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# Comparison of Noise-Filtering Ability of Vegetation – A Literature Review

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**ABSTRACT**

Vegetation belts may offer an effective and economical solution for reducing noise pollution as an environmental impact where sufficiently large areas are available. However, the complexity of the attenuation process makes choosing the right plant species or variety a complicated task. That studies have employed different methods to examine the noise-reducing properties of individual hedges and shrubby groups of trees only complicates matters further. The present study interprets and summarises the achieved results via an analysis of the relevant literature using statistical methods. We focused on the following areas: (1) commonness and value range to compare the general data of the selected studies, (2) location types and the measurement layouts, (3) the parameters used to describe the vegetation strips, and (4) the parameters used for noise measurement and attenuation calculation. In addition to the diversity of the examined environment and vegetation in the studies, the description of the implementation and physical characteristics of the measurements was, in many cases, incomplete in several aspects. At the same time, the differences between the employed parameters and their evaluation resulted in partially comparable noise attenuation data, thereby increasing the inhomogeneity in the literature.

**TANULMÁNY INFÓ**

*Kulcsszavak:*
Növénysávok
Zajcsillapítás
Szakirodalmi áttekintés
Statisztikai módszerek

**KIVONAT**

**Különböző növénysávok zajvédelmének összehasonlítása – szakirodalmi áttekintés.** A zajszennyezés, mint környezeti ártalom csökkentésére megfelelő méretű területeknél a növénysávok hatékony és gazdaságos megoldást kínálhatnak. Figyelembe véve a csillapítási folyamat összetettségét, a megfelelő típus és növényfaj kiválasztása azonban bonyolult feladatot jelent. Ezt nehezíti továbbá, hogy a különböző tanulmányok eltérő módszerekkel vizsgálták az egyes sövények és bokros facsoportok zajcsillapító tulajdonságait is. Jelen cikk célja ezért az volt, hogy a vonatkozó szakirodalmak áttekintésével és elemzésével segítséget nyújtson az elért eredmények értelmezésében és összefoglalásában. Ennek érdekében statisztikai módszerekkel összehasonlításra kerültek a kiválasztott tanulmányok általános adatai (1), a helyszínek típusai és a mérési elrendezés (2), a növénysávok leírására alkalmazott paraméterek (3) valamint a zajméréshez és a csillapítás kiszámításához felhasznált paraméterek (4) különösen gyakoriság és érték-terjedelem szempontjából. Összességében a vizsgált környezet és növényzet változatossága mellett a mérések kivitelezésének és fizikai jellemzőinek leírása sok esetben több szempontból hiányos volt. Ezzel párhuzamosan a felhasznált paraméterek és az azok kiértékelése közötti különbségek egymással részlegesen összehasonlítható zajcsillapítási adatokat eredményeztek, növelve ezzel a szakirodalmi inhomogenitást.

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## 1 INTRODUCTION

Noise and unwanted sound can be a disturbing environmental factor in urban and rural areas; however, reducing the effects by increasing the distance between the noise source and the affected area is often impossible. Erecting solid barriers to block the noise is not always feasible (Dobson – Ryan, 2000). Although vegetation can reduce noise over a wide frequency range, the potential of forests or narrow tree belts alongside surface transport corridors for reducing noise is often dismissed, particularly in studies involving conflicting experimental evidence (Attenborough – Taherzadeh, 2016). Nevertheless, planting vegetation of appropriate density can offer a cost-effective solution in high traffic areas (e.g. near motorways) where the construction of conventional noise abatement methodologies, primarily noise barrier walls, would be economically unfeasible (Harris – Cohn, 1985). Moreover, the ubiquitous green elements in many European cities can substantially mitigate air pollution through carbon dioxide sequestration during photosynthetic activity, depending on the leaf surface area (Gratani – Varone, 2013), while also reducing individual subjective noise annoyance by visually obscuring the noise sources (Bangjun et al., 2003).

The noise attenuation of vegetation depends on belt spacing, height, and depth as well as foliage density; nonetheless, meteorological conditions such as temperature, humidity, and wind make precisely quantifying such parameters difficult (Kerby, 1974). Nonlinear attenuation is mainly due to multiple scattering of sound energy in the canopy, which is affected by leaf density, leaf area per unit volume of the canopy, leaf width, and frequency (Aylor, 1972a). Leaf orientation and amount (on the order of two·$10^5$ pieces in a mature tree) in the sound field (Martens – Michelsen, 1981) also contributes to sound scattering, as does the behaviour of the branches and the trunk as oscillators, adding to absorption due to transverse vibrations at lower frequencies (Embleton 1963).

The noise attenuation of vegetation strips is a complex process. In addition to extensive field measurements, noise prediction methods were also refined for sound propagation, vegetative barriers, and interactions with complex physical barriers (Borthwick et al., 1977). For example, in studies on traffic noise propagation, 3D finite-difference time-domain (FDTD) calculations proved that limited-depth (15 m) vegetation belts—tree spacing of less than 3 m and stem diameters of more than 0.11 m—can achieve significant noise reduction, despite the sound attenuation and reflection properties of the ground surface (Van Renterghem et al. 2012). Moreover, tall trees and dense underbrush with a planting depth of at least 30 m can provide reliable attenuation of 5–8 dB, with a line of sight of 15 m (i.e. visibility depth), depending on traffic density (Reethof, 1973). According to the Cadna/A simulation software results, the most effective green belt width range can be placed between 30–50 m, and the greatest noise attenuation intensity can be observed in vegetation strips 30–90 m in length (Su et al., 2023). As for tree height, among the factor indices created from LIDAR point cloud data, which provide the basis for the structural optimisation of urban green areas, 5 m was the most significant positive correlation with the attenuation, which was the percentage of point cloud grid (parameter defined by the authors). However, the coverage degree or the leaf area index as a function of the absolute height does not correlate with the actual reduction (Xu et al., 2022).

Based on the studies analysed, green belts can have a significant attenuation effect; however, inadequate consideration of spatial factors and the absence of urban planning processes necessitate mapping methods to identify optimal planting locations (Fletcher et al., 2022). Suitable plant species selection is also vital. For example, bamboo species that can be planted densely, grow quickly, and adapt to a short life cycle in sandy/clay soil layers are the most appropriate choice in the subtropical climate zone in Asia (Yasin et al., 2020). On the other hand, the triangular conifer species would be more efficient in continental climates in Europe or North America because most of the biomass is near the canopy base. Thus, the microclimate changes due to a denser and lower canopy influence sound propagation and attenuation. Moreover, conifers do not shed their needles during winter (Van Renterghem et al., 2015).

Choosing the most suitable vegetation for the given conditions is a complicated and complex task requiring the evaluation of many parameters. The present study aims to clarify this task by different studies and categorising the systems of criteria used for research, noise measurement distances, and attenuation results.

## 2 MATERIALS AND METHODS

We selected 32 studies according to the following criteria:

1. The literature should cover a relatively wide interval of measurement methodology and data processing, starting from one of the earliest commonly cited works (e.g. Eyring, 1946) to the present day (Meng et al., 2025).
2. The geographical location and climate of the measurement sites by using the distribution of the Köppen climate zones (Kottek et al., 2006), as well as the type and character of the examined vegetation belts, should be different by presenting variant plant species, including forests (Huisman – Attenborough 1991), maintained and unmaintained hedges (Biocca et al., 2019), or agricultural plantations (Bashir et al., 2015).
3. Sound propagation differences entailed using point and line sources (e.g. Aylor, 1972b; Kragh, 1979) (not necessarily in the same study) either from a random/calibrated natural noise source or artificially induced effects with loudspeakers.
4. A detailed description of the measurement arrangement, including an available sketch, schematic diagram, or photograph documentation, to determine the typical distances between the plants and the tools or instruments used.
5. The authors should describe the characteristics of the examined belts with as many quantified parameters as possible (for which, as found in the studies, a correlation or functional relationship was established between the individual properties and the possible noise attenuation).
6. Finally, results related to octave-band (Pal et al., 2000), third-octave band (Fan et al., 2010), and discrete frequency values (Zhang et al., 2024) (regardless of the full or partial spectrum width covering the human hearing range), and the noise parameter used to calculate the attenuation should be clearly indicated.

Cases were not excluded from the comparison due to the absence of a criterion (which became evident during processing), provided that this did not adversely affect the conclusions drawn on other criteria.

Once the selected studies were processed, the data related to the individual aspects were summarised in the tables in the Appendix, displaying the results. Tables in some categories contain text-based parameters (e.g. when indicating the type of climate zone or the examined vegetation belt) or display a numerical value (e.g. for distances or the degree of attenuation). In addition, the presence or absence of the relevant parameter in the given article is marked with yes/no categories as a third grouping method. These are supplemented by the textual explanation of the data that cannot be determined clearly, helping to establish the basis for the comparison.

# 3 RESULTS AND DISCUSSION

## 3.1 General data of the selected studies

Based on the general data summarised in *Appendix Table 1*, the studies cover an interval of nearly eight decades, starting from the often-cited jungle acoustics published by Eyring in 1946 and extending to 2025. In addition, 18 of the sources (56.3%) examined the properties of green belts in different Asian countries. Nine, approximately a third (28.1%), examined European countries, while one study (de Oliveira et al. 2022) refers to South America.

Based on the locations indicated in the literature, *Figure 1/a* illustrates the distribution of the Köppen climate zones belonging to each study area. Concerning the distribution between the continents, the humid subtropical and subtropical monsoon climate typical in South Asian areas shows a particularly high number alongside the temperate continental and oceanic temperate zones of Europe and North America. However, the overlap in the 13 categories is low, as only four studies covered two climate zones simultaneously, partly due to measurements in several countries and the distance between locations within a country. Two studies are exceptions to the climate classification (Horoshenkov et al., 2013; Webb et al., 2023), in which the authors used laboratory measurements on small plant samples under artificial conditions instead of the open field.

*Figure 1/b* presents the vegetation belt types (based on the terminology used by the researchers) as objects. Of the vegetation types selected for the analysis, hedgerows, forest belts, and woody and shrubby vegetation strips of various shapes and layouts were the most numerous, while the other types show diversity in physical characteristics (for example, dimensions or density) from shrub belts (only densely planted shrubs in contrast to the vegetation strip) to jungle. In terms of overlap, six studies examined more than one category, which can be explained by the different measurement areas, as well as categorisation differences in the wording of textual descriptions and overlaps between the individual categories.

Based on the data aggregation, 27 studies named 226 plant species (an average of 8), of which 94 were coniferous (an average of 5 in 18 studies), and 130 were deciduous (also an average of 5 in 26 studies). As an exception, the difference between the total value (226) and deciduous/evergreen value (224) appeared in Bashir et al. (2015), in which the large-leaved corn and winter wheat examined in the agricultural area can be defined as annual crops. In two of the remaining five sources (Ow – Ghosh, 2017; de Oliveira et al., 2022), the semi-deciduous and evergreen vegetation could only be assumed based on the location and climate zone, while in another two (Liu et al., 2023; Zhang et al., 2024), the selected vegetation was only distinguished according to composition. The fifth, Huisman and Attenborough (1991), only provided the forest type where the measurements were taken. Overall, detailed information can be found in studies, including a list with the Latin species nomenclature (e.g. Tyagi et al., 2013) and a description without the vegetation composition, thereby reducing the homogeneity of the literature.

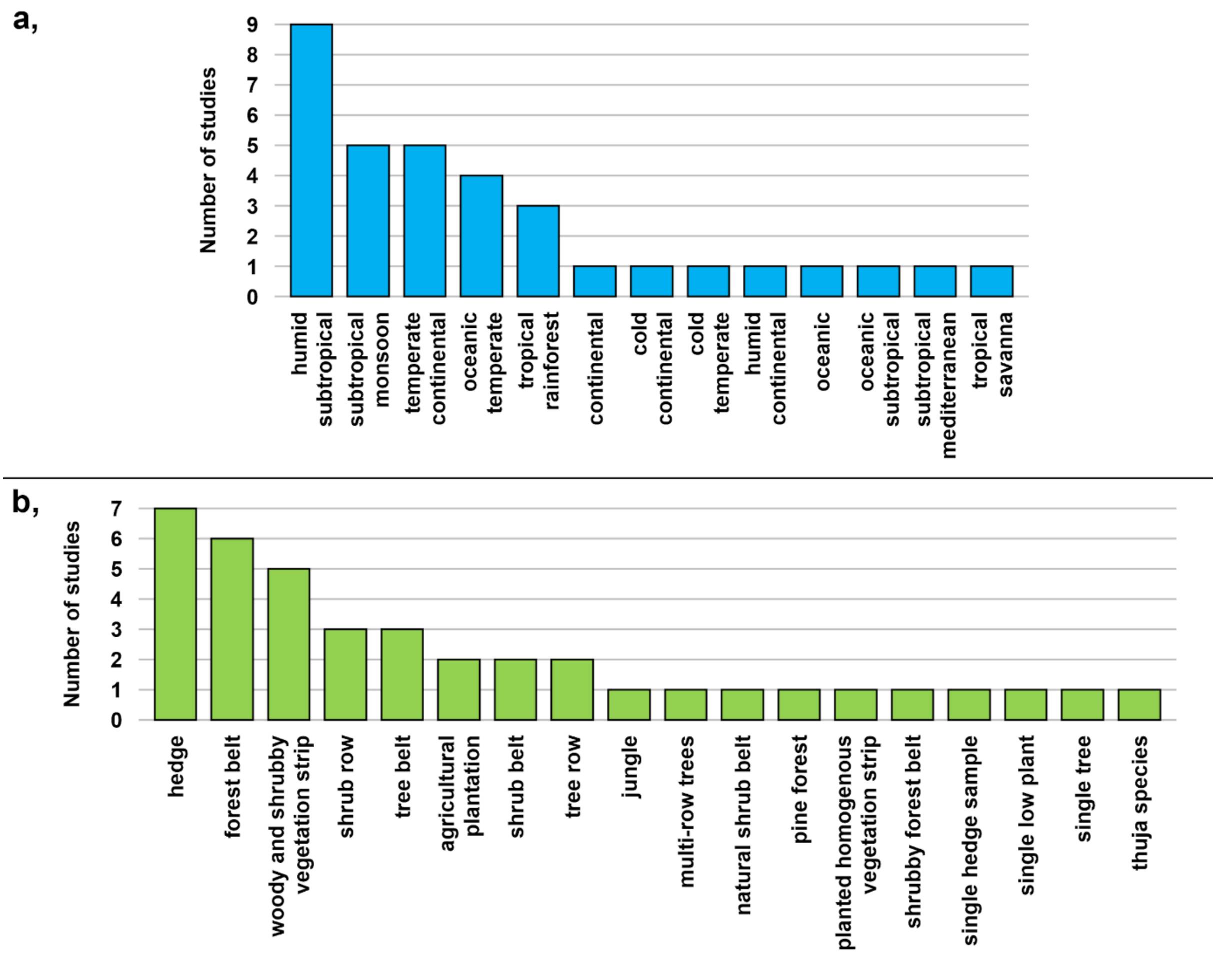


*Figure 1. Köppen climatic zones belonging to the examined areas (a) and the distribution of the vegetation belt types (b)*

### 3.2 Comparison of the location types and measurement layout

The next evaluation step involved classifying the measurement locations into five types: residential, industrial, agricultural, natural and laboratory (*Appendix Tables 2 and 3*). A total of 451 locations were distinguishable in the 32 studies; however, the average value of 7 per study doubled by the 217 city points indicated in Liu et al. (2023). The numerical composition of the location types in two studies (Fang – Ling, 2003; Fang, 2004) could not be clearly identified. Thus, measurements were taken in or near inhabited areas in almost 80% of cases, and the 40 natural and agricultural sites, presumably burdened with less environmental disturbance, appeared in only 11 studies.

The following differences between point and line sources (which are significantly different from the point of view of physical sound propagation) found in the selected studies should be highlighted regarding noise sources. For line sources, the authors used a real source in each case. These could be roads (e.g. Liu et al., 2024) or railway traffic noise (e.g. Kragh, 1979), but in the absence of data on vehicles passing in each lane during a given time, they were not quantified. On the contrary, the point sources used for attenuation calculation or control measurement, such as truck noise, could have been artificial, pre-recorded, and played back from loudspeakers, (e.g. Cook – Haverbeke, 1974), or they could have been noises from natural sources, such as vehicle engines (e.g. Oh et al., 2009), lawnmowers (e.g. Cook – Haverbeke, 1977), air conditioning units (e.g. Biocca et al., 2019) or motorised lawnmowers (e.g. Mohamed

– Krisantia, 2009). A double point source was used only by Eyring (1946) due to the technical limitations of producing the necessary frequency spectrum in that era.

The present study applied the following signs to compare the distance and height data of the measurement arrangements, as shown in *Figure 2*:

- **$L_1$**: distance between the noise source and the microphone located in front of or at the border of the vegetation belt,
- **$L_2$**: distance between the noise source and the border of the vegetation belt,
- **$L_3$**: distance between the end of the vegetation belt and the first microphone placed behind the belt,
- **$L_4$**: distance between the end of the vegetation belt and the last microphone placed behind the belt,
- **$L_{belt,max}$**: maximum vegetation belt width,
- **$L_{min}$**: distance between the noise source and the first microphone placed behind the vegetation belt,
- **$L_{max}$**: distance between the noise source and the last microphone placed behind the vegetation belt,
- **$H_s$**: height of noise source from ground level,
- **$H_{R1}$**, **$H_{R2}$**, **$H_{R3}$**: height of microphones from ground level.

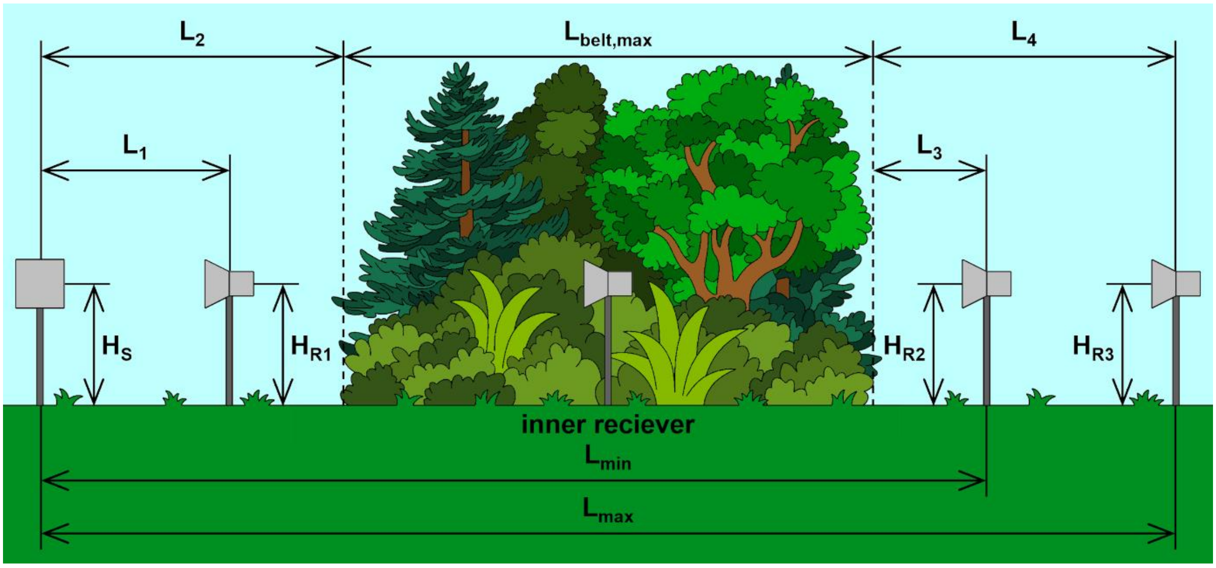


*Figure 2. Applied distance and height signs for the measurement arrangement comparison*

The largest distance values in *Appendix Tables 2 and 3* established the limits of the intervals. In cases involving more than one measurement location (due to differences between the devices and the layout of the vegetation belts), selection focused on where the most parameters could be clearly determined (e.g. Van Rentenghem et al., 2014). All values could at least be quantified at one measurement location in only a quarter of the studies (e.g. Lu et al., 2024); however, the sole exception where none of the data was available was the laboratory study by Horoshenkov et al. (2013), which investigated the noise reflectivity and absorption of plants placed in an impedance tube. For the remaining 23 studies containing partial information, some distances, such as $L_3$ and $L_4$, were not interpretable when the required measurements were made within the vegetation belt (e.g. Price et al. 1988) or if one of the measuring microphones depicted in *Figure 2* was missing from the arrangement (Kim et al., 1989). For the most comprehensive processing, an approximate value was possible in four studies. In three of these, the distance between the road as a line source and the vegetation or one of the microphones could be estimated based on the lane width that generally corresponds to three meters (Oh et al., 2009; de Oliveira et al., 2022; Liu et al., 2024), while in Eyring (1946), the values given in non-SI units could be converted by rounding.

*Figure 3* summarises the differences between the intervals that can be specified for each applied distance, including the mean values. No significant difference was observed between the mean and range values of the source and microphone placed in front of the vegetation belt. Nevertheless, the differences in these same parameters were of magnitudes thirteen and seven times greater for the microphones placed behind the belt. Fang and Ling (2003) investigated the widest vegetation belt (within a substantially narrower measurement range), whereas the narrowest appears in Webb et al. (2023). The largest measurement range appears in Eyring (1946), resulting from internal measurements without specifying the width of the vegetation belt. The minimum of the $L_1$ and $L_4$ microphone distances and the width of the vegetation had a value greater than zero; however, for the interval of the $L_2$ and $L_3$ parameters, this zero value also occurred in several cases when the source or microphone was placed at the border of the belts.

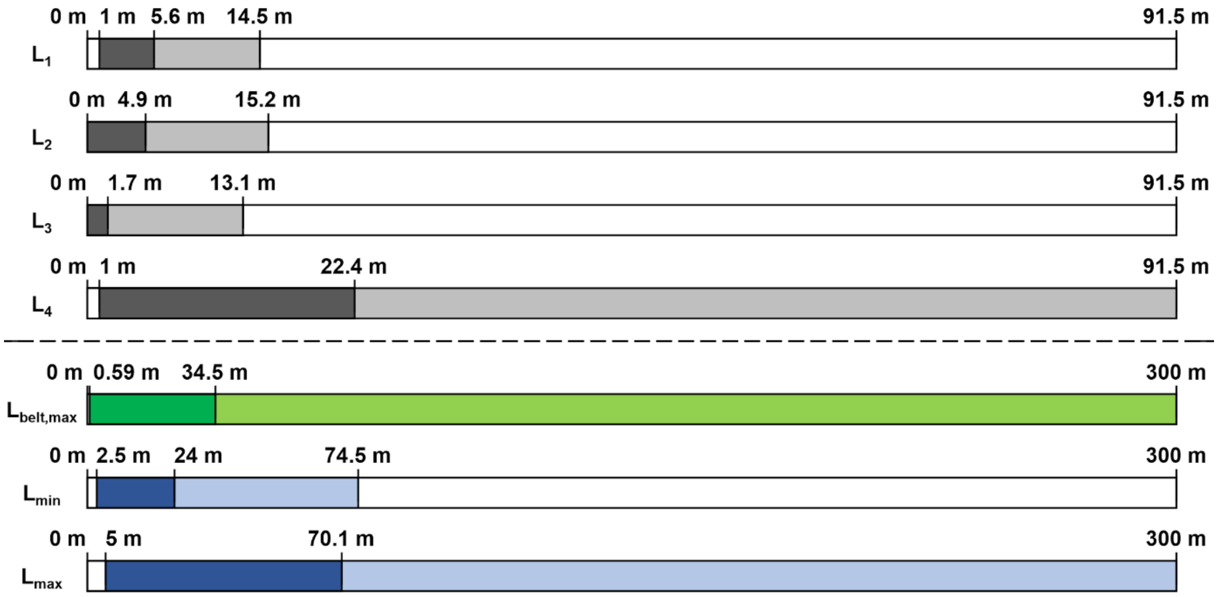

*Figure 3. The interval and mean value of the applied distances*

Numerically, the authors provided the number of microphones in 25 studies (nearly 80%), including the measurements made entirely within the vegetation. Internal microphones were also used in 13 studies (about 40%), and due to the multiple angles, height, direction, and attenuation in front of the belt, data were generally recorded using at least two microphones on average. From a practical perspective, the generally accepted measurement height of 1.5 meters above the ground level (which in Hungary is defined in the 27/2008. (XII. 3.) KvVM-EüM joint decree on environmental noise measurements) was used in half of the studies (e.g. Fang and Ling, 2005). In the remaining studies, the height ranged from 0.3 to 7.36 m, and in one research (Watts et al., 1999), microphone locations could not be determined from the description and the photographs. The source height varied between 0 and 1.5 meters depending on its type. In 13 studies (e.g. Pathak et al., 2008), the artificial point source and the microphones were positioned at the same height, while in the research of Tayagi et al. (2006), the engine height of the vehicles used as sources could be estimated at 0.5 m.

Information on ground cover, which is important in terms of sound reflection and attenuation, was unavailable in five studies (15.6%) (e.g. Karbalaei et al., 2015); however, in

18 cases, at least two types of soil could be distinguished. The detail and scope of the description also had an influence. For example, Aylor (1972b) explicitly provided numerical values for layer thickness. Watts et al. (1999) provided photographs that allowed the cover to be inferred near the source and the vegetation, whereas in Pathak et al. (2008), the public road and sidewalk referred only to the area surrounding the noise source.

### 3.3 Parameters used for describing the vegetation belts

For easier interpretation, the quantifiable parameters the authors used to characterise the vegetation belts were classified into parameter categories, considering the partially overlapping concepts and the same or similar measurement units. As a result, the 57 categories could be separated and were included in *Appendix Table 4/1, 4/2, 5/1 and 5/2*, along with their usage indicated on a yes/no basis and their corresponding measurement units. Parameters with similar meanings but different wording appeared across 14 categories; however, the measurement units used were identical within each category in six categories (as well as in all categories containing only a single parameter). Parallel to the above, by summarising the number of categories used in each study (*Figure 4*), we found that 21 studies (approximately 65%) specified five or fewer characteristic quantities. Two cases (Liu et al., 2023; Zhang et al., 2024) provided no numerical values. Horoshenkov et al. (2013) defined the highest number of categories (12) during laboratory measurements, while the average number per study was five (by rounding to the nearest whole number).

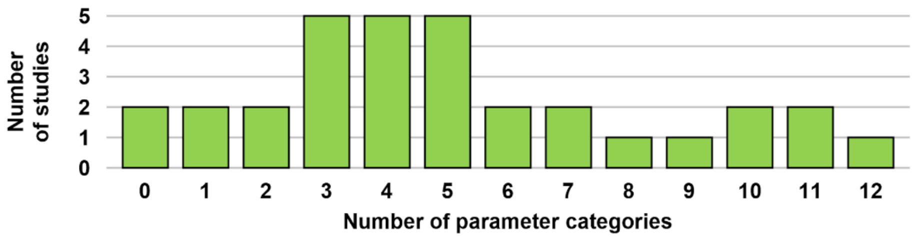


*Figure 4. Distribution of the number of studies for the used parameter categories*

*Figure 5* illustrates the categories that appear in more than one research, together with their frequencies and measurement units. Among the 22 categories, the first three with the highest frequencies corresponded to the basic three spatial dimensions (height, depth, and length) of the vegetation belts; however, the simultaneous use of all three was observed only 11 times, barely a third (34.4%) of the compared studies. Another important finding is that the frequency of the visibility parameter was relatively low; however, its use for characterising the vegetations was already recommended by Eyring in 1946, one of the earliest pioneering studies. The visibility parameter is determined using the so-called white-glove method described by Fang (2004), in which one researcher wearing a raised white glove stops at several predetermined distances within the vegetation belt until the observer standing at the edge can no longer see the glove.

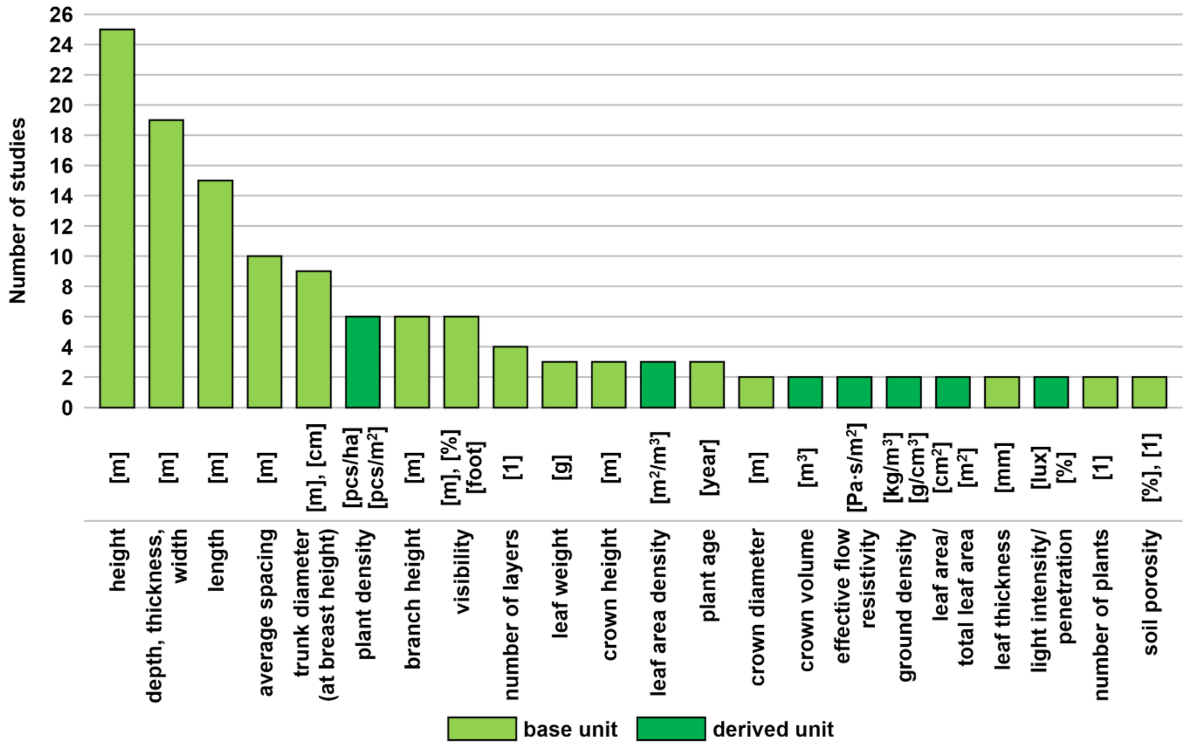


*Figure 5. Frequency of parameter categories appearing in more than one study and their classification by measurement unit*

In the grouping according to basic and derived units, 15 of the displayed categories (approximately 70%) were associated with base units or were dimensionless, of which ten referred to length, one each to mass and plant age, and three expressed characteristic values in the form of number of pieces or percentage. The exception to the only base unit/derived unit classification, also shown in the figure and classified in the derived group, was light intensity or penetration, where the value of the former is given in lux by Oh et al. (2009). The latter was expressed as a simple percentage form by Pal et al. (2000). Overall, the ratio of the categories was 44/13 (77/33%), showing a clear advantage for the basic units. In addition to the above, five studies also recorded physical obstacles located within or complementing the vegetation (e.g. garden beds, fences, walls), further increasing the complexity of the system of criteria and distorting the parallelisation of the given values for noise attenuation.

### 3.4 Parameters used for noise measurement and attenuation calculation

*Appendix Tables 6 and 7*, which have a structure similar to the categories of vegetation belts, summarise the 27 noise parameters used in the individual studies along with their symbols. These include both metrics commonly applied in acoustic measurement practice (such as SPL, $L_{eq}$, or $L_{max}$) and quantities defined by specific authors using functions (for example, NC, TNI, or $L_{np}$ as described by Pathak et al. (2008)). In terms of counts, only one parameter was used in seven studies (approximately 20%). The seven parameters considered the highest number were distinguished by Pathak et al. (2008), and the average number of parameters reported per study, by rounding, was two.

The noise parameters used in at least two studies are illustrated in *Figure 6* with their frequencies and symbols, which can be listed in descending order of frequency according to general acoustic terminology, with the following definition:

- **sound pressure level (SPL)**: as a fundamental acoustic parameter, it expresses the sound pressure at a given point and moment compared to the reference sound pressure,
- **equivalent sound pressure level ($L_{eq}$)**: the constant sound pressure level that contains the same amount of sound energy over the examined period as the actual, time-varying sound pressure level,
- **relative attenuation (–)**: the difference in sound pressure level reduction between two different propagation conditions (e.g. two sound paths, vegetation types, or reference vs measurement sites),
- **insertion loss (IL)**: the difference in sound pressure level reduction on the protected side before and after the installation of the noise protection solution (e.g. wall, embankment, vegetation) at the same measurement location,
- **maximum noise level ($L_{max}$)**: specifies the highest instantaneous sound pressure level value measured during the given period,
- **sound value exceeding 10% of the time ($L_{10}$)**: as a statistical characteristic of noise distribution, the sound pressure level that is exceeded by the measured sound pressure level during 10% of the time,
- **sound/noise level (L)**: depending on the context, indicates the sound pressure level or noise level,
- **excess attenuation ($A_e$)**: the reduction in sound pressure level that exceeds the value of the expected reduction in sound pressure level resulting from the geometric and atmospheric sound propagation in free space (in an unattenuated environment),
- **sound value exceeding 50% of the time ($L_{10}$)**: as a statistical characteristic of noise distribution, the sound pressure level that is exceeded by the measured sound pressure level during 50% of the time.

An interesting observation in addition to the data was that the value of SPL was used more frequently than $L_{eq}$ in some studies. One reason is that an artificial or natural source with a slightly varying noise level (e.g. Kim et al., 1989; Biocca et al., 2019), $L_{eq}$ by expressing the energetic average, does not provide additional information compared to SPL. Both parameters were simultaneously included in only one research (Karbalaei et al., 2015). Nevertheless, the insertion loss or excess attenuation that can be used for site condition assessment and the maximum noise level (which shows magnitude differences) were used in a relatively small number of cases.

Another important aspect is that 11 literature sources (more than one third) did not apply the A-filter, which best represents the characteristics of human hearing, or its use could not be clearly determined. Moreover, only seven studies mentioned one of the six standards listed below, which greatly aid reproducibility:

- **ISO 10534-2:1998**: Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method,
- **ISO 9613-1:1993 and 2:1996**: Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere; Part 2: General method of calculation,
- **NBR 10151:2000**: Acoustics – Evaluation of noise in inhabited areas aiming at the comfort of the community – Procedure (Brazilian national standard),
- **GB 3096-2008**: Environmental Quality Standard for Noise (Chinese national standard),
- **ISO 1996-2:2007**: Acoustics – Description, measurement, and assessment of environmental noise – Part 2: Determination of environmental noise levels.

In connection with this, it is worth noting that in the examination of the frequency spectrum considered complete in practice and managed by most instruments (16–16,000 Hz), which was used in five studies (approximately 15%), the researchers consistently applied octave or third-octave band division. In contrast, among the 14 cases (more than 40%) analysing a partial spectrum, five did not apply such a division due to continuous spectrum measurement (e.g. Bashir et al., 2015), or the specification of the division was missing (e.g. Price et al., 1988). In addition to the documents containing five non-overlapping octave bands and nine third-octave band measurements, one study examined only discrete frequencies (Kim et al., 1989), while another (Zhang et al., 2024) used both the full spectrum and discrete values.

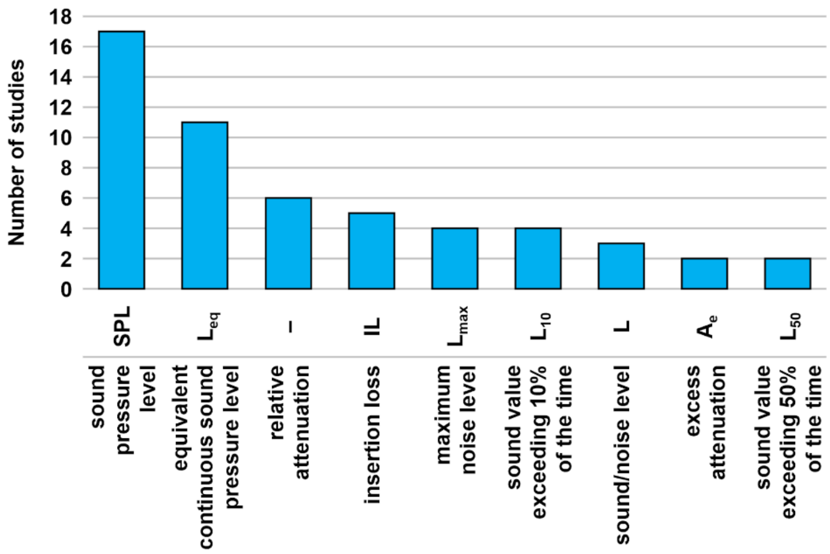


*Figure 6. Frequency of noise parameters used more than once*

As a final point of comparison, the following results show the maximum attenuation values given for each study, as noted in *Appendix Tables 6 and 7*. From a statistical perspective (based on the requirement of having at least two different maximum attenuation values to calculate the minimum, maximum, and range), the authors provided at least two different maximum attenuation values for four parameters (*Figure 7*), which in descending order according to interval range and data number, were $L_{eq}$ (9 data), SPL (8 data), IL (3 data), and L (3 data). Based on the sound energy doubling per 3 dB derived from the basic acoustic equations and interval range, a full order of magnitude difference was detectable, even for the L noise parameter, which showed the smallest standard deviation. For the $L_{eq}$, the same difference exceeded a factor of twelve. Considering these findings, it can therefore be stated that, alongside the numerous described modifying conditions, the differences resulting from the measurement procedures have a significant impact, which calls into question the possibility of comparing the obtained results.

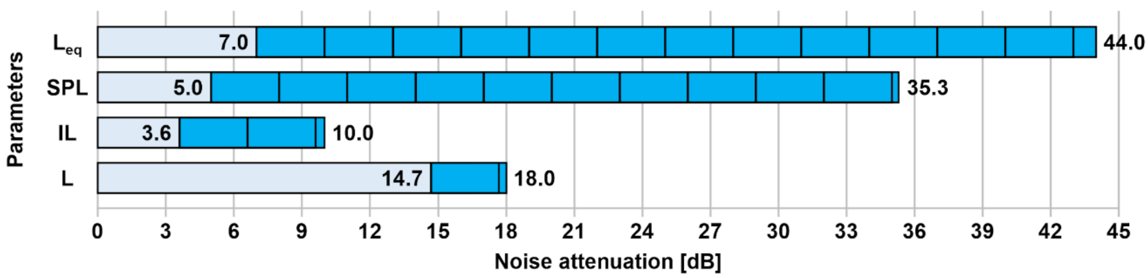


*Figure 7. Range of noise attenuations with markings of energetic orders of magnitude*

## 4 CONCLUSIONS

The 32 studies that the present paper analysed and included in the comparison have demonstrated that the selection of vegetation required to achieve effective noise attenuation is a complex task, as is the measurement of such attenuation. In addition to the diversity of noise sources and the significant differences observed in measurement configurations, the type of vegetation may substantially influence the actual attenuation achieved.

For example, Huisman and Attenborough (1991) reported that a maximum attenuation of 13.2 dB (SPL) could be achieved over a distance of 100 m in a coniferous forest, while Pal et al. (2000) demonstrated that a 20 dB reduction was achievable over nearly half that distance (60 m) in subtropical monsoon forests with dense understory vegetation. In contrast, properly designed hedges with adequate density can provide 3–14 dB attenuation (IL and L) over a much shorter distance of approximately 6 m (Van Rentenghem et al. 2014; Oh et al. 2009). Between these two categories, Ow and Ghosh (2017) measured an $L_{eq}$ reduction of 11 dB within 30 m for woody and shrubby vegetation belts, while, depending on the measurement methodology, Tyagi et al. (2006) reported reductions that exceeded twice this value, reaching up to 24 dB (SPL) within 20 m.

Facilitating the harmonisation of future research necessitates standardising the measurement point selection process and introducing fundamental parameters for characterising vegetation belts. Together with the application of relevant international standards, this could substantially reduce inconsistencies among studies and facilitate the quantitative determination of the physical parameters required for noise propagation modelling, thereby also supporting evidence-based urban planning.

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## APPENDIX

*Table 1. General data of the selected studies*

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Eyring 1946** | **Aylor 1972b** | **Cook – Haverbeke 1974** | **Cook – Haverbeke 1977** | **Kragh 1979** | **Price et al. 1988** | **Kim et al. 1989** | **Huisman – Attenborough 1991** | **Watts et al. 1999** | **Pal et al. 2000** | **Fang and Ling 2003** | **Fang 2004** | **Fang and Ling 2005** | **Tyagi et al. 2006** | **Pathak et al. 2008** | **Mohamed – Krisantia 2009** |
| **Continent*** | N. A. | N. A. | N. A. | N. A. | E. | E. | A. | E. | E. | A. | A. | A. | A. | A. | A. | A. |
| **Country**** | PA | US | US | US | DK | UK | KR | NL | UK | IN | TW | TW | TW | IN | IN | MY |
| **Climatic zone***** | T. R. | H. C. | C. | T. C. | T. C. | T. C. | H. S. | O. T. | O.T. | T. S. S. M. | H. S. | H. S. | H. S. | S. M. | S. M. | T. R. |
| **Type of objects****** | J. | T. R. S. R. A. P. | M. T. | T. R. S. R. | F. B. S. F. | F. B. | H. T. S. | P. F. | F. B. S. B. W. S. | F. B. | P.S. | H. | F. B. | W. S. | S. R. | H. |
| **Number of described species** | 3 | 10 | 7 | 8 | 8 | 3 | 2 | – | 4 | 16 | 20 | 5 | 6 | 16 | 4 | 6 |
| **Number of deciduous species** | – | 8 | 5 | 1 | 7 | – | – | – | 2 | 5 | 10 | 1 | 1 | 8 | – | – |
| **Number of evergreen species** | 3 | 2 | 2 | 7 | 1 | 3 | 2 | – | 2 | 11 | 10 | 4 | 5 | 8 | 4 | 6 |

| | 17. | 18. | 19. | 20. | 21. | 22. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Oh et al. 2009** | **Fan et al. 2010** | **Horoshenkov et al. 2013** | **Tyagi et al. 2013** | **Van Renterghem et al. 2014** | **Bashir et al. 2015** | **Karbalaei et al. 2015** | **Ow and Ghosh 2017** | **Biocca et al. 2019** | **de Oliveira et al. 2022** | **Liu et al. 2023** | **Webb et al. 2023** | **Lu et al. 2024** | **Zhang et al. 2024** | **Liu et al. 2024** | **Meng et al. 2025** |
| **Continent*** | A. | A. | E. | A. | E. | E. | A. | A. | E. | S. A. | A. | E. | A. | A. | A. | A. |
| **Country**** | KR | CN | UK | IN | DE FR UK | UK | IR | SG | IT | BR | CN | UK | CN | CN | CN | CN RU |
| **Climatic zone***** | H. S. | H. S. | – | S. M. | O. T. T. C. | O. T. | H. S. O. | T. R. | S. D. | O. S. | S. M. | – | H. S. | C. T. | H. S. | C. C. T. C. |
| **Type of objects****** | H. | H. | S. L. | N. S. | H. | A. P. | T. B. | W. S. | H. | T. B. | W. S. | S. H. | S. T. | W. S. | F. B. | T. B. S. B. |
| **Number of described species** | 9 | 6 | 4 | 46 | 7 | 2 | 12 | – | 2 | – | – | 2 | 7 | – | 5 | 6 |
| **Number of deciduous species** | – | – | 2 | 25 | 3 | – | 8 | – | – | – | – | 1 | 4 | – | 2 | 1 |
| **Number of evergreen species** | 9 | 6 | 2 | 21 | 4 | – | 4 | – | 2 | – | – | 1 | 3 | – | 3 | 5 |

* **A.** – Asia, **E.** – Europe, **N. A.** – North America, **S. A.** – South America

** **BR** – Brazil, **CN** – China, **DE** – Germany, **DK** – Denmark, **FR** – France, **IN** – India, **IR** – Iran, **IT** – Italy, **KR** – South Korea, **MY** – Malaysia, **NL** – Netherlands, **PA** – Panama, **RU** – Russia, **SG** – Singapore, **TW** – Taiwan, **UK** – United Kingdom, **US** – United States

*** **C.** – continental, **C. C.** – cold continental, **C. T.** – cold temperate, **H. C.** – humid continental, **H. S.** – humid subtropical, **O.** – oceanic, **O. S.** – oceanic subtropical, **O. T.** – oceanic temperate, **S. D.** – subtropical mediterranean, **S. M.** – subtropical monsoon, **T. C.** – temperate continental, **T. R.** – tropical rainforest, **T. S.** – tropical savanna

**** **A. P.** – agricultural plantation, **F. B.** – forest belt, **H.** – hedge, **J.** – jungle, **M. T.** – multi-row trees, **N. S.** – natural shrub belt, **P. F.** – pine forest, **P. S.** – planted homogeneous vegetation strip, **S. B.** – shrub belt, **S. R.** – shrub row, **S. F.** – shrubby forest belt, **S. H.** – single hedge sample, **S. L.** – single low plant, **S. T.** – single tree, **T. S.** – thuja species, **T. B.** – tree belt, **T. R.** – tree row, **W. S.** – woody and shrubby vegetation strip

*Table 2. Data of the location types and measurement layout*

| | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | | **Eyring 1946** | **Aylor 1972b** | **Cook – Haverbeke 1974** | **Cook – Haverbeke 1977** | **Kragh 1979** | **Price et al. 1988** | **Kim et al. 1989** | **Huisman – Attenborough 1991** | **Watts et al. 1999** | **Pal et al. 2000** | **Fang and Ling 2003** | **Fang 2004** | **Fang and Ling 2005** | **Tyagi et al. 2006** | **Pathak et al. 2008** | **Mohamed and Krisantia 2009** |
| **Number of locations** | | 5 | 5 | 4 | 10 | 2 | 3 | 3 | 1 | 3 | 8 | 35 | 5 | 6 | 11 | 11 | 2 |
| **Location** | **Residential** | – | – | – | 10 | – | – | – | – | 3 | – | √ | – | 6 | 11 | 11 | 2 |
| | **Industrial** | – | – | – | – | – | – | – | – | – | 8 | – | – | – | – | – | – |
| | **Agricultural** | – | 3 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | **Natural** | 5 | 2 | 3 | – | 2 | 3 | 2 | 1 | – | – | √ | – | – | – | – | – |
| | **Laboratory** | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – |
| **Noise source: point (P), line (L)** | | P | P | P, L | P | L | P | P | P | L | P | P | P | P | L | P | P |
| **Noise source: real (R), artificial (A)** | | A | A | R, A | R | R | A | A | A | R | A | A | A | A | R | A | A |
| **Number of sources** | | 2 | 1 | 1 | 1 | – | 1 | 1 | 1 | – | 1 | 1 | 1 | 1 | – | 1 | 1 |
| **Distances [m]** | $L_1$ | – | 3 | – | – | 7.5 | 2 | – | 10 | – | 10 | 1 | – | – | 5 | 5 | – |
| | $L_2$ | – | 0 | 15.2 | 13.1 | 0 | – | 3 | 0 | 8 | 10 | 1 | 2 | 2 | 5 | 5 | 1 |
| | $L_{belt,\,max}$ | – | – | 30.5 | 13.8 | 55 | – | 1 | – | – | 50 | 300 | 3 | 3 | 15 | 3 | – |
| | $L_3$ | – | – | 0 | 13.1 | – | – | 0 | – | 10 | 0 | – | 2 | 2 | 0 | 5 | 1 |
| | $L_4$ | – | – | 91.5 | – | 5.5 | – | 1 | – | – | – | – | 17 | 57 | – | 20 | 3 |
| | $L_{min}$ | ≈30 | 65 | 45.7 | 40 | 55 | 12 | 4 | 10 | 18 | 60 | 16 | 7 | 7 | 20 | 13 | – |
| | $L_{max}$ | ≈300 | – | 137.2 | – | 68 | 96 | 5 | 100 | – | – | – | 62 | 62 | – | 28 | – |
| **Number of microphones** | | 4 | 2 | 1 | 1 | 4 | 3 | – | – | – | 2 | – | – | 2 | 2 | 2 | 1 |
| **Inner microphone** | | √ | √ | – | – | √ | √ | – | √ | – | √ | √ | – | – | – | – | – |
| **Heights [m]** | $H_S$ | ≈1.5 | 1,5 | 1.5 | ≈0.2 | 0 | 1.2 | 1 | 1 | ≈0.5 | 0.25 | 1.2 | 1.5 | 1.5 | ≈0.5 | 1.2 | 1.2 |
| | $H_{R1}$ | – | 1.5 | – | 1.5 | 1.1 | 1.2 | – | 1 | – | 1.5 | 1.2 | – | – | 1.5 | 1.2 | – |
| | $H_{R2}$ | ≈1.5 | 1.5 | 1.7 | – | 1.5 | 1.2 | 1 | 1 | – | 1.5 | 1.2 | 1.5 | 1.5 | 1.5 | 1.2 | 1.2 |
| | $H_{R3}$ | ≈1.5 | – | 1.7 | – | 1.5 | 1.2 | 1 | 1 | – | – | – | 1.5 | 1.5 | – | 1.2 | 1.2 |
| **Ground cover*** | | J. V. | H. L. C. | Gs. U. A. | G. N. | P. S. | N. C. | – | B. N. | P. R. G. | V. C. | – | – | – | P. R. S. W. | P. R. S. W. | P. R. S. W. |

* **B. N.** – soft ground thickly covered with branches and pine needles, **B. S.** – barren soil, **C. F.** – cultivated field, **C. S.** – clay-based soil, **E. S.** – exposed soil, **F. B.** – flower bed, **F. W.** – concrete floor covered with acoustic foam and natural wool, **G.** – grass, **G. A.** – grass-covered areas, **G. S.** – gravel surface, **Gd.** – grassed, **Gs.** – covered with grass species, **J. V.** – jungle-like undergrowth vegetation, **L.** – lawn, **L. C.** – leaf-covered ground, **H.** – 7-8 cm layer of humus, **N.** – natural, **N. C.** – needle-covered, **O. M.** – other soft materials, **P.** – paved, **P. R.** – public road, **P.S.** – peat soil covered with freshly cut grass, **S.** – soil, **S. S.** – substratum soil, **S. W.** – sidewalk, **U. A.** – uncovered agricultural land, **V. C.** – vegetation-covered, **V. H.** – covered with vegetation of varying heights

*Table 3. Data of the location types and measurement layout (continued)*

| | | 17. | 18. | 19. | 20. | 21. | 22. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | | Oh et al. 2009 | Fan et al. 2010 | Horoshenkov et al. 2013 | Tyagi et al. 2013 | Van Renterghem et al. 2014 | Bashir et al. 2015 | Karbalaei et al. 2015 | Ow – Ghosh 2017 | Biocca et al. 2019 | de Oliveira et al. 2022 | Liu et al. 2023 | Webb et al. 2023 | Lu et al. 2024 | Zhang et al. 2024 | Liu et al. 2024 | Meng et al. 2025 |
| **Number of locations** | | 9 | 6 | 1 | 11 | 3 | 1 | 9 | 3 | 2 | 3 | 217 | 1 | 6 | 27 | 2 | 36 |
| **Location** | **Residential** | 9 | – | – | 11 | 3 | – | – | 1 | 2 | 3 | 217 | – | 6 | 27 | 2 | 36 |
| | **Industrial** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| | **Agricultural** | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – |
| | **Natural** | – | 6 | – | – | – | – | 9 | 2 | – | – | – | – | – | – | – | – |
| | **Laboratory** | – | – | 1 | – | – | – | – | – | – | – | – | 1 | – | – | – | – |
| **Noise source: point (P), line (L)** | | P | P | P | L | P, L | P | P | L | P | L | L | P | P | L | L | L |
| **Noise source: real (R), artificial (A)** | | R | A | A | R | R, A | A | A | R | A | R | R | A | A | R | R | R |
| **Number of sources** | | 1 | 1 | 1 | – | 1 | 1 | 1 | – | 1 | – | – | 1 | 1 | – | – | – |
| **Distances [m]** | **$L_1$** | ≈1.5 | 5 | – | 5 | – | 1 | – | – | – | ≈1.5 | – | – | 5.66 | 10 | ≈14.5 | 8 |
| | **$L_2$** | ≈1.8 | 5 | – | 5 | 2.4 | – | 1 | – | 5 | ≈4.5 | 0 | – | 5.66 | – | ≈14.5 | 12 |
| | **$L_{belt, max}$** | 2.5 | 3.2 | – | 15 | 1.8 | – | 100 | – | 1.9 | – | – | 0.59 | 6.53 | – | 70 | 15 |
| | **$L_3$** | 1 | 0 | – | 0 | 0.7 | – | – | – | 1 | 0 | 0 | 0.37 | 0 | – | 0 | 0 |
| | **$L_4$** | 2 | – | – | – | – | – | – | – | 5 | – | – | – | – | – | – | – |
| | **$L_{min}$** | ≈5.3 | 8.2 | – | 20 | 4.9 | 2.5 | 26 | 27.5 | 7.9 | 60 | – | 4.1 | 12.19 | ≈13 | ≈74.5 | 27 |
| | **$L_{max}$** | ≈6.3 | – | – | – | – | 10 | 101 | – | 12.9 | – | 44.72 | – | – | ≈18 | – | – |
| **Number of microphones** | | 3 | 2 | 2 | 2 | 2 | 4 | 1 | – | 1 | 2 | 8 | 4 | 2×2 | 2 | 7 | – |
| **Inner microphone** | | – | – | – | – | – | ✓ | ✓ | – | – | ✓ | ✓ | – | – | – | ✓ | ✓ |
| **Heights [m]** | **$H_S$** | ≈0.5 | 1.5 | – | ≈0.5 | ≈0.5 | 0.3 | – | ≈0.5 | 0.8 | ≈0.5 | ≈0.5 | 1.16 | 1.5 | ≈0,5 | ≈0.5 | ≈0.5 |
| | **$H_{R1}$** | 1 | 1.5 | – | 1.5 | ≈1.5 | 0.3 | – | – | – | ≈1.5 | 1.5 | 1.16 | 7.36 | 1,5 | 1.2 | 1.5 |
| | **$H_{R2}$** | 1 | 1.5 | – | 1.5 | ≈1.5 | 0.3 | 1.2 | 1.5 | 0.8 | ≈1.5 | 1.5 | 1.16 | 7.36 | 1,5 | 1.2 | 1.5 |
| | **$H_{R3}$** | 1 | – | – | – | – | 0.3 | 1.2 | – | 0.8 | – | – | – | – | – | – | – |
| **Ground cover*** | | P. R. S. W. | S. L. O. M. | S. S. C. S. | P. R. S. W. | P. R. S. W. | C. F. | – | G. | P. R. G. S. | G. E. S. | P. R. S. W. G. A. | F. W. | V. H. | S. W. F. B. Gd. P. | P. R. L. C. | P. R. S. W. Gd. |

* **B. N.** – soft ground thickly covered with branches and pine needles, **B. S.** – barren soil, **C. F.** – cultivated field, **C. S.** – clay-based soil, **E. S.** – exposed soil, **F. B.** – flower bed, **F. W.** – concrete floor covered with acoustic foam and natural wool, **G.** – grass, **G. A.** – grass-covered areas, **G. S.** – gravel surface, **Gd.** – grassed, **Gs.** – covered with grass species, **J. V.** – jungle-like undergrowth vegetation, **L.** – lawn, **L. C.** – leaf-covered ground, **H.** – 7-8 cm layer of humus, **N.** – natural, **N. C.** – needle-covered, **O. M.** – other soft materials, **P.** – paved, **P. R.** – public road, **P.S.** – peat soil covered with freshly cut grass, **S.** – soil, **S. S.** – substratum soil, **S. W.** – sidewalk, **U. A.** – uncovered agricultural land, **V. C.** – vegetation-covered, **V. H.** – covered with vegetation of varying heights

*Table 4/1. Parameters used for describing the vegetation belts*

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Eyring 1946** | **Aylor 1972b** | **Cook – Haverbeke, 1974** | **Cook – Haverbeke 1977** | **Kragh 1979** | **Price et al. 1988** | **Kim et al. 1989** | **Huisman – Attenborough 1991** | **Watts et al. 1999** | **Pal et al. 2000** | **Fang – Ling 2003** | **Fang 2004** | **Fang – Ling 2005** | **Tyagi et al. 2006** | **Pathak et al. 2008** | **Mohamed – Krisantia 2009** |
| **Parameter categories and units** | 2 | 8 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 10 | 7 | 4 | 5 | 2 | 3 | 5 |
| **aggregation size of the soil [μm]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average plant density [pcs/ha], density [pcs/m$^2$], plant/tree/trunk density [pcs/m$^2$]** | – | ✓ | – | – | – | ✓ | – | ✓ | – | ✓ | – | – | – | – | – | ✓ |
| **average canopy cover [m]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **average leaf inclination [°]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average mass density of leaves [kg/m$^3$]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average mass of leaves [g], fresh leaf weight [g], leaf weight [g]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average spacing between consecutive plants) [m], average interval [m], horizontal distance [m], planting distance [m], tree spacing [m]** | – | – | ✓ | ✓ | – | – | – | – | – | ✓ | ✓ | – | ✓ | – | – | ✓ |
| **basal area [m$^2$/ha]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **branchless lower trunk [m], branch height [m], minimum height of branches [m]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **canopy branch cover [m]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **canopy leaf density [pcs/m$^2$]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **characteristic leaf dimension [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **crown diameter [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **crown height [m]** | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – |
| **crown volume [m$^3$]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **crown width [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **degree of vegetation screening [%]** | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – |
| **depth, thickness, width [m]** | – | – | ✓ | ✓ | ✓ | – | ✓ | – | – | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – |
| **diameter at breast height [m], effective scattering diameter [m], trunk diameter [cm]** | – | ✓ | – | – | – | – | – | ✓ | – | ✓ | ✓ | – | – | – | – | – |
| **dominant angle of leaf orientation [°]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **effective tortuosity [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **equivalent acoustical thickness [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **flow/effective flow resistivity [Pa·s/m$^2$]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **ground bulk density [g/cm$^3$], soil density [kg/m$^3$]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **ground cover [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **height [m]** | – | ✓ | ✓ | ✓ | – | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – | ✓ | ✓ |
| **impervious area [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **layer thickness of needles [cm]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf area [cm$^2$], determination of total leaf area by visual calculation [m$^2$]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |

*Table 4/2. Parameters used for describing the vegetation belts (continued)*

| | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Eyring 1946** | **Aylor 1972b** | **Cook – Haverbeke 1974** | **Cook – Haverbeke 1977** | **Kragh 1979** | **Price et al. 1988** | **Kim et al. 1989** | **Huisman – Attenborough 1991** | **Watts et al. 1999** | **Pal et al. 2000** | **Fang – Ling 2003** | **Fang 2004** | **Fang – Ling 2005** | **Tyagi et al. 2006** | **Pathak et al. 2008** | **Mohamed – Krisantia 2009** |
| **Parameter categories and units** | 2 | 8 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 10 | 7 | 4 | 5 | 2 | 3 | 5 |
| **leaf area density [m²/m³], foliage area per unit volume [m²/m³]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf area index of crown [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf area index of low-growing plants [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf shape by length/width [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf tacility [g/cm²]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf/average leaf thickness [mm]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **length [m]** | – | – | ✓ | – | ✓ | – | ✓ | – | ✓ | – | ✓ | ✓ | ✓ | – | ✓ | ✓ |
| **light intensity [lux], horizontal/vertical light penetration [%]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **lines of trees [1], number of layers [1]** | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | ✓ |
| **living vegetation volume of low-growing plants [m³]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **mean leaf width [cm]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **mean/measured leaf size [mm]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **moisture level of the soil [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **number of plants/trees [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **one sees a distance of approximately [foot], visibility [m, %]** | ✓ | – | – | – | – | – | – | – | – | – | ✓ | ✓ | ✓ | ✓ | – | – |
| **optical porosity [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **percentage of vegetation cover [%]** | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – |
| **plant absorption coefficient [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **plant age [year]** | – | – | – | – | ✓ | ✓ | ✓ | – | – | – | – | – | – | – | – | – |
| **plant porosity [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **planting width [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **propagation path length through vegetation [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **ratio of species [%]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **rows of plants/trees [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **soil porosity [%, 1]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **terrain loss coefficient [dB/foot]** | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **terrain slope [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **vertical distance [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Obstacles in the belt (raised garden bed, wall, fence, etc.)** | – | – | ✓ | ✓ | – | – | – | – | – | – | – | – | – | – | – | – |

*Table 5/1. Parameters used for describing the vegetation belts (continued)*

| | 17. | 18. | 19. | 20. | 21. | 22. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Oh et al. 2009** | **Fan et al. 2010** | **Horoshenkov et al. 2013** | **Tyagi et al. 2013** | **Van Renterghem et al. 2014** | **Bashir et al. 2015** | **Karbalaei et al. 2015** | **Ow – Ghosh 2017** | **Biocca et al. 2019** | **de Oliveira et al. 2022** | **Liu et al. 2023** | **Webb et al. 2023** | **Lu et al. 2024** | **Zhang et al. 2024** | **Liu et al. 2024** | **Meng et al. 2025** |
| **Parameter categories and units** | 5 | 9 | 12 | 3 | 6 | 5 | 1 | 1 | 5 | 11 | 0 | 6 | 10 | 0 | 11 | 7 |
| **aggregation size of the soil [μm]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average plant density [pcs/ha], density [pcs/m²], plant/tree/trunk density [pcs/m²]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **average canopy cover [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **average leaf inclination [°]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – |
| **average mass density of leaves [kg/m³]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| **average mass of leaves [g], fresh leaf weight [g], leaf weight [g]** | – | ✓ | ✓ | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| **average spacing between consecutive plants) [m], average interval [m], horizontal distance [m], planting distance [m], tree spacing [m]** | – | ✓ | – | – | – | – | – | – | – | ✓ | – | – | – | – | ✓ | ✓ |
| **basal area [m²/ha]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **branchless lower trunk [m], branch height [m], minimum height of branches [m]** | – | ✓ | – | – | – | – | – | – | – | ✓ | – | – | ✓ | – | ✓ | ✓ |
| **canopy branch cover [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **canopy leaf density [pcs/m²]** | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – |
| **characteristic leaf dimension [m]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **crown diameter [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | ✓ |
| **crown height [m]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | ✓ | – | – | – |
| **crown volume [m³]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | ✓ | – |
| **crown width [m]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – |
| **degree of vegetation screening [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **depth, thickness, width [m]** | ✓ | ✓ | – | ✓ | ✓ | – | – | – | ✓ | – | – | ✓ | – | – | ✓ | – |
| **diameter at breast height [m], effective scattering diameter [m], trunk diameter [cm]** | – | – | – | – | – | – | – | ✓ | – | ✓ | – | – | ✓ | – | ✓ | ✓ |
| **dominant angle of leaf orientation [°]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **effective tortuosity [1]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **equivalent acoustical thickness [m]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **flow/effective flow resistivity [Pa·s/m²]** | – | – | ✓ | – | – | ✓ | – | – | – | – | – | – | – | – | – | – |
| **ground bulk density [g/cm³], soil density [kg/m³]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **ground cover [%]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **height [m]** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | – | – | ✓ | ✓ | – | ✓ | ✓ | – | ✓ | ✓ |
| **impervious area [%]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **layer thickness of needles [cm]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf area [cm²], determination of total leaf area by visual calculation [m²]** | – | ✓ | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |

*Table 5/2. Parameters used for describing the vegetation belts (continued)*

| | 17. | 18. | 19. | 20. | 21. | 22. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | **Oh et al. 2009** | **Fan et al. 2010** | **Horoshenkov et al. 2013** | **Tyagi et al. 2013** | **Van Renterghem et al. 2014** | **Bashir et al. 2015** | **Karbalaei et al. 2015** | **Ow – Ghosh 2017** | **Biocca et al. 2019** | **de Oliveira et al. 2022** | **Liu et al. 2023** | **Webb et al. 2023** | **Lu et al. 2024** | **Zhang et al. 2024** | **Liu et al. 2024** | **Meng et al. 2025** |
| **Parameter categories and units** | 5 | 9 | 12 | 3 | 6 | 5 | 1 | 1 | 5 | 11 | 0 | 6 | 10 | 0 | 11 | 7 |
| **leaf area density [m²/m³], foliage area per unit volume [m²/m³]** | – | – | – | – | ✓ | ✓ | – | – | – | – | – | – | – | – | – | – |
| **leaf area index of crown [1]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – |
| **leaf area index of low-growing plants [1]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – |
| **leaf shape by length/width [1]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf tacility [g/cm²]** | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **leaf/average leaf thickness [mm]** | ✓ | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **length [m]** | ✓ | ✓ | – | – | ✓ | – | ✓ | – | ✓ | – | – | ✓ | – | – | – | – |
| **light intensity [lux], horizontal/vertical light penetration [%]** | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **lines of trees [1], number of layers [1]** | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | ✓ | – |
| **living vegetation volume of low-growing plants [m³]** | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – |
| **mean leaf width [cm]** | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – |
| **mean/measured leaf size [mm]** | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – |
| **moisture level of the soil [%]** | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – |
| **number of plants/trees [1]** | – | – | – | – | – | – | – | – | – | ✓ | – | ✓ | – | – | – | – |
| **one sees a distance of approximately [foot], visibility [m, %]** | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – |
| **optical porosity [%]** | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – |
| **percentage of vegetation cover [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **plant absorption coefficient [1]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **plant age [year]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **plant porosity [1]** | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **planting width [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ |
| **propagation path length through vegetation [m]** | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – |
| **ratio of species [%]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **rows of plants/trees [1]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| **soil porosity [%, 1]** | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – |
| **terrain loss coefficient [dB/foot]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **terrain slope [%]** | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **vertical distance [m]** | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ |
| **Obstacles in the belt (raised garden bed, wall, fence, etc.)** | ✓ | – | – | – | ✓ | – | – | – | – | – | – | – | – | ✓ | – | – |

*Table 6. Parameters used for noise measurement and attenuation calculation*

| | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Author(s) and year** | | Eyring 1946 | Aylor 1972b | Cook – Haverbeke 1974 | Cook – Haverbeke 1977 | Kragh 1979 | Price et al. 1988 | Kim et al. 1989 | Huisman – Attenborough, 1991 | Watts et al. 1999 | Pal et al. 2000 | Fang – Ling 2003 | Fang 2004 | Fang – Ling 2005 | Tyagi et al. 2006 | Pathak et al. 2008 | Mohamed – Krisantia 2009 |
| **Parameter and symbol** | | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 1 | 4 | 2 | 3 | 2 | 2 | 2 | 7 | 1 |
| absorption coefficient | α | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| background noise | B. N. | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – |
| corrected level difference attenuation spectrum(3) | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – |
| equivalent continuous sound pressure level | $L_{eq}$ | – | – | – | – | ✓ | – | – | – | ✓ | ✓ | – | – | – | – | ✓ | – |
| equivalent noise level | $dB_{eq}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| excess attenuation | $A_e$ | – | ✓ | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – |
| fast A-weighted maximum noise level | $L_{AF,max}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| insertion loss | IL | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| intensity level(1) | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| level difference between microphones | LD | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| loudness level | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – |
| masking level(2) | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| maximum noise level | $L_{max}$ | – | – | – | – | ✓ | – | – | – | ✓ | ✓ | – | – | – | – | – | – |
| noise average relative attenuation | $\Delta L_{Aep}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise climate | NC | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| noise decrement | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise difference | $R_{noise}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise pollution level | $L_{np}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| noise/sound level | L | – | – | ✓ | ✓ | – | – | – | – | – | – | – | – | – | – | – | – |
| relative attenuation(4) | – | – | – | ✓ | ✓ | – | – | – | – | – | – | ✓ | ✓ | ✓ | ✓ | – | – |
| sound pressure level | SPL | – | – | ✓ | – | – | – | ✓ | ✓ | – | – | ✓ | ✓ | ✓ | ✓ | – | ✓ |
| sound value exceeding 1% of the time | $L_1$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| sound value exceeding 10% of the time | $L_{10}$ | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | ✓ | – |
| sound value exceeding 50% of the time | $L_{50}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| sound value exceeding 90% of the time | $L_{90}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| traffic noise index | TNI | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| transfer function for the sound wave | H | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Filter type** | | – | – | A | A | A | – | – | – | A | A | A | A | A | A | – | – |
| **Measurement standard** | | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Interval – full spectrum (16-16,000 Hz)** | | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **Interval – partial spectrum** | | ✓ | ✓ | ✓ | – | – | ✓ | – | ✓ | ✓ | – | ✓ | – | – | ✓ | ✓ | – |
| **Discrete frequency values** | | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – |
| **Octave band measurement** | | – | – | ✓ | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| **Third-octave band measurement** | | – | – | – | – | – | – | – | ✓ | ✓ | – | ✓ | – | – | ✓ | ✓ | – |
| **Parameter used to determine noise attenuation** | | (1) (2) | $A_e$ | L | L | $L_{eq}$ | (3) | SPL | SPL | $L_{eq}$ | $L_{eq}$ $L_{max}$ | (4) | SPL | SPL | SPL | $L_{eq}$ | SPL |
| **Maximum attenuation [dB]** | | 0.02* | 27.0 | 15.0 | 18.0 | 9.0 | 20.0 | 35.3 | 13.2 | 7.0 | 21.1 | 10** | 5.0 | 5.0 | 24.0 | 26.0 | 7.9 |

* in dB/foot; ** in dB(A)/20 m

*Table 7. Parameters used for noise measurement and attenuation calculation (continued)*

| | | 17. | 18. | 19. | 20. | 21. | 22. | 23. | 24. | 25. | 26. | 27. | 28. | 29. | 30. | 31. | 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Author(s) and year | | Oh et al. 2009 | Fan et al. 2010 | Horoshenkov et al. 2013 | Tyagi et al. 2013 | Van Renterghem et al. 2014 | Bashir et al. 2015 | Karbalaei et al. 2015 | Ow – Ghosh 2017 | Biocca et al. 2019 | de Oliveira et al. 2022 | Liu et al. 2023 | Webb et al. 2023 | Lu et al. 2024 | Zhang et al. 2024 | Liu et al. 2024 | Meng et al. 2025 |
| **Parameter and symbol** | | 2 | 2 | 2 | 4 | 3 | 3 | 2 | 4 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 2 |
| absorption coefficient | α | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| background noise | B. N. | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| corrected level difference attenuation spectrum | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| equivalent continuous sound pressure level | $L_{eq}$ | – | ✓ | – | – | – | – | ✓ | ✓ | ✓ | – | ✓ | – | – | – | ✓ | ✓ |
| equivalent noise level | $dB_{eq}$ | – | – | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – |
| excess attenuation | $A_e$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| fast A-weighted maximum noise level | $L_{AF,max}$ | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – |
| insertion loss | IL | – | – | – | – | ✓ | ✓ | – | ✓ | – | – | – | ✓ | ✓ | – | – | – |
| intensity level | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| level difference between microphones | LD | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – |
| loudness level | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| masking level | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| maximum noise level | $L_{max}$ | – | – | – | – | – | – | – | ✓ | – | – | – | – | – | – | – | – |
| noise average relative attenuation | $\Delta L_{Aep}$ | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise climate | NC | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise decrement | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise difference | $R_{noise}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – |
| noise pollution level | $L_{np}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| noise/sound level | L | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| relative attenuation | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| sound pressure level | SPL | – | – | – | ✓ | ✓ | ✓ | ✓ | – | ✓ | – | – | – | ✓ | ✓ | ✓ | ✓ |
| sound value exceeding 1% of the time | $L_1$ | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – |
| sound value exceeding 10% of the time | $L_{10}$ | – | – | – | ✓ | – | – | – | ✓ | – | – | – | – | – | – | – | – |
| sound value exceeding 50% of the time | $L_{50}$ | – | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – |
| sound value exceeding 90% of the time | $L_{90}$ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| traffic noise index | TNI | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| transfer function for the sound wave | H | – | – | ✓ | – | – | – | – | – | – | – | – | – | – | – | – | – |
| **Filter type** | | – | A | – | A | A | A | A | A | A | – | A | – | A | A | A | A |
| **Measurement standard*** ** | | – | – | (I) | (II) (III) | (III) | – | – | – | – | (IV) | – | – | (II) | – | (V) | (VI) |
| **Interval – full spectrum (16-16,000 Hz)** | | – | ✓ | – | – | – | – | – | – | ✓ | – | – | – | ✓ | ✓ | – | – |
| **Interval – partial spectrum** | | – | – | – | ✓ | ✓ | ✓ | – | – | – | – | – | ✓ | – | – | ✓ | – |
| **Discrete frequency values** | | – | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | – | – |
| **Octave band measurement** | | – | – | – | – | – | – | – | – | – | – | – | – | ✓ | ✓ | ✓ | – |
| **Third-octave band measurement** | | – | ✓ | – | ✓ | ✓ | – | – | – | ✓ | – | – | – | – | – | – | – |
| **Parameter used to determine noise attenuation** | | L | $\Delta L_{Aep}$ | H | $L_{1,10}$ $L_{50}$ | IL | SPL | $L_{eq}$ | $L_{eq}$ | $L_{eq}$ | $dB_{eq}$ | $L_{eq}$ | IL | IL | SPL | $R_{noise}$ | $L_{eq}$ |
| **Maximum attenuation [dB]** | | 14.7 | ≈7.0 | 75* | 20.0 | 3.6 | 14.7 | 44.0 | 11.0 | 7.0 | 14.8 | 1** | ≈10 | 10.0 | 5.2 | 6.6 | 8.0 |

* in %; ** in dB/1%; *** **(I)** ISO 10534-2:1998, **(II)** ISO 9613-1:1993, **(III)** ISO 9613-2:1996, **(IV)** NBR 10151:2000, **(V)** GB 3096-2008, **(VI)** ISO 1996-2:2007