Department for Environment Food & Rural Affairs

Acoustic Benefits of Green Infrastructure in Urban Areas

A Rapid Evidence Review – Industry Roundtable Sessions

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A Commission by: Department for Environment, Foods & Rural Affairs

Anderson Acoustics

Tranquil City

acoustic sensor networks

maploom

12-14th March 2024

Agenda

- What is Green Infrastructure?
- What is the policy context?
- Why are the acoustic benefits of Green Infrastructure important?
- How can Green Infrastructure provide acoustic benefit in urban areas?
    1. Reduce environmental noise
    2. Improve the perception of noise
    3. Introduce positive sounds and enhance the soundscape
    4. Support biodiversity
- What are the gaps in the evidence that should be addressed?
- Are these findings easily accessible to non-acousticians?
- Roundtable Discussion

What is Green Infrastructure?

What is Green Infrastructure?

A network of multi-functional green & blue spaces and other natural features

That deliver environmental, economic, health and wellbeing benefits

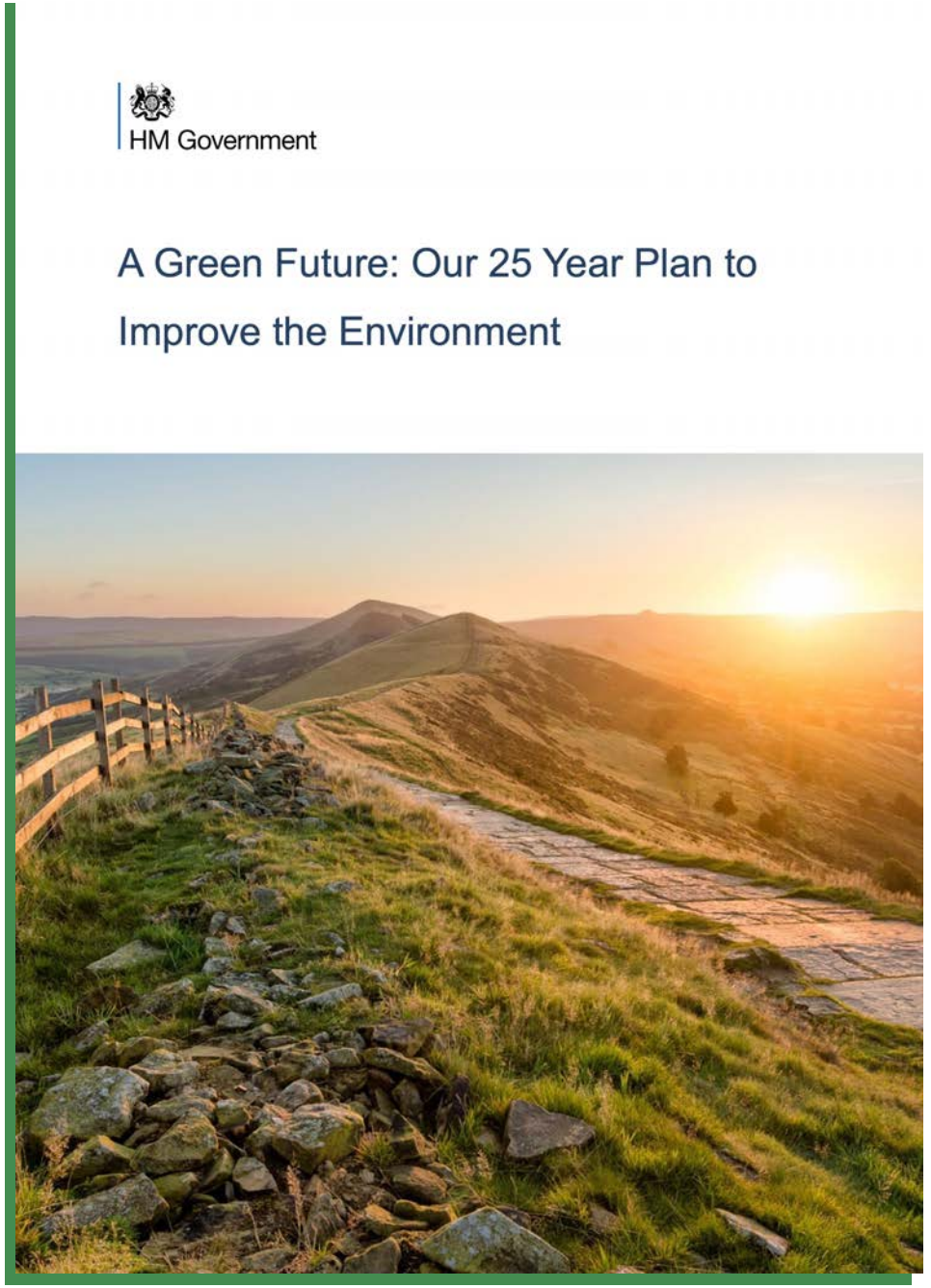
National Planning Policy Framework, 2023

What is the policy context?

What is the policy context?

25-Year Environment Plan says Green Infrastructure delivers benefits of:

"sequestering carbon, **absorbing noise**, cleansing pollutants, absorbing surface water and reducing high temperatures."



HM Government, 25-Year Environment Plan

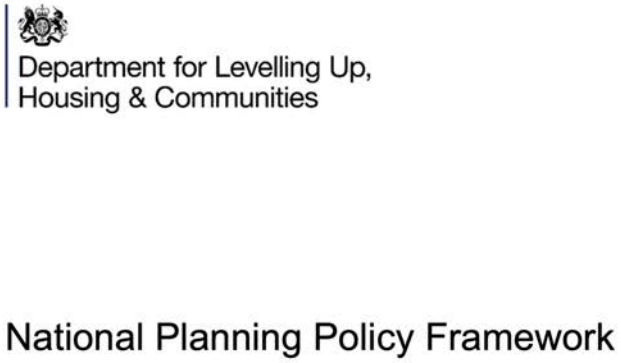
What is the policy context?

National Planning Policy Framework refers to the protection of tranquil areas

Environmental Noise (England) Regulations 2006 requires the mapping of quiet areas

Noise policies don’t specifically mention the use of Green Infrastructure

This contrasts with other disciplines such as Air Quality & Biodiversity



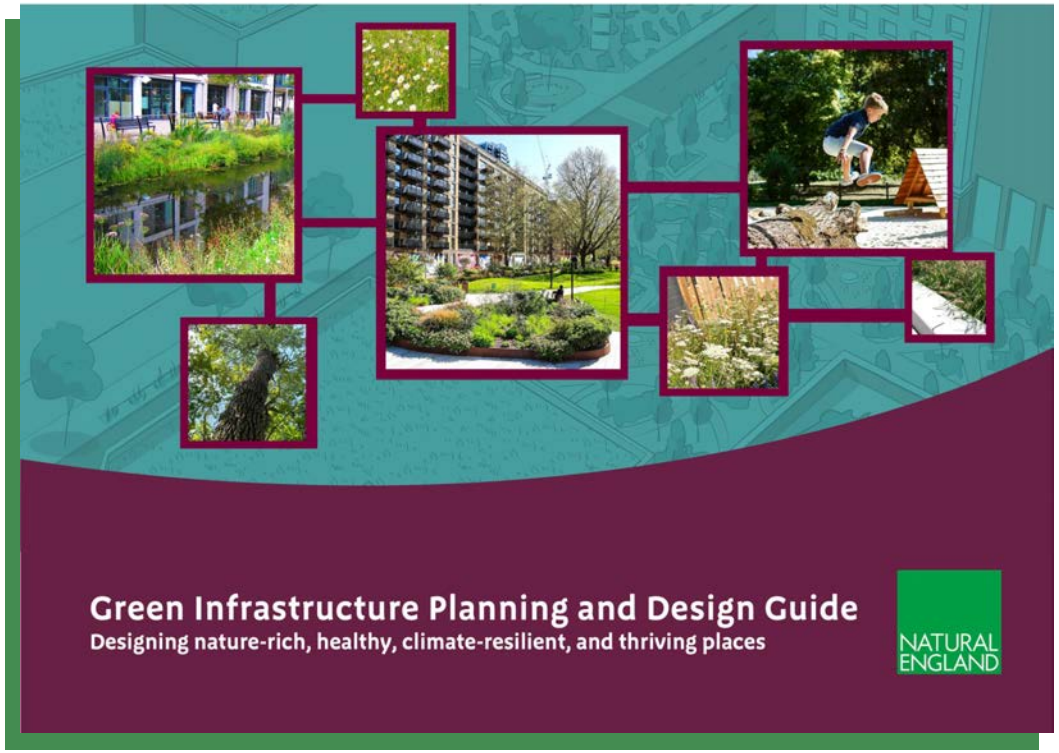
National Planning Policy Framework, 2023
Environmental Noise (England) Regulations 2006

What is the policy context?

Natural England Green Infrastructure Framework published in early 2023

Design & Planning guide includes chapter called **“Noise & Soundscapes”:**

- Noisy streets can act as a barrier to access of green spaces
- Noise affects the use and activities of greenspaces
- Noise negatively impacts perceptions of tranquillity
- Noise pollution impacts biodiversity
- Trees and shrubs can reduce noise propagation
- Tree leaves and branches can reduce higher-frequency noise
- Green roofs and walls can reduce the amount of noise entering a building by 50%
- Benefits mental health by providing natural sounds and noise respite
- Indirectly reduces transport noise, by increasing active travel



Natural England, Green Infrastructure Framework 2023

Why are the acoustic benefits of Green Infrastructure important?

The case for **Urban Green Infrastructure** is **rapidly growing**

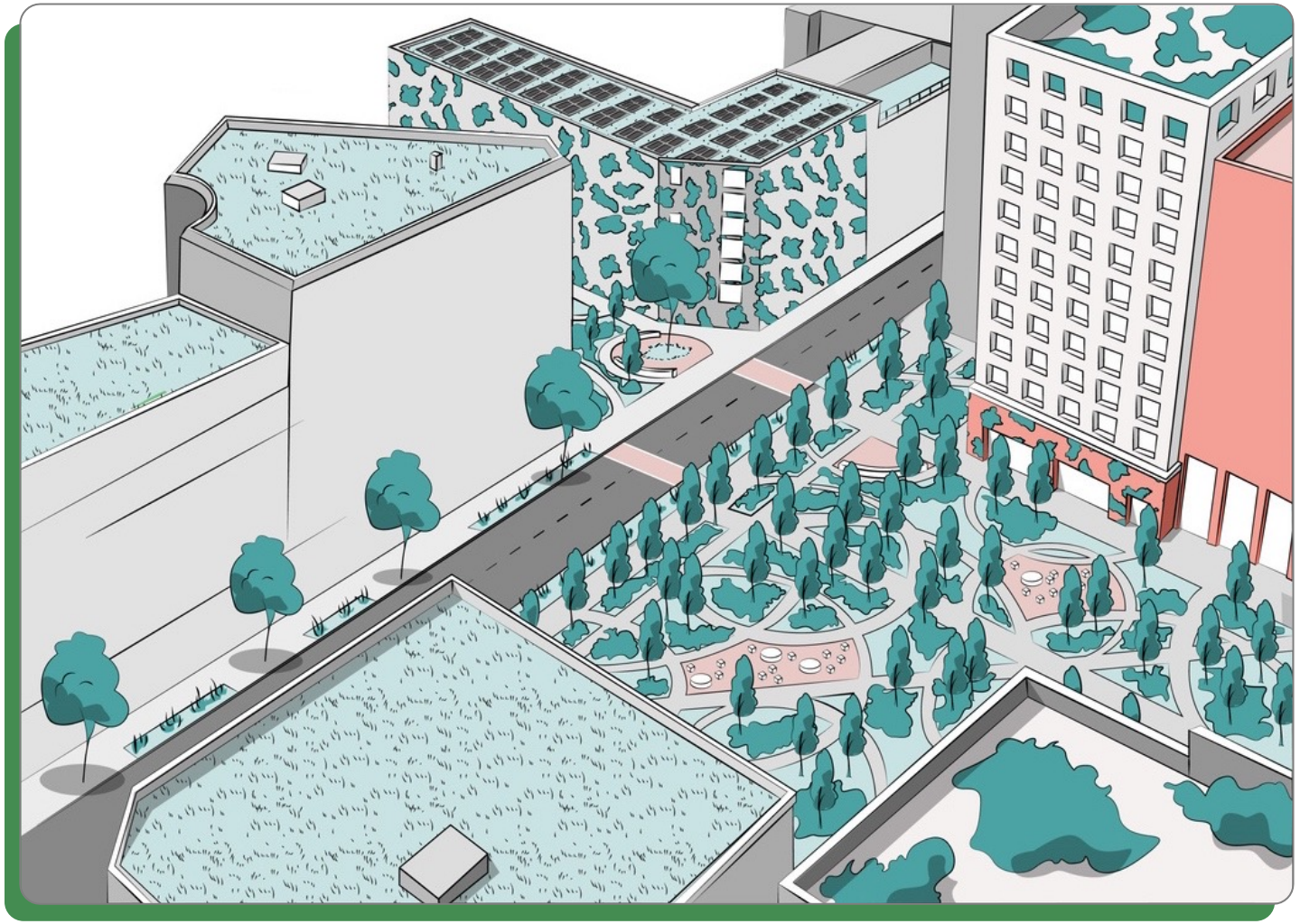


Image: Natural England Green Infrastructure Framework, Design & Planning guide, 2023.

University College London. Green Infrastructure for London: A Review of the evidence. 2018
Lovell, R., et al. A rapid scoping review of health and wellbeing evidence for the Green Infrastructure Standards. 2020.
Forest Research, Benefits of green infrastructure. 2010, Report to Defra and CLG: Farnham, UK.

So why not optimise Green Infrastructure in cities for to address noise issues?

Holistic solution

Benefits
health & wellbeing

Benefits
nature & climate

How can Green Infrastructure provide acoustic benefit in urban areas?

1

Reduce environmental noise

2

Improve the perception of noise

3

Introduce positive sounds & enhance the soundscape

4

Support biodiversity

1. Reduce environmental noise

Strategic planning of Green Infrastructure in cities is important

Well distributed plan of green spaces can reduce significance of transportation noise exposure in a city

Strategic planning can identify locations where forestry belts can have sufficient depths and densities

Case study: £6 million benefits in noise reduction was achieved with 3.9% increase in forestry cover

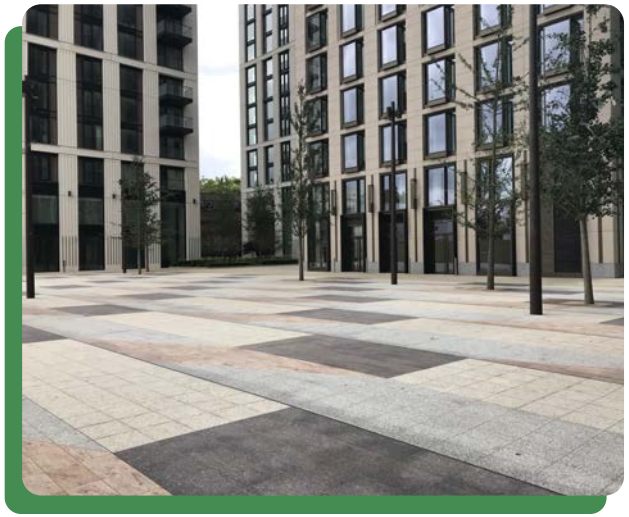
1

Reduce environmental noise

Margaritis, E. and J. Kang, Relationship between urban green spaces and other features of urban morphology with traffic noise distribution. 2016.
Margaritis, E. and J. Kang, Relationship between green space-related morphology and noise pollution. 2017.
Fletcher, D.H., et al., Location, Location, Location: Modelling of Noise Mitigation by Urban Woodland Shows the Benefit of Targeted Tree Planting in Cities. 2022.

Greener ground cover types provide more noise reduction

Landscape composition can reduce the propagation of road traffic noise



Hard landscaping

Mowed Grassland
+ 5 dBA

Wildflower Meadow
+ 8 dBA

Case study: Accounting for green landscape types in traditional acoustic modelling can increase road traffic noise reductions by ~5-6 dBA

1

Reduce environmental noise

HOSANNA, Novel solutions for quieter and greener cities. 2013..
Margaritis, E., et al., The influence of vegetation and surrounding traffic noise parameters on the sound environment of urban parks. 2018.

Forestry & tree belts can notably reduce noise but are highly dependent on composition and placement

15 m forest belt = ~6 dB reduction

Attenuation is mainly provided by forest floor and trunks

Performance depends on depth, tree spacing and trunk size

Lower-level shrubs can improve performance to equivalent of traditional noise barrier

1

Reduce environmental noise

Attenborough, K. and S. Taherzadeh. Sound propagation through forests and tree belts. 2016.
Chen, S., et al., Benefits of the ecosystem services provided by urban green infrastructures: Differences between perception and measurements. 2020.

Leaves can provide some reductions of road traffic noise, so performance will reduce in autumn and winter months

Larger leaf size = higher reduction

Without leaves, performance reduces by 0.6 – 2.3 dBA

Medium-to-low height forestry & tree belts, with high density are best candidates

Li, M. and J. Kang, Influence of Leaf Physical Properties on Single-Leaf Vibrational Response to Sound. 2020.
Islam, M.N., et al., Pollution attenuation by roadside greenbelt in and around urban areas. 2012.
Klingberg, J., et al., Influence of urban vegetation on air pollution and noise exposure – A case study in Gothenburg, Sweden. 2017.
Blanusa, T., et al., 'Urban hedges: A review of plant species and cultivars for ecosystem service delivery in north-west Europe'. 2019.

Vegetation only barriers can help reduce the significance of mid-high frequency noise

Shallow hedges and vegetation can provide 1-4 dBA reduction

Factors affecting performance include porosity, depth and leaf area

Reductions are poor below 1 kHz, with benefits at mid-high frequencies

Could be key to improve speech quality for more walkable streets

Van Renterghem, T., et al., Measured light vehicle noise reduction by hedges. 2014.
Islam, M.N., et al., Pollution attenuation by roadside greenbelt in and around urban areas. 2012.
Transport for London, Guide to the Healthy Streets Indicators - Delivering the Healthy Streets Approach. 2017.
Halim, H., et al., Effectiveness of Existing Noise Barriers: Comparison between Vegetation, Concrete Hollow Block, and Panel Concrete. 2015.
Kim, Y.H., et al., Effects of vegetation on soundscape of an urban religious precinct: Case study of Myeong-dong cathedral in Seoul. 2019.

1

Reduce environmental noise

Vertical Greenery Systems provide good absorption performance in otherwise reflective environments

Absorption coefficient of 0.4 and 1.0 (αw)

Typically outperform most external building materials for absorption

Performance due to vegetation density and soil depth, exposure area and moisture

Case study: Living walls in a building courtyard reduce reverberation time by 81% and speech build-up by 9 dBA

Azkorra, Z., et al., Evaluation of green walls as a passive acoustic insulation system for buildings. 2015..
Wong, N.H., et al., Acoustics evaluation of vertical greenery systems for building walls. 2010.
Horoshenkov, K., et al., Acoustic performance of vegetation and soil substratum in an urban context. 2014
SemperGreenwall. Acoustic test of SemperGreenwall Indoor gives positive result. 2021.
Lacasta, A.M., et al., Acoustic evaluation of modular greenery noise barriers. 2016.
Davis, M.J.M., et al., More than just a Green Facade: The sound absorption properties of a vertical garden with and without plants. 2017.

1

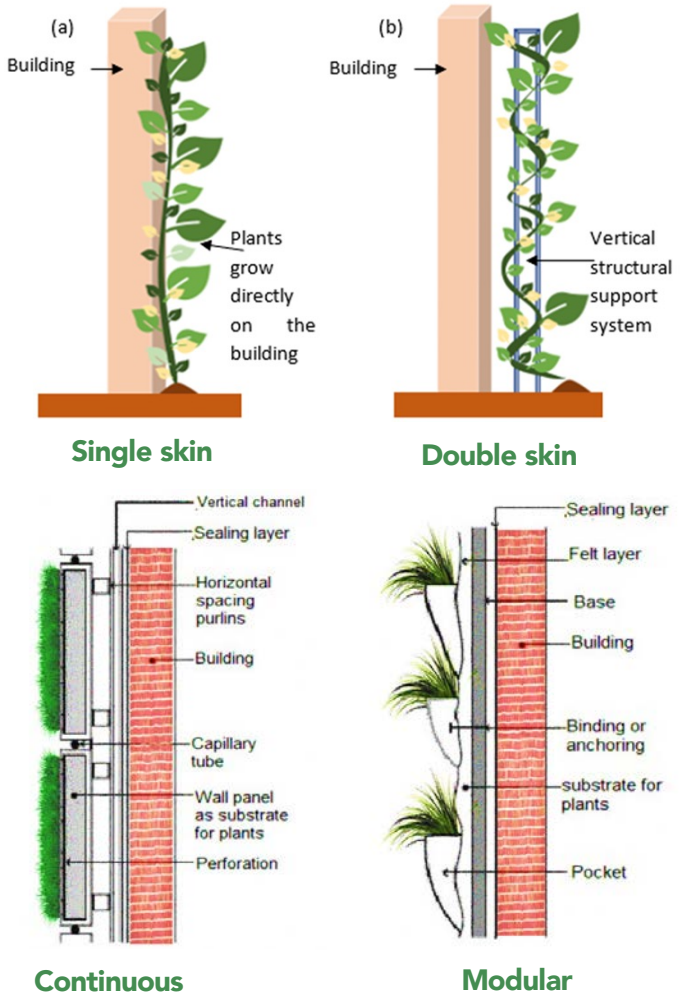
Reduce environmental noise

Vertical Greenery Systems can also provide airborne sound reduction but design optimisation is needed

The addition of vegetation to solid noise barriers can enhance reduction by 4 dBA

Vertical Greenery Systems in façade systems are expected to provide modest benefits (15 - 18 dB R_w)

Could be optimised to enhance the sound insulation performance of lightweight façade systems



Green façades

Living Walls

Illustration top: Al-Kayiem, H. H., et al. (2020)
Illustration bottom: Shushunova, N. et al. (2022)

Azkorra, Z., et al., Evaluation of green walls as a passive acoustic insulation system for buildings. 2015.
Wong, N.H., et al., Acoustics evaluation of vertical greenery systems for building walls. 2010.
Lacasta, A.M., et al., Acoustic evaluation of modular greenery noise barriers. 2016.
Pérez, G., et al., Acoustic insulation capacity of Vertical Greenery Systems for buildings. 2016.

1

Reduce environmental noise

Green Roofs can reduce sound diffraction over buildings

Create quieter facades and noise screening to green spaces

Reduces sound propagation over large distances by 2 - 6 dBA

Up to 10 dB reduction at low frequencies

Performance may be increased by higher substrate depth

Performance may be reduced by higher moisture content

1

Reduce environmental noise

Van Renterghem, T. and D. Botteldooren, Numerical evaluation of sound propagating over green roofs. 2008.
Van Renterghem, T. and D. Botteldooren, Reducing the acoustical façade load from road traffic with green roofs. 2009
Hornikx, M. and J. Forssén, Noise abatement schemes for shielded canyons. 2009.

Green Roofs can provide both airborne & impact insulation

Green roofs can provide airborne sound reduction of 29-37 dB R_w

Performance improved by increasing substrate and root depth

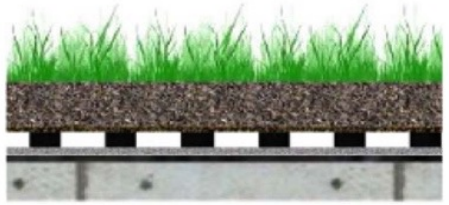
Further improved with insulated cavity (up to 43 dB R_w)

Preliminary evidence suggests they can benefit impact sound insulation

Intensive

Semi-intensive

Extensive



Illustrations: Besir & Cuce (2018)

1

Reduce environmental noise

Galbrun, L. and L. Scerri, Sound insulation of lightweight extensive green roofs. 2017.
Connelly, M. and M. Hodgson, Experimental investigation of the sound transmission of vegetated roofs. 2013
Rodriguez, J.R. and M. Connelly Comparative Field Test Evaluation of the Impact Insulation Class of Roofs. 2015.

2. Improve the perception of noise

Views of Green Infrastructure can reduce perceived road traffic noise levels

Up to 10 dBA reduction when compared to no greenery

Street level greening can reduce negative perception of noise, despite high noise levels (circa. 75 dBA)

Adding greenery to noise barriers improves:

- Predicted noise attenuation
- Attractiveness
- Overall environmental quality
- Perceived performance compared to other barrier types

Dzhambov, A.M. and D.D. Dimitrova, Green spaces and environmental noise perception. 2015.
Yang, F., Z.Y. Bao, and Z.J. Zhu, An assessment of psychological noise reduction by landscape plants. 2011.
Bogdanov, V.B., et al., Nature and the City: Audiovisual interactions in pleasantness and psychophysiological reactions. 2022.
Van Renterghem, T., Towards explaining the positive effect of vegetation on the perception of environmental noise. 2019.
Van Renterghem, T. and D. Botteldooren, View on outdoor vegetation reduces noise annoyance for dwellers near busy roads. 2016.
Hong, J.Y. and J.Y. Jeon, The effects of audio–visual factors on perceptions of environmental noise barrier performance. 2014.
Echevarria Sanchez, G.M., et al., Using Virtual Reality for assessing the role of noise in the audio-visual design of an urban public space. 2017.
Gidlöf-Gunnarsson, A. and E. Öhrström, Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. 2007
Schäffer, B., et al., Residential green is associated with reduced annoyance to road traffic and railway noise but increased annoyance to aircraft noise exposure. 2020.
Mueller, W., et al., Urban greenspace and the indoor environment: Pathways to health via indoor particulate matter, noise, and road noise annoyance. 2020.
Aletta, F., T. Van Renterghem, and D. Botteldooren, Influence of Personal Factors on Sound Perception and Overall Experience in Urban Green Areas. 2018.

2

Improve the perception of noise

The perceptual benefits are dependent on noise source

The benefit of visual greenery on noise perception is less for rail noise (~ -6 dBA)

Residents with more nearby green areas are more annoyed by aviation noise (equivalent to a 10 dBA increase in level)

Schäffer, B., et al., Residential green is associated with reduced annoyance to road traffic and railway noise but increased annoyance to aircraft noise exposure. 2020.

2

Improve the perception of noise

Access to green and blue elements can mediate the negative effects of noise exposure

People with more green space nearby were reported to be less sensitive to noise

Views of blue spaces may mediate the negative perceptions of noise that lead to annoyance

2

Improve the perception of noise

Gidlöf-Gunnarsson, A. and E. Öhrström, Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. 2007

Dzhambov, A.M. and D.D. Dimitrova, Green spaces and environmental noise perception. 2015.

Peris, E. and B. Fenech, Associations and effect modification between transportation noise, self-reported response to noise and the wider determinants of health: A narrative synthesis of the literature. 2020.

Li, H.N., et al., On the study of the effects of sea views, greenery views and personal characteristics on noise annoyance perception at homes. 2012.

Leung, T.M., et al., On the study of effects of views to water space on noise annoyance perceptions at homes. 2014.

Greener neighbourhoods with tree cover can also mediate the negative effects of noise and reduce risks to wellbeing

People living in greener neighbourhoods were less likely to experience long-term noise annoyance

Neighbourhoods with more than 5% tree coverage showed reduced risks to wellbeing due to noise

Dimitrova, D.D. and A.M. Dzhambov, Perceived access to recreational/green areas as an effect modifier of the relationship between health and neighbourhood noise/air quality: Results from the 3rd European Quality of Life Survey (EQLS, 2011–2012). 2017.
Dzhambov, A.M., et al., Residential greenspace might modify the effect of road traffic noise exposure on general mental health in students. 2018.
Gidlöf-Gunnarsson, A. and E. Öhrström, Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. 2007

2

Improve the perception of noise

3. Introduce positive sounds & enhance the soundscape

Green spaces in cities provide people with respite from noise

Especially important for people exposed to high levels of noise at home or with no outdoor space

This escape is likely to reduce the mental health and stress-related psychosocial impacts due to noise

The availability of high-quality green space is dependent on socioeconomic status (income, nationality and homeownership).

3

Introduce positive sounds & enhance the soundscape

URS, The Economic Value of Quiet Areas. 2011.
Public Health England, Improving access to greenspace: A new review for 2020.
Department for Environment Food & Rural Affairs (DEFRA). Noise Action Plan. 2019.
Kenna, T., Cities of neurodiversity: New directions for an urban geography of neurodiversity. 2022.
Öhrström, E., et al., Effects of road traffic noise and the benefit of access to quietness. 2006.
Lovell, R., et al. A rapid scoping review of health and wellbeing evidence for the Green Infrastructure Standards. 2020.
Misiune, I., J.P. Julian, and D. Veteikis, Pull and push factors for use of urban green spaces and priorities for their ecosystem services: Case study of Vilnius, Lithuania. 2021.

Greenery can increase the dominance of natural sounds

Natural sounds can provide "informational masking" that can promote mental restoration

People with more green spaces near their homes reported to hear birdsong significantly more

Birdsong and water elements are the most preferred natural sounds in urban parks

3

Introduce positive sounds & enhance the soundscape

HOSANNA, Novel solutions for quieter and greener cities. 2013.
Perillo, A., et al., Anthropogenic noise reduces bird species richness and diversity in urban parks. 2017.
Van Renterghem, T., Towards explaining the positive effect of vegetation on the perception of environmental noise. 2019.
Lutgen, M., et al., Improving the soundscape quality of urban areas exposed to aircraft noise by adding moving water and vegetation. 2018.
Peris, E. and B. Fenech, Associations and effect modification between transportation noise, self-reported response to noise and the wider determinants of health: A narrative synthesis of the literature. 2020.
Lutgen, M., M. Karacaoglu, and K. White. A VR experiment testing the effects of fountain sounds and visible vegetation on soundscape quality in areas exposed to aircraft noise. 2017.
Gidlöf-Gunnarsson, A. and E. Öhrström, Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. 2007.
Chen, Z., et al., How to integrate the soundscape resource into landscape planning? A perspective from ecosystem services. 2022.

Natural sounds support more restorative environments

Serene environments were correlated with neighbourhood satisfaction

Presence of natural sounds increased preference, pleasantness & tranquillity

But nature sound preference is dependent on several demographic characteristics

3

Introduce positive sounds & enhance the soundscape

Watts, G., The effects of "greening" urban areas on the perceptions of tranquillity. 2017.
Song, X., et al., Spatial-temporal change analysis of plant soundscapes and their design methods. 2018.
de Jong, K., et al., Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health. 2012.
Chen, Z., et al., How to integrate the soundscape resource into landscape planning? A perspective from ecosystem services. Ecological Indicators, 2022.
Zhao, Y., et al., Temporal and Spatial Characteristics of Soundscape Ecology in Urban Forest Areas and Its Landscape Spatial Influencing Factors. 2022.
Deng, L., et al., Effects of integration between visual stimuli and auditory stimuli on restorative potential and aesthetic preference in urban green spaces. 2020.

Landscape design is an important tool for promoting natural soundscapes in cities

Positive soundscape quality has been described as a combination of “naturalness”, “diversity” & “appropriateness”

- Broad-leaved trees promote more wind-induced sounds & birdsong
- Combining trees and water elements can promote greater bird song presence
- Flowing water bodies are helpful for noise masking and reduction of stress
- High intensity flowing water sounds can reduce pleasantness and tranquillity.

Watts, G.R., et al., Measurement and Subjective Assessment of Water Generated Sounds. 2009.
Chen, Z., et al., How to integrate the soundscape resource into landscape planning? A perspective from ecosystem services. Ecological Indicators, 2022.
Hong, X.-C., et al., Perceived Occurrences of Soundscape Influencing Pleasantness in Urban Forests: A Comparison of Broad-Leaved and Coniferous Forests. 2019.
Morelli, F., et al., Effects of urbanization on taxonomic, functional and phylogenetic avian diversity in Europe. 2021.
Bogdanov, V.B., et al., Nature and the City: Audiovisual interactions in pleasantness and psychophysiological reactions. 2022.
Zhao, Y., et al., Temporal and Spatial Characteristics of Soundscape Ecology in Urban Forest Areas and Its Landscape Spatial Influencing Factors. 2022.
Rådsten-Ekman, M., Ö. Axelsson, and M.E. Nilsson, Effects of Sounds from Water on Perception of Acoustic Environments Dominated by Road-Traffic Noise. 2013.
Hong, J.Y., et al., Effects of contexts in urban residential areas on the pleasantness and appropriateness of natural sounds. 2020.
Galbrun, L. and T.T. Ali, Acoustical and perceptual assessment of water sounds and their use over road traffic noise. 2013.
Jones, L., et al., A typology for urban Green Infrastructure to guide multifunctional planning of nature-based solutions. 2022.
Peris, E. and B. Fenech, Associations and effect modification between transportation noise, self-reported response to noise and the wider determinants of health: A narrative synthesis of the literature. 2020.

3

Introduce positive sounds & enhance the soundscape

4. Support biodiversity

Anthropogenic noise exposure to habitats can reduce biodiversity

Noise exposure can result in reduced bird and insect populations

Affects species differently and is dependent on their vocal call

Birds with higher frequency calls were more significantly affected

Boats, road and railways crossings affect fish population courting calls

Photo by Jan Meeus

Holt, D.E. and C.E. Johnston, Traffic noise masks acoustic signals of freshwater stream fish. 2015.
Perillo, A., et al., Anthropogenic noise reduces bird species richness and diversity in urban parks. 2017.
Cicort-Lucaciu, A.-Ş., et al., Urban avifauna distribution explained by road noise in an Eastern European city. 2022.
Proppe, D.S., C.B. Sturdy, and C.C. St Clair, Anthropogenic noise decreases urban songbird diversity and may contribute to homogenization. 2013.

Landscape design of Green Infrastructure should consider the interrelationship between soundscapes for people and for wildlife

Grass, trees and water streams increase bird communities

Even small patches of trees, hedges or bushes have a positive effect on promoting biodiversity

Green Infrastructure elements could provide noise protection to areas important for biodiversity

4

Support biodiversity

Morelli, F., et al.,'Effects of urbanization on taxonomic, functional and phylogenetic avian diversity in Europe', 2021.

What are the gaps in the evidence?

What are the gaps in the evidence?

Objective sound reduction evidence is established but lacks in-situ examples

Subjective response and health outcomes evidence is less established, with further research needed on the dependencies of Green Infrastructure quality and socio-demographic preferences

Long-term studies on the ability to reduce perceived noise levels and how this results in sustained health and wellbeing outcomes

Evidence on biodiversity impacts are limited to the study of how reduced noise levels benefit species richness, and was only found to include limited species type

Links between sustainable urban development are speculative at best, and need to be coordinated with in-situ examples and long-term studies on health outcomes

What are the policy implications?

What are the policy implications?

Specific mention of Green Infrastructure in noise and soundscape policy

Dissemination of the findings of this review to the urban development sector and beyond

Strategic mapping to be coordinated between multiple disciplines and to consider the subjective response to sound when heard in context

Coordinate findings with work being conducted on condition of habitats towards Biodiversity Net Gain

Are these findings easily accessible to non-acousticians?

We asked the industry for their views on how to disseminate the findings to industry professionals

Are these findings easily accessible to non-acousticians?

89% felt that the Executive Summary & Visual Summary information was either relevant or very relevant to their role.

91% felt that the level of technical detail in the main report body was appropriate for them.

50% felt it would be “easy” or “very easy” to apply the findings in their work, with 11% feeling like it would be “difficult”.

61% did not think an alternative design of the Executive Summary & Visual Summary was needed, with 22% saying “maybe” and 17% saying “yes”.

18 Organisations took part

8 Regional/Local Authorities
5 Landscape Architects/ Consultants,
4 Greening Solution Providers,
1 Property Developer

Did participants share any relevant case studies?

Only a handful of participants discussed possible case studies relevant to the topic.

Generally, these were projects that were yet to conduct formal quantification of the acoustic benefits to confirm claims. Some participants offered these projects as potential future case studies to be studied via in-situ gathering of evidence.

The conclusion was to host small roundtable sessions on the topic to introduce practitioners to each other with the aim of sparking collaborations that can lead to practical applications of the review findings.

Department for Environment Food & Rural Affairs

Thank you

Q & A & Roundtable Discussion

Grant Waters, Director of Tranquil City, Principal Consultant at Anderson Acoustics

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maploom

12-14th March 2024

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