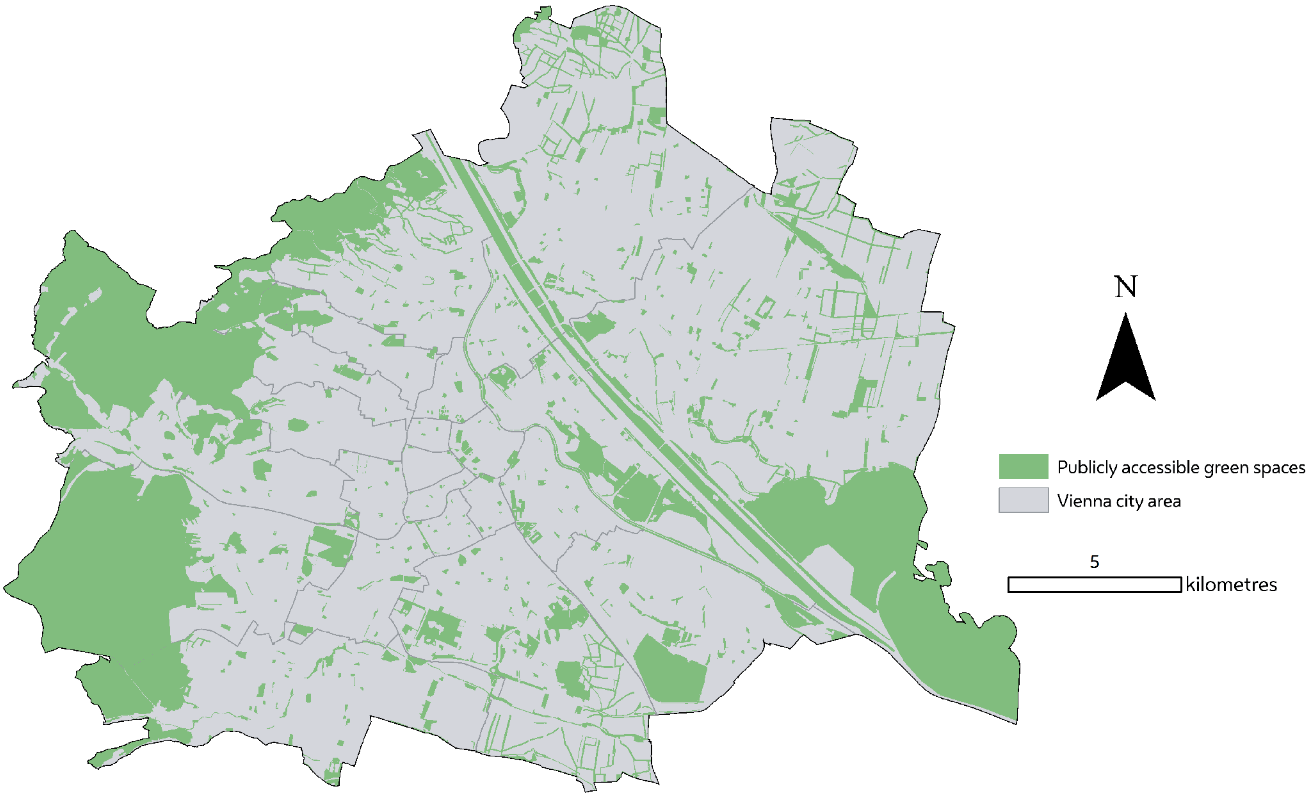

Figure 5: Publicly accessible green spaces in Vienna with a contiguous area of > 3000 m² (districts 1-9, 15, 20) or > 5000 m2 (remaining districts), including cemeteries. Data source: MA 22 (2015); in-house illustration.

Among all the publicly accessible green spaces, those with a contiguous area of > 3000 m² or > 5000 m² are filtered out. This differentiation is intended to take into account the inner districts (1 to 9, 15 and 20), which are smaller and more centrally located, so they often do not boast large parks, cemeteries, etc. due to their established structure. The minimum size is intended to prevent sporadic patches of green, which may be separated from each other by traffic carriers, from being included. Likewise, isolated trees can be sorted out this way. If these selection criteria are applied to the total amount of public green spaces in Vienna, a picture as shown in Figure 5 emerges.

Lobau, Prater, Lainzer Tiergarten, the Vienna Woods and the Danube Island are among the largest public green spaces with a high amenity value. However, smaller parks such as Augarten, Schönbrunn Palace Park, Laaer Wald and the Central Cemetery also fall into this category.

A problem similar to that identified in the analysis of quiet places arises in the context of publicly accessible green spaces: Here, too, it is easier for a large district on the outskirts of the city to boast large publicly accessible green spaces than for small districts in the core area. For this reason, an evaluation was carried out with regard to the share of publicly accessible green spaces in the respective registration district areas (see Figure 6).

Similar to the quiet places, the data shows an almost exponential distribution, as many registration districts have no or only a very small proportion of publicly accessible green spaces in relation to their total area. For this reason, the data was broken down into three quantiles.

2.4 MULTI-TEMPORAL TEMPERATURE CLASSIFICATION

Urban development and associated factors such as soil sealing, or the presence of green spaces and water, influence the climate in cities, which is why the term "urban climate" is also used in this context. Increasing urban development leads to the formation of so-called "urban heat islands". These hot spots (in the literal sense of the word) are characterised by temperatures higher than those of the surrounding areas. The second important influencing factor apart from urban heat islands is the difference between the city and the surrounding areas regards the wind. Wind can transport hot air away, which in turn means cooling (cf. City of Vienna, undated).

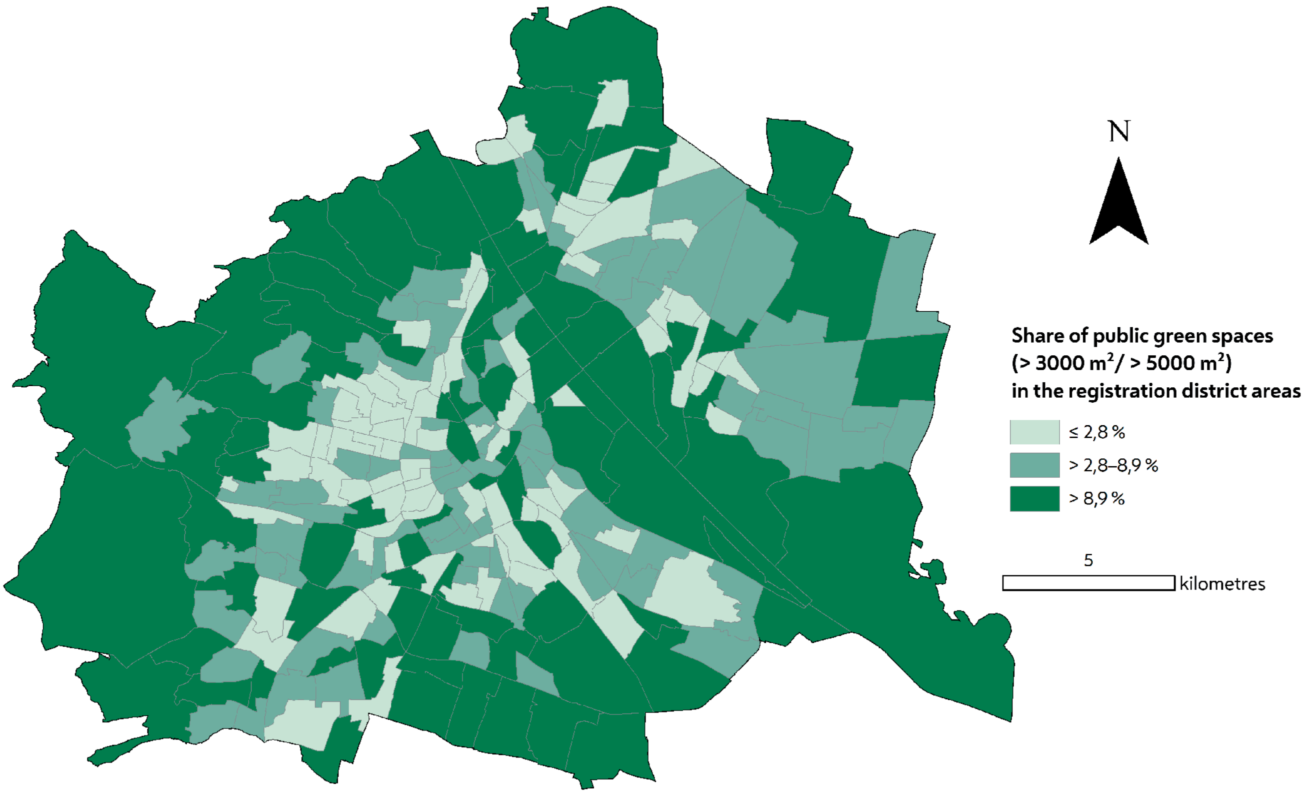

Figure 6: Share of publicly accessible green spaces with a contiguous area of > 3000 m² or > 5000 m² in the registration district areas, including cemeteries. Data source: MA 22 (2015); in-house illustration.

On behalf of Municipal Department MA 22 (Environmental Protection) of the City of Vienna, the company SPACETEC Steinicke & Streifeneder Umweltuntersuchungen GbR (see SPACETEC 2003) carried out a thermal survey on August 15 and 16, 2001. On the basis of these two aerial surveys and their analysis (= multi-temporal classification), the behaviour of the surface was broken down into different classes, depending on the degree of cooling (strong to weak) and surface temperature (cold air surface to heat island) (see Figure 7) (City of Vienna undated).

The application of the Weninger colour scheme to the related data results in the following detailed temperature classification for Vienna:

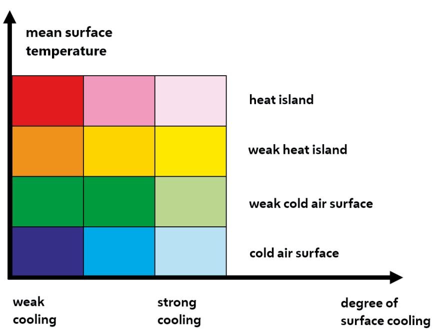

Figure 7: Multi-temporal temperature classification according to the factors "degree of surface cooling" and "mean surface temperature". Source of illustration: City of Vienna (undated).

Figure 8 shows where heat islands and slight cooling meet in Vienna. This is more often the case in the inner city area whereas areas in the "cold air surface" category and areas with stronger cooling properties can more often be found towards the outskirts of the city.

Although the data on which this study is based is 20 years old and therefore no longer up to date, it does provide an initial point of reference. The comparison with the Urban Heat Vulnerability Index, which is calculated at registration district level (see next chapter), allows the timeliness and significance of the multi-temporal temperature classification to be examined.

2.5 URBAN HEAT VULNERABILITY INDEX

In 2019 the Urban Heat Vulnerability Index (UHVI) for Vienna was calculated by Ecoten Smart Energy Solutions, an urban environmental engineering firm from Prague, on behalf of the City of Vienna and Municipal Department 20 - Energy Planning (Ecoten 2019). This index identifying an area's vulnerability to urban heat islands was calculated at registration district level. It is influenced by three factors:

1. Exposure or susceptibility to actual heat in urban areas. According to Ecoten (2019), areas with a high susceptibility are characterised by very high temperatures, i.e. they are literal "hot spots". The value expressing this is the so-called "Exposure Index" (EI).

2. Sensitivity describes the intensity of human reaction to heat in urban areas. Certain population groups react more strongly to it than others, which makes them particularly vulnerable. Ecoten (2019) counts people under 14 and over 60 among these particularly vulnerable population groups. This factor is expressed in the form of the "Sensitivity Index" (SI).

3. Adaptive capacity describes the ability to cope with, recover from and adapt to problems arising due to the heat. Ecoten (2019) refers to the important role urban ecosystems play in connection with urban heat islands. Accordingly, the presence of green and blue infrastructure is included in this factor. The "Adaptive Capacity Index" (ACI) is derived from this.

These factors are combined using a formula:

UHVI = EI * SI – ACI

A UHVI value of 1 or 100 % corresponds to a registration district's maximum vulnerability to urban heat islands. The lower the UHVI values, the better can the population cope with heat events as they occur, a process mitigated either by existing green and blue infrastructure, or the less frequent occurrence of heat events.

Based on the findings and data produced by Ecoten (2019), a spatial classification according to the Urban Heat Vulnerability Index can therefore be produced for the individual Viennese registration districts (see Figure 9).

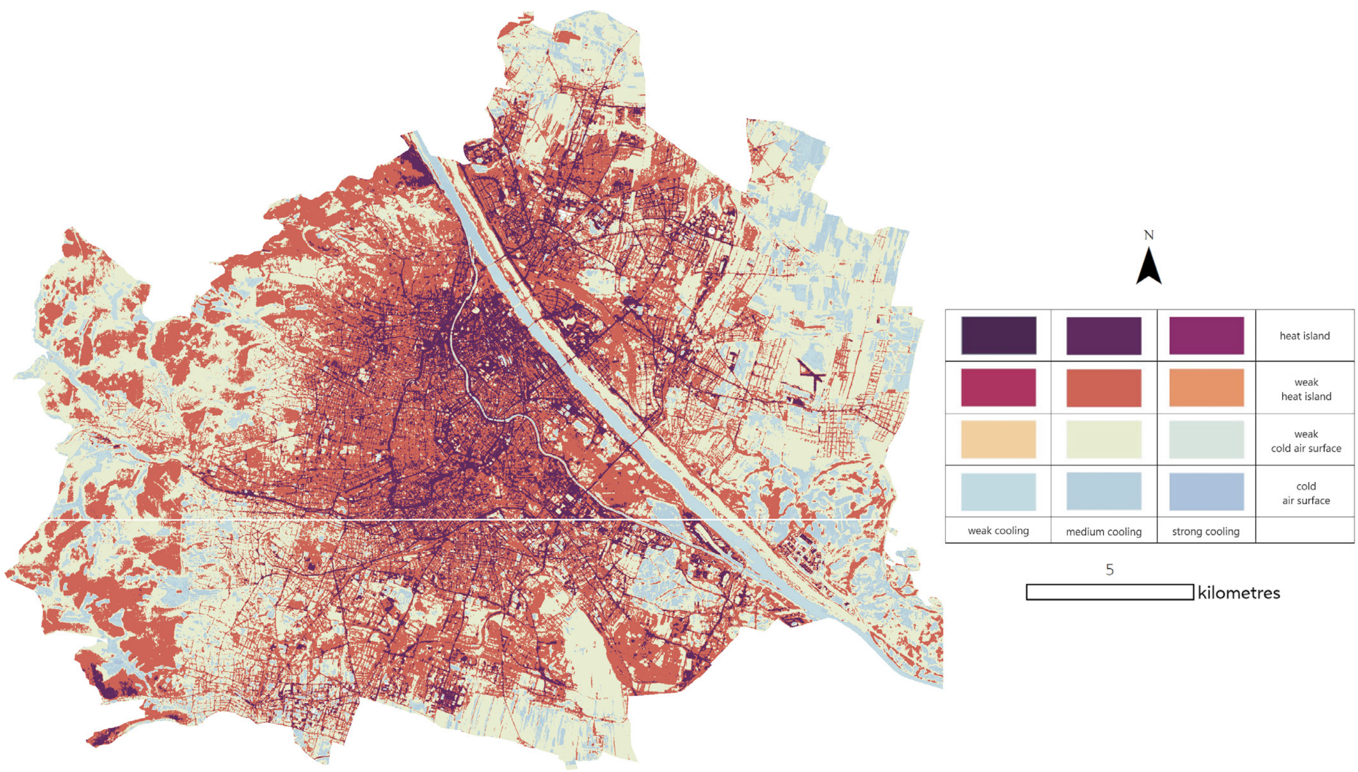

Figure 8: Multi-temporal temperature classification of Vienna according to the colour scheme by Beate Weninger (2015).
Data source: SPACETEC (2003); in-house illustration.

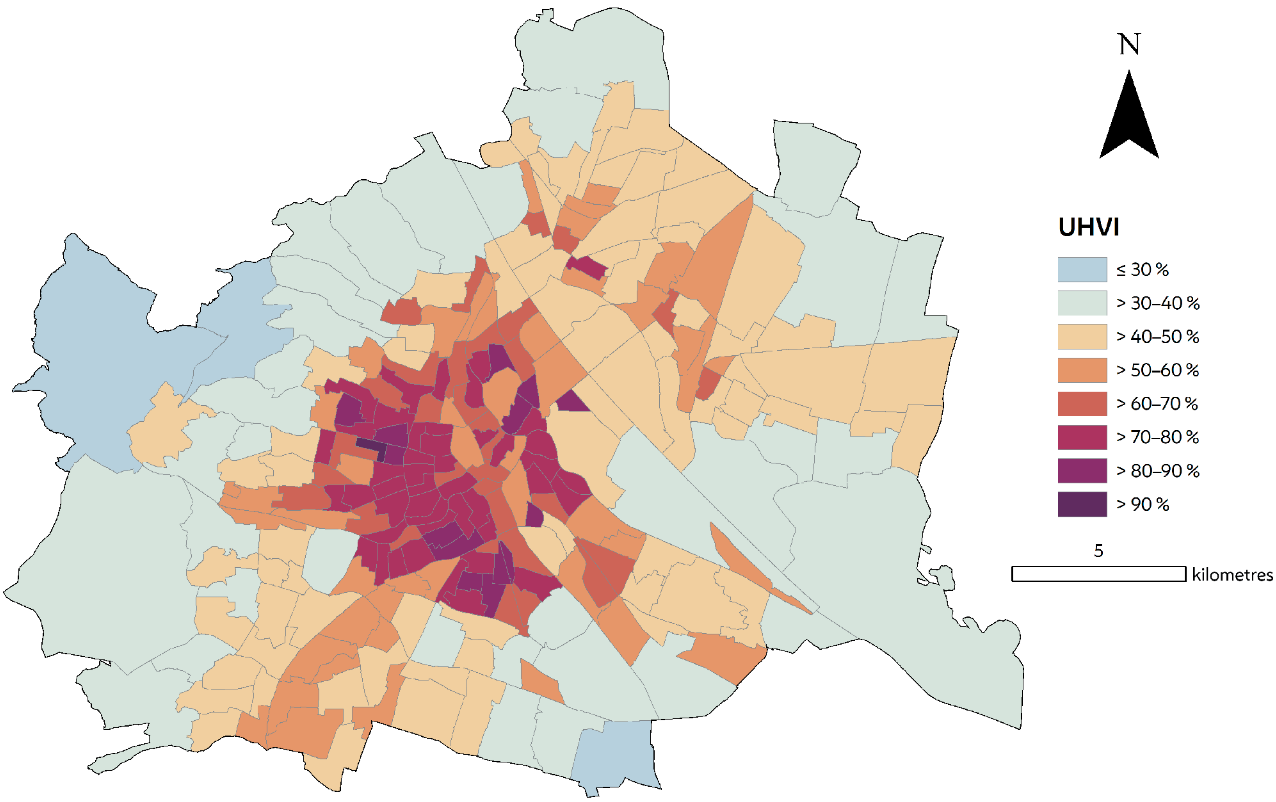

Figure 9: Vienna's registration districts, coloured according to the Urban Heat Vulnerability Index. Data source: Ecoten (2019); in-house illustration.

As can be seen in Figure 9, registration districts in the central area of the city show particularly high values in the Urban Heat Vulnerability Index. Towards the outskirts of the city, the Urban Heat Vulnerability Index and thus the susceptibility of the registration districts decrease. This means that high temperatures occur less frequently here, the population is better able to cope with such events and there is more green and blue infrastructure. The Urban Heat Vulnerability Index value is often particularly high in registration districts near the Gürtel, the ring road separating the inner city districts and the outer districts. By comparison, the multi-temporal temperature classification shows a similar picture with a concentration of heat islands and little cooling in the central areas and a tendency towards cold air areas and more cooling in the outskirts of the city. However, as the data from the Urban Heat Vulnerability Index is more up-to-date and also includes population vulnerability, the Urban Heat Vulnerability Index is used for further analyses instead of the multi-temporal temperature classification.

When comparing quiet places and publicly accessible green spaces of high amenity value, a correlation between the three factors emerges: There are few quiet places in the city centre and publicly accessible green spaces of high amenity value also tend to be sparse here; instead, according to the Urban Heat Vulnerability Index, a high vulnerability to heat becomes evident. And where there is more quiet and greenery – towards the outskirts of the city - the resilience to urban heat islands is also much higher than in the central areas. This roughly results in a trend towards a **"core area-urban fringe" gradient.**

To facilitate the combination of the Urban Heat Vulnerability Index data with the data on quiet places, publicly accessible green spaces and social status (see next chapter), data are broken down into three classes. As the values for the Urban Heat Vulnerability Index show an approximate normal distribution, these values are z-standardised. This allows for the values to be described based on their distance from the mean value (see Georgii 2015). The three classes are thus formed using the standard deviation (σ):

$z < -1\sigma$ → Value **below average** in relation to the mean value

$-1\sigma \leq z \leq 1\sigma$ → **Average** value in relation to the mean value

$z > 1\sigma$ → Value **above average** in relation to the mean value

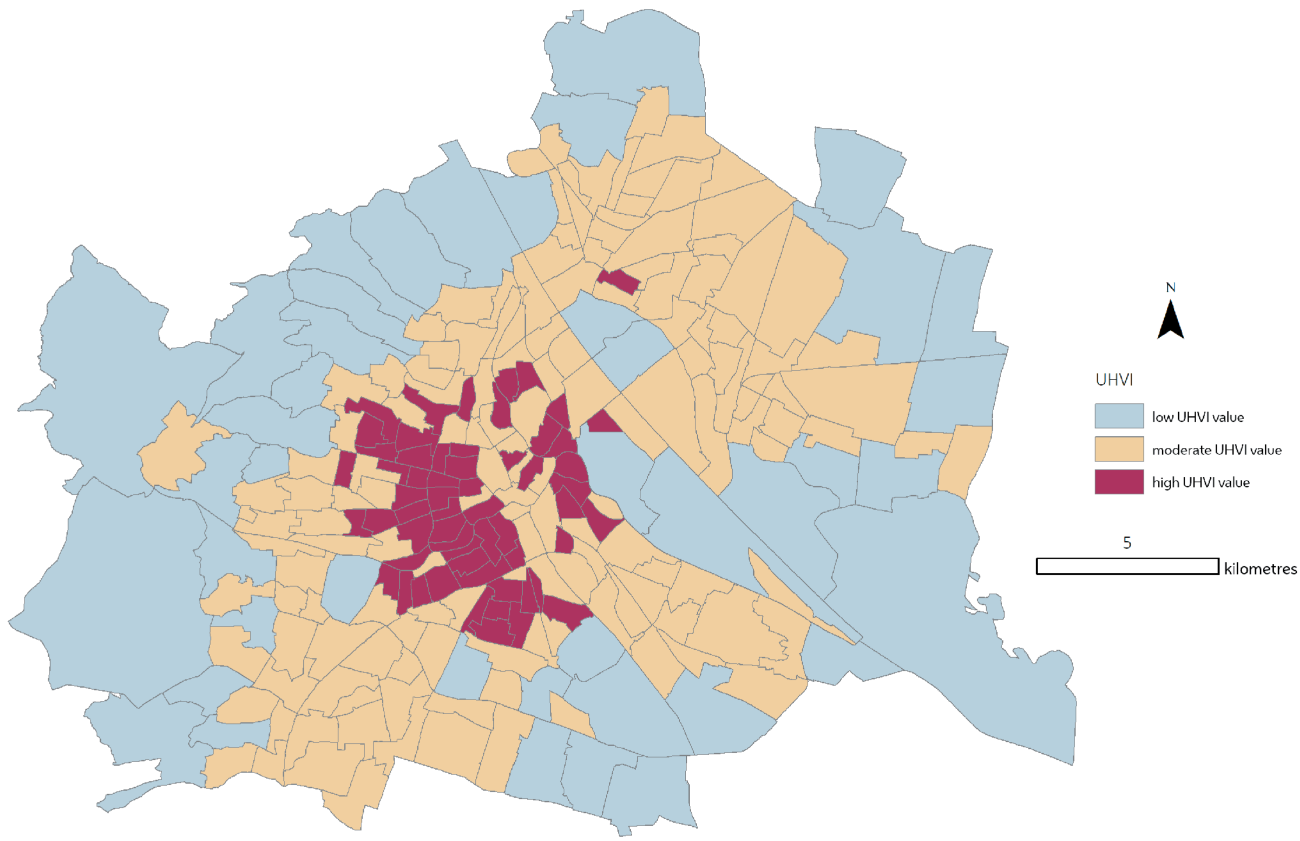

Figure 10: Classification of the Urban Heat Vulnerability Index, based on z-standardisation and subsequent breakdown into three classes based on the distance from the mean value. Data source: Ecoten (2019); in-house illustration.

This results in a spatial distribution of the Urban Heat Vulnerability Index as shown in Figure 10. First and foremost, an above-average value in the Urban Heat Vulnerability Index comes to bear in registration districts close to the Gürtel, near Vienna Central Station, along the Danube Canal and in one registration district east of the Danube. In the outskirts of the city, the Urban Heat Vulnerability Index value tends to be lower. In the core area as well as in the southwest, southeast and northeast, most of the registration districts show an average value in the Urban Heat Vulnerability Index when we compare them with the other registration districts.

2.6 SOCIAL STATUS

As already indicated in the chapter on the Urban Heat Vulnerability Index, challenges affecting the environment cannot and should not be considered in isolation from society. In terms of a holistic approach, it is desirable to look for an integrative route which accounts for people and the environment equally, as problems in one area have an impact on the other in most cases.

For this reason, socio-economic data are also used for further analysis. Social status is used here; it was developed as part of a study on social space monitoring by the Department of Sociology at the University of Vienna and the Vienna Chamber of Labour (Molina et al. 2020). The basic assumption here is

"[...] that in Vienna, like elsewhere, the residences of people of higher and lower status are not randomly distributed across the city area, but that status differences are also expressed in differences in the ability to create and acquire a 'life-friendly' housing situation and living environment." (Molina et al. 2020, p. 25f)

The status index results from the analysis and subsequent combination of four standardised indicators:

- The average monthly net per capita income in 2017
- The share of people with a university degree as their highest formal educational qualification in the resident population aged 15 and over in 2015
- The share of unemployed persons in the resident population over 15 in 2015
- The share of persons with compulsory schooling as the highest formal educational qualification in the working-age population in 2015

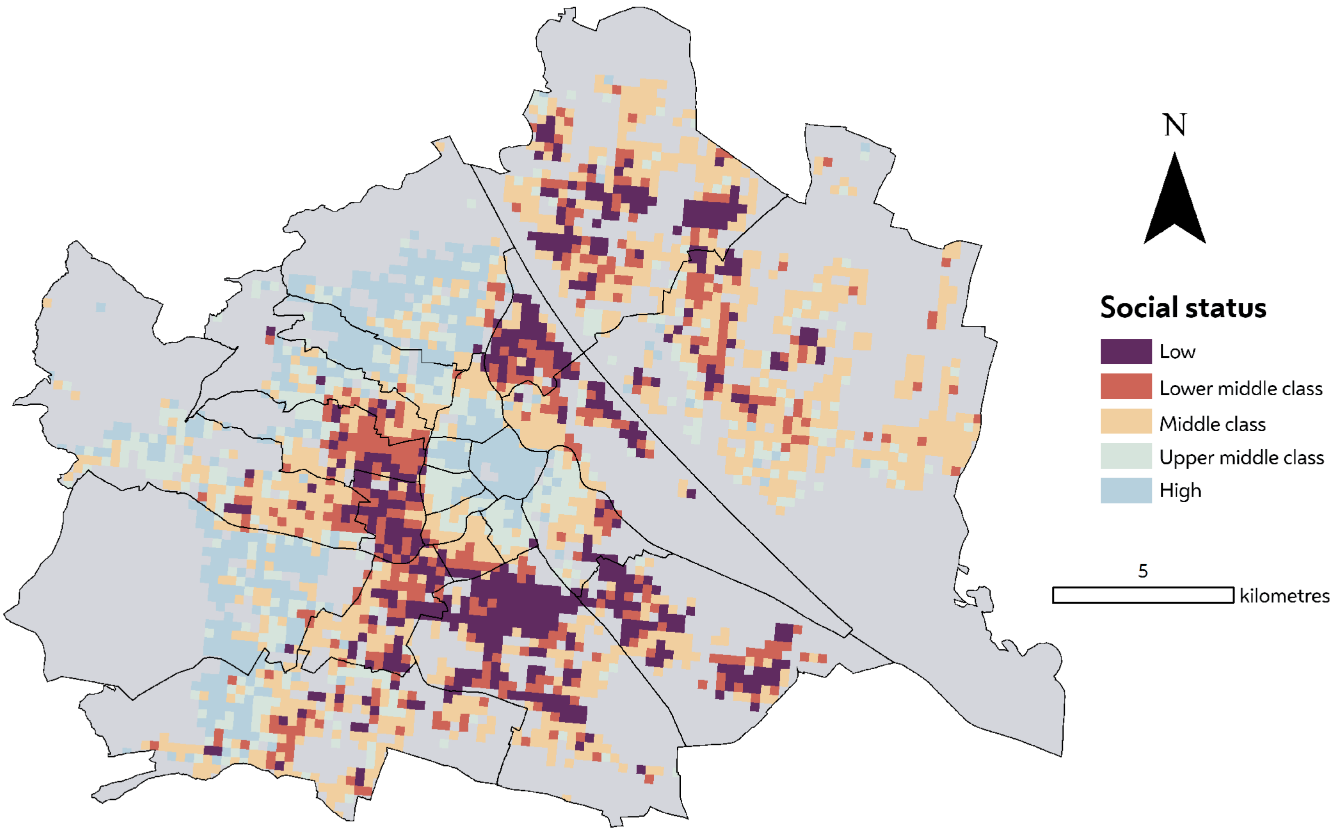

Figure 11: Spatial distribution of social status in Vienna. Data source: Molina et al. (2022); in-house illustration.

Data are available in spatial resolution in the form of a 250 x 250 m grid. This is an abstract breakdown, as the boundaries of the grid cells are independent of administrative or geographical boundaries. However, many grid cells are uninhabited and therefore irrelevant for further analysis. Moreover, the authors of the study wanted to preserve the anonymity of the residents and minimise the influence of random fluctuations, which is why only the grid cells in which the population comprises at least 30 people were included in the further analyses (cf. Molina et al. 2020).

The four indicators were first examined with regard to correlations. All status variables were then aligned equally (high values indicating high status). Z-standardisation was then carried out for each of the four indicators in order to make the status variables comparable with each other. Finally, within each grid cell, the four standardised and equally aligned indicators were "added up to a status sum, which in turn was z-standardised in the same way as the individual status variables" (Molina et al. 2020, p. 31). The breakdown into classes was based on the distance from the mean value, defined by the standard deviation:

$z < -1\,\sigma$ → Value **strongly below average** in relation to the mean value = low social status

$-1\,\sigma \leq z < -0{,}5\,\sigma$ → Value **below average** in relation to the mean = corresponds to lower middle class status

$-0{,}5\,\sigma \leq z \leq 0{,}5\,\sigma$ → **Average** value in relation to the mean value = middle class status

$0{,}5\,\sigma < z \leq 1\,\sigma$ → Value **above average** in relation to the mean = upper middle class status

$z > 1\,\sigma$ → Value **strongly above average** in relation to the mean value = high social status

The social status determined this way can now be expressed in the form of a map (see Figure 11): Areas with a high social status of the population can be found in the city centre as well as in the west and northwest. Areas with a social status in the "upper middle class" and "middle class" categories are mostly directly adjacent to these. In the east, most of the grid cells also correspond to the "middle class" category. Along the Gürtel ring road and in the south and north-east, there are more areas where social status is low or belongs to the "lower middle class" category.

For ease of comparison and combination with the other parameters, data are also broken down into three classes here. After consultation with the Vienna Chamber of Labour, the previous categories of "upper middle class" and "middle class" were combined to form the new category "middle social status". The previous categories "lower middle class" and "low status" are combined to form the category "low social status" (see Figure 12). This means that the spatial distribution is somewhat less differentiated than shown in Figure 11, although the same trend can be seen.

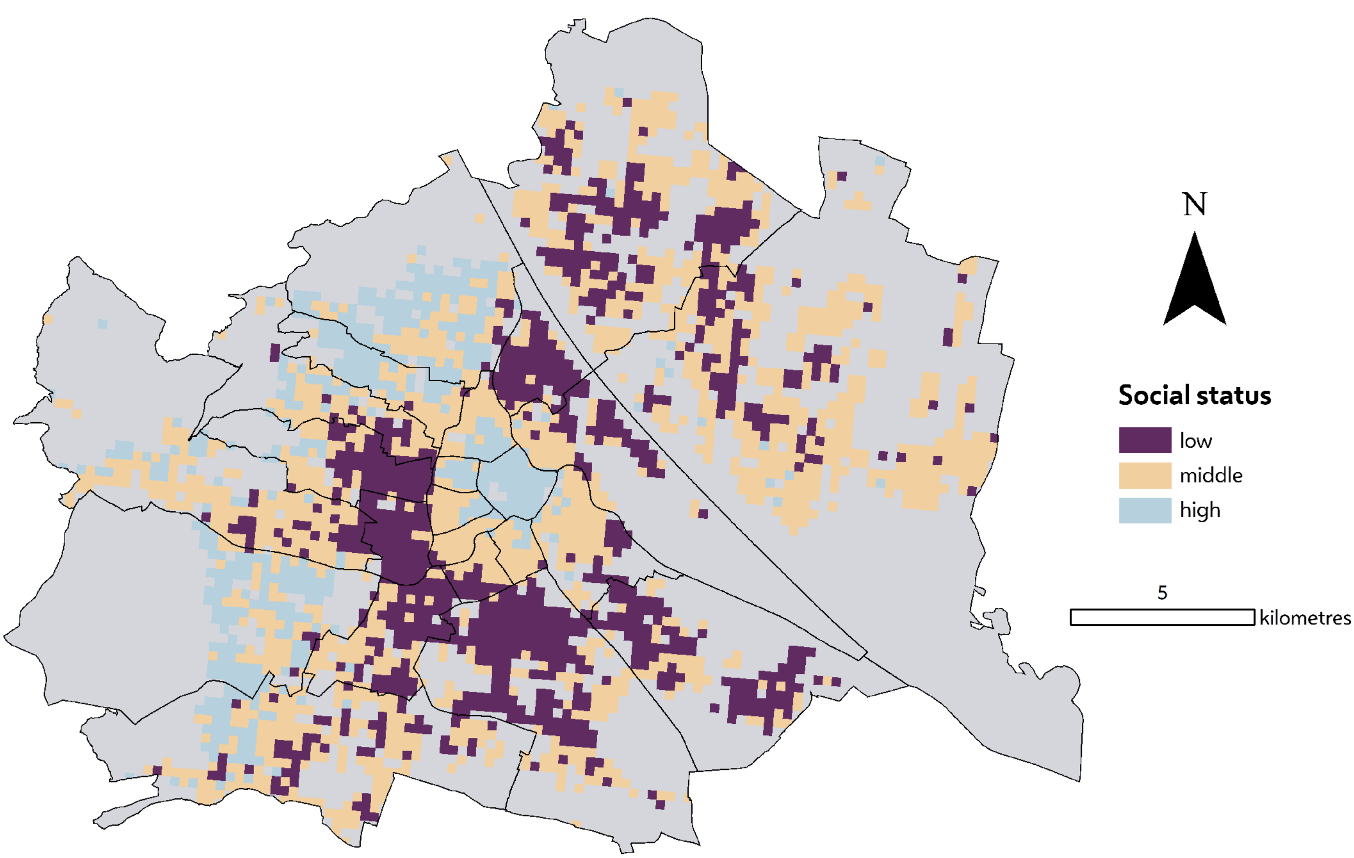

Figure 12: Spatial distribution of social status in Vienna, broken down into or rather summarised in three classes. Data source: Molina et al. (2020); in-house illustration.

3. Combinations

The data processed and standardised this way can now be combined with each other. Most of the combinations are based on the registration district level. Only when combining with social status - where data are available on an even smaller scale - the smaller-meshed grid is superposed on the registration districts. In order to ensure that the influence of the individual factors on the final product is as comprehensible as possible, the individual intermediate steps and the final combination are presented in the form of a matrix. This allows the most detailed information possible to be illustrated in a visualisation which is easy to understand.

3.1 QUIET & GREEN

A matrix is created by combining the shares of quiet places in a registration district area with the share of publicly accessible green spaces in the same registration district area. The darker the individual registration districts, the more they tend towards purple, the less tranquillity and greenery can be found there. The lighter and bluer the colouring of the registration district, the more quiet and green areas there are. Terms such as "much/many" and "little/few" or the like refer to the characteristic values of one registration district in relation to the other registration districts, not to an absolute value.

In the core area, there is a tendency towards fewer quiet places and fewer publicly accessible green spaces. In the immediate vicinity of the core, there are more quiet places and a moderate to larger number of green spaces. The most quiet and green areas can be found on the outskirts of the city, especially to the east, west and northwest. This shows the major role played by the local recreational areas such as Lobau, Vienna Woods, Lainzer Tiergarten and Bisamberg. The south and north-east are dominated by areas with little tranquillity, but there are also districts with a high share of greenery, such as Alte Donau, Prater, Schönbrunn, Kurpark Oberlaa, Wienerberg and

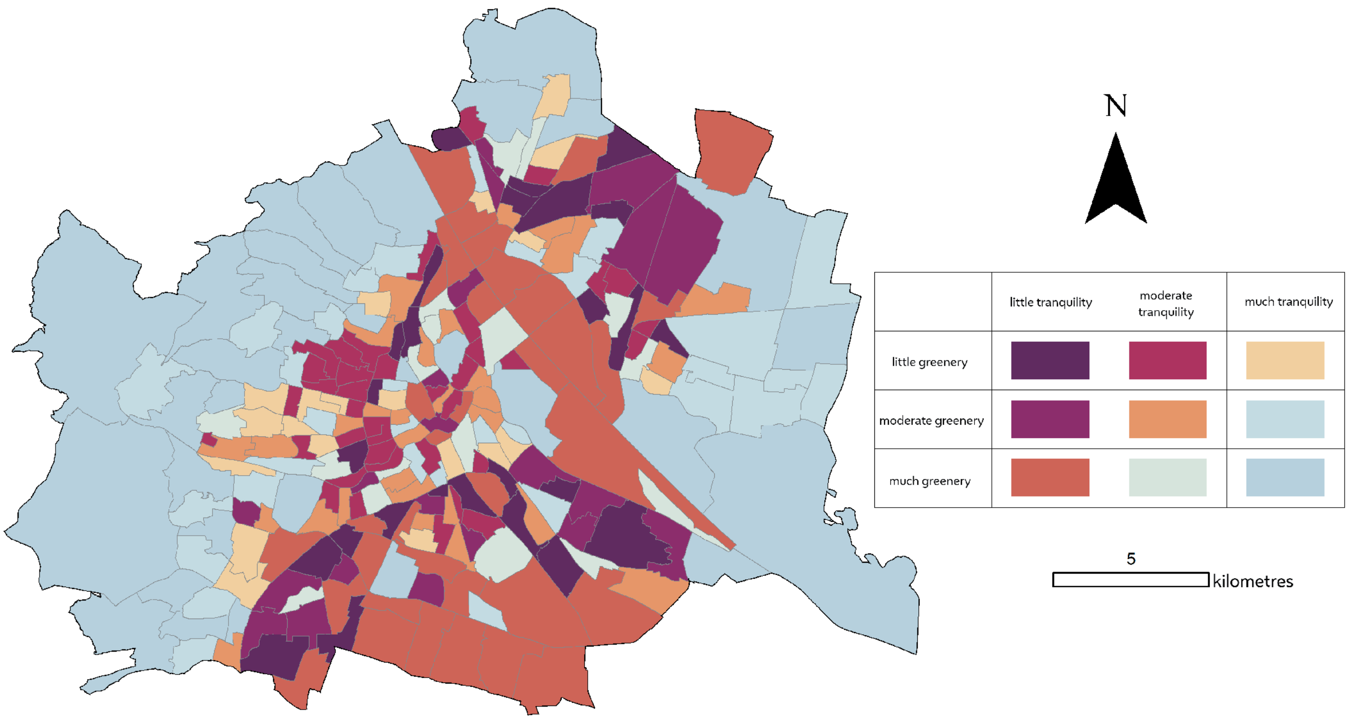

Figure 13: Overlay of quiet and green spaces in the individual registration districts. Data sources: MA 22 (2022), MA 22 (2015); in-house illustration.

Laaer Wald. However, there are also more areas with a very small share of greenery (see Figure 13). As all analyses in this study were carried out against the background of noise protection and abatement, the focus of the visualisation is on the category "quiet". Areas with much tranquillity and little greenery are therefore given a slightly more positive colour in the scheme than areas with little tranquillity and much greenery.

3.2 URBAN HEAT VULNERABILITY INDEX & QUIET & GREEN

The next step is to combine the Urban Heat Vulnerability Index with the "Quiet & Green" map just generated. For this purpose, the categories between "little" to "much tranquillity" and "little" to "much greenery" are summarised in three groups (see Figure 14). This simplification does not fully do justice to the complex situation, but the areas with "little tranquillity" and "little greenery", "moderate tranquillity" and "moderate greenery" as well as "much tranquillity" and "much greenery" are retained precisely as such to ensure a certain degree of comprehensibility.

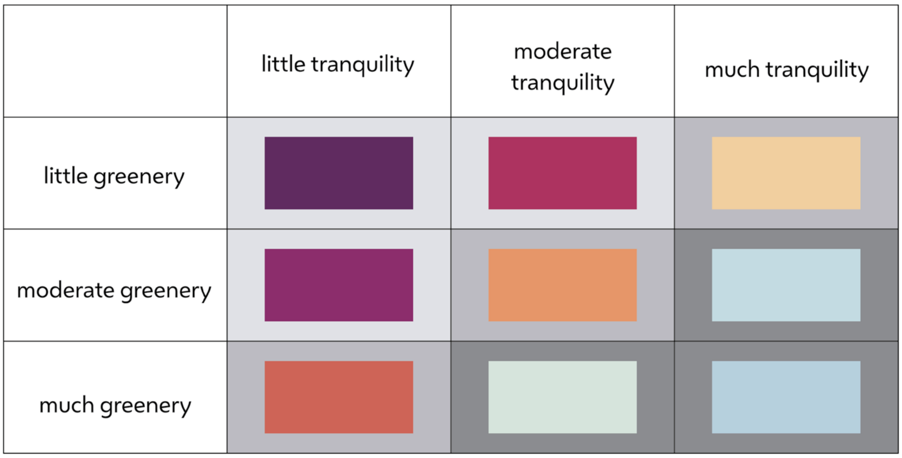

Figure 14: Combination of the characteristics "Quiet" and "Green" into three new sub-areas (unfavourable/moderate/favourable); in-house illustration.

When combining the data on the Urban Heat Vulnerability Index with the "Quiet & Green" map, the pattern remains similar to one combining quiet places with publicly accessible green spaces, but the interplay of unfavourable factors is inten-

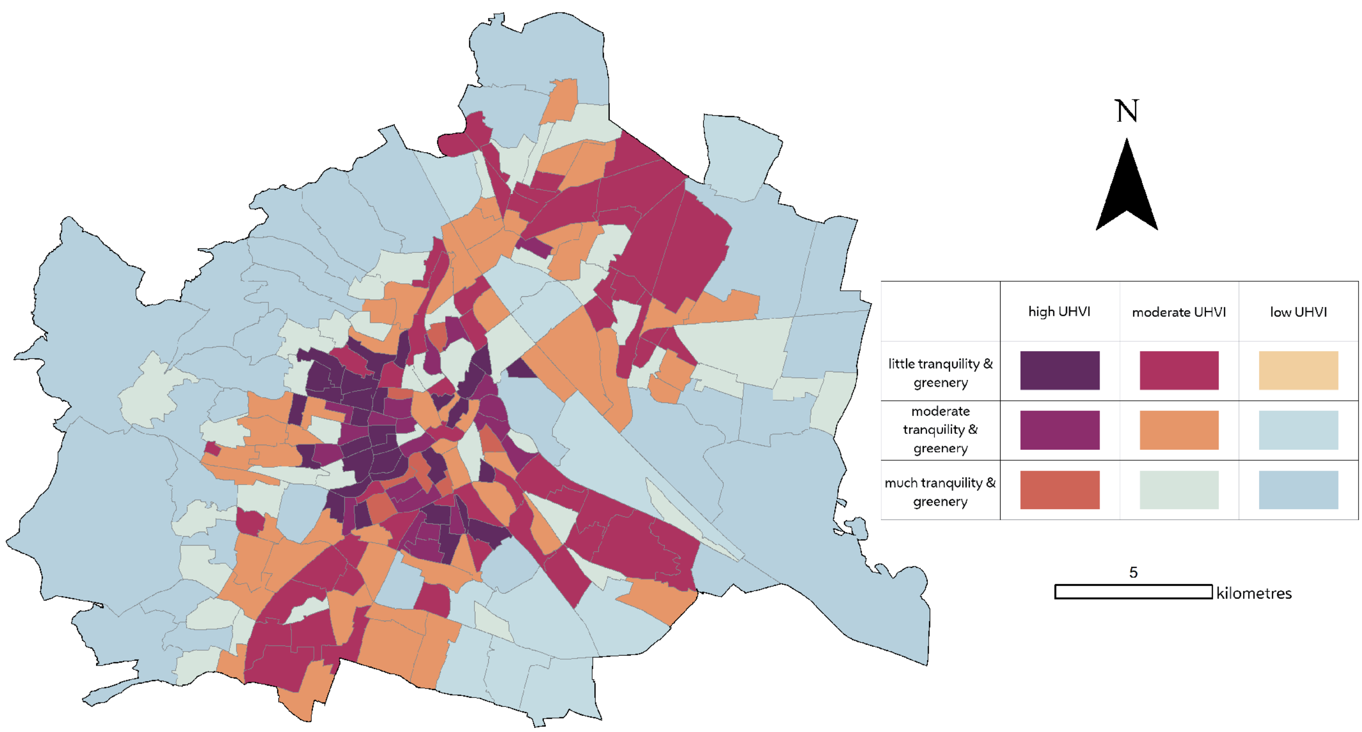

Figure 15: Spatial combination of the Urban Heat Vulnerability Index with quiet and green areas. The tendency towards a hot, noisy and less green core area is reinforced, while the outskirts of the city remain cool, quiet and green. Data sources: Ecoten (2019), MA 22 (2022), MA 22 (2015); in-house illustration.

sified, especially in the area of the Gürtel and the entire core area, which can be described in simple terms as "hot, noisy and not very green" (see Figure 15). At the same time, the trend towards a quiet and green urban fringe remains, and it is also characterised by a low value in Urban Heat Vulnerability Index. Moreover, demographic characteristics are included in the analysis for the first time, as the age of the population has an influence on sensitivity to heat events.

3.3 ACTION MATRIX

The final step is to combine the Urban Heat Vulnerability Index & the Quiet & Green maps just generated with social status. The spatial analysis is no longer carried out at registration district level; instead, the smaller-scale social status grid is superposed. For the purpose of combination, the classes pertaining to the "Urban Heat Vulnerability Index & the Quiet & Green maps must first be simplified, or summarised, again (see Figure 16).

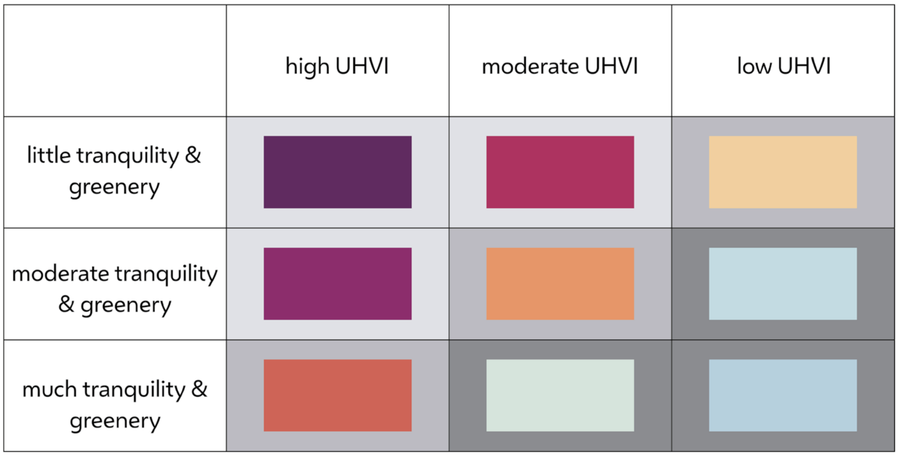

Figure 16: Combination of the characteristics "Quiet" and "Green" with the Urban Heat Vulnerability Index to form three new sub-areas (unfavourable/moderate/favourable); in-house illustration.

The subsequent combination of the values in the Urban Heat Vulnerability Index and those for peace and greenery with social status produces a so-called "action matrix". It can be used as an indicator for the need for action or potential for change:

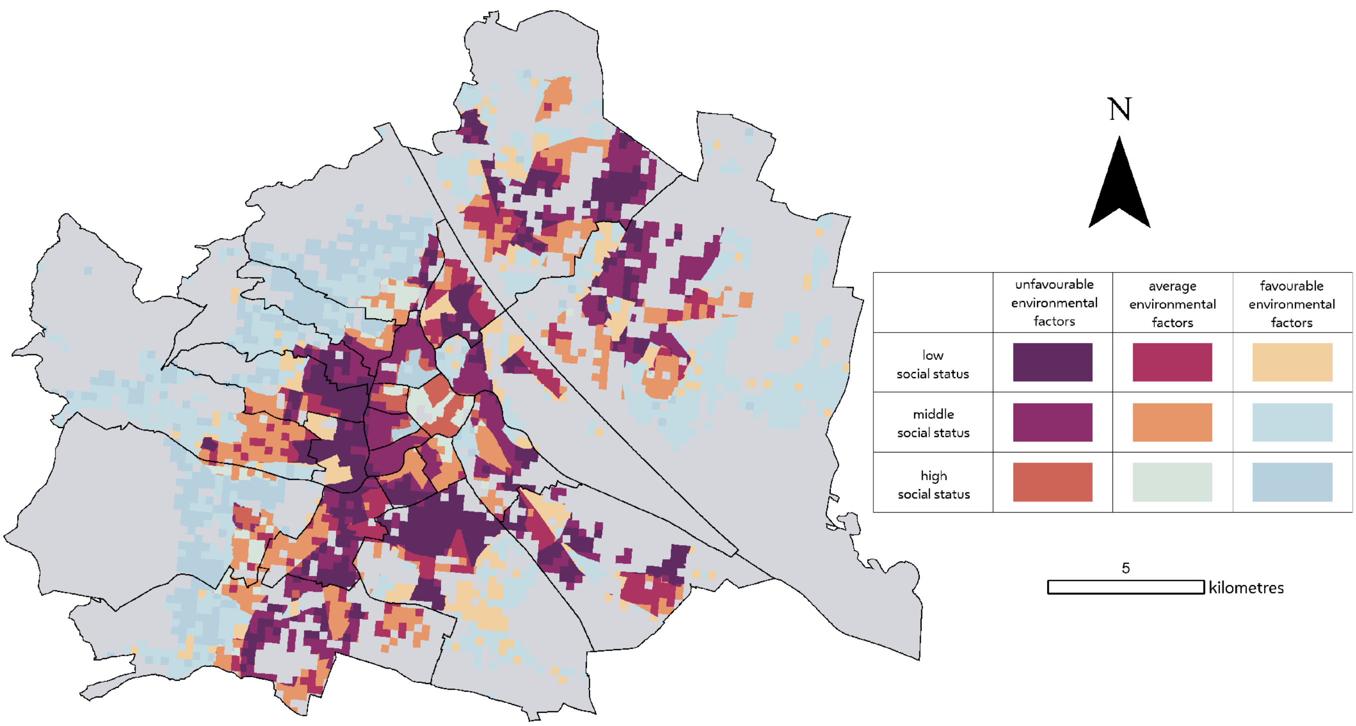

Figure 17: The action matrix results from the spatial superposition and combination of the factors "share of quiet places", "share of publicly accessible green spaces", "Urban Heat Vulnerability Index" and "social status". Data sources: MA 22 (2022), MA 22 (2015), Ecoten (2019), Molina et al. (2020); in-house illustration.

The areas highlighted are those where there is the greatest need for measures to be taken, taking into account the aspects selected for this study. The darker the colour, the less favourable the combination of environmental factors - "unfavourable" means a lower share of tranquility and greenery as well as higher vulnerability to urban heat - and the social status is all the lower. Conversely, the brighter the colour, the more favourable the combination of environmental factors - "favourable" meaning a higher share of quiet places and greenery as well as a higher resilience to urban heat - in combination with a high social status. By using the action matrix, projects with the **greatest added value** can be identified and developed in the course of noise abatement planning and in accordance with the principles of economic efficiency and economy.

The following patterns and trends emerge according to the spatial combination and superposition (see Figure 17): In contrast to where the Urban Heat Vulnerability Index is combined with tranquillity and greenery, the local recreation areas on the outskirts of the city no longer have such a clear impact, as the focus only remains on the inhabited areas. Apart from this, however, there does appear to be a spatial correlation between social status, Urban Heat Vulnerability Index, quiet places and publicly accessible green spaces: In the inner city, high social status meets environmental factors which are largely in the middle range. Around the inner city, the environmental factors become increasingly unfavourable and the social status also decreases until both social status and unfavourable environmental factors converge in the area around the Gürtel. Moving further towards the outskirts of the city, social status increases again in combination with moderate environmental factors. In the south-east and north-east in particular, social status tends to remain low; here it is primarily the quality of the environmental factors which increases. In the immediate vicinity of the local recreation areas, social status is then high and comes together with favourable environmental factors.

This means that the data obtained is not only suitable for identifying Vienna-wide "hot spots", but also for a detailed analysis of the situation at district level. The small-scale structure, based on the 250 x 250 m grid cells, allows for individual grid cells to be examined in detail and appropriate measures to be planned. However, a district-wide view is also advantageous if measures are to be implemented in a larger area.

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