FACULTY OF ENGINEERING AND ARCHITECTURE

DEPARTMENT INFORMATIONTECHNOLOGY
RESEARCHGROUPWAVES

# GREENING AND SOUND

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## OVERVIEW

- How can vegetation be used to reduce physical sound pressure levels?
  - Tree belt along road
  - Natural berms
  - Building envelope greening (green roofs)
- How can the noise perception improvement by vegetation be explained ?



## VEGETATION BELTS

- A lot of ad-hoc research
- Divergent findings leading to conservative advice and prediction schemes
- Need for design!



## VEGETATION BELTS

- Leaves
  - Scattering of sound
  - Absorption processes
    - Visco-thermal effects at the surface
    - Damped vibrations

## VEGETATION BELTS

- Trunks
  - Multiple scattering of sound
  - Multiple interactions with partly absorbing bark
- Forest floor
  - Destructive interference



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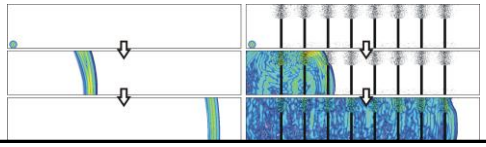
## VEGETATION BELTS

- Guidelines
  - Experiments
  - Full-wave simulations
    - Scattering by impedance cylinders
    - Validated forest floor models including input data



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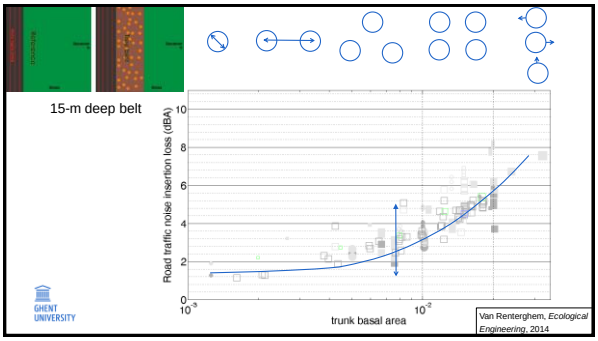


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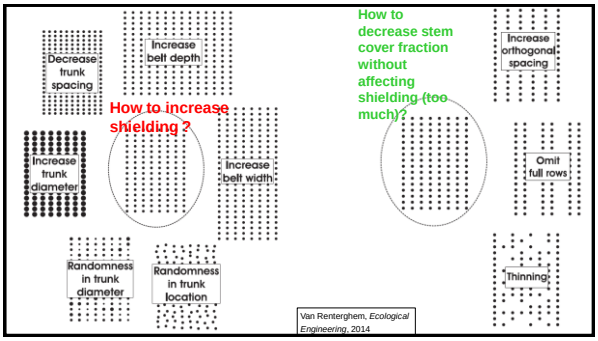

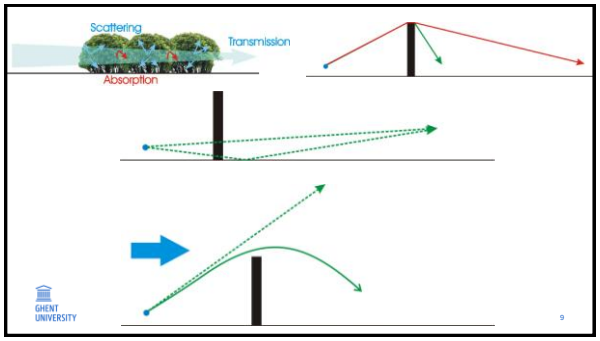
Scattering
Transmission
Absorption
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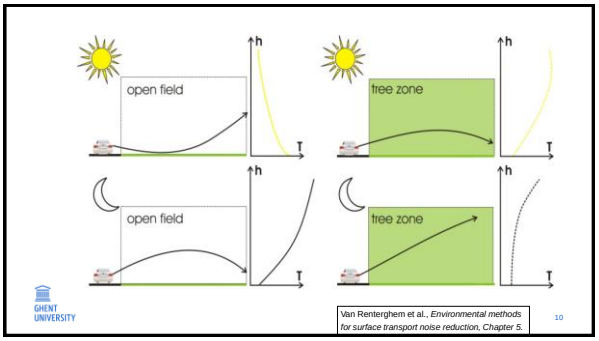
open field
tree zone
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Van Renterghem et al., Environmental methods for surface transport noise reduction, Chapter 5.
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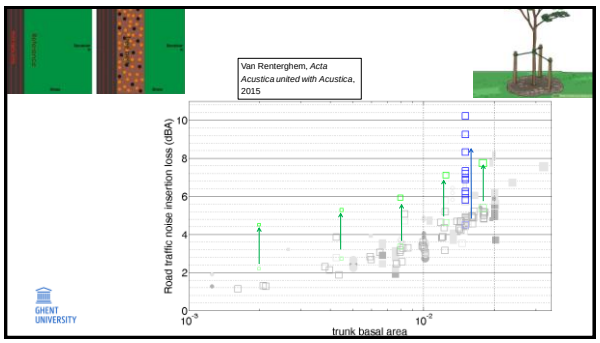
Van Renterghem, Acta Acustica united with Acustica, 2015
Road traffic noise insertion loss (dBA)
trunk basal area
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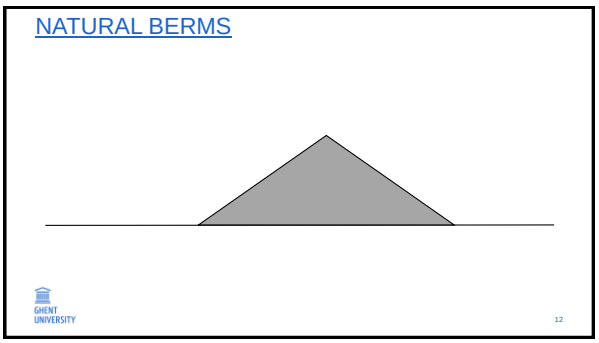
NATURAL BERMS
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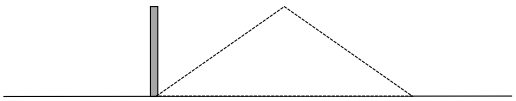
## NATURAL BERMS



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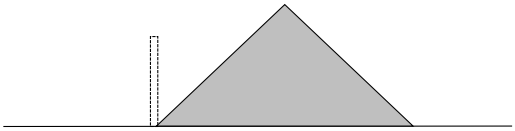
## NATURAL BERMS



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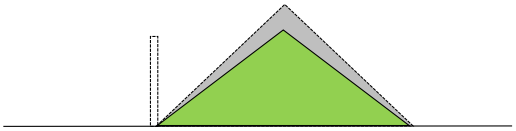

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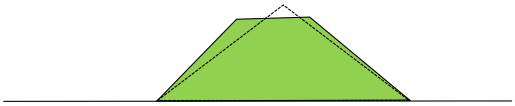
## NATURAL BERMS



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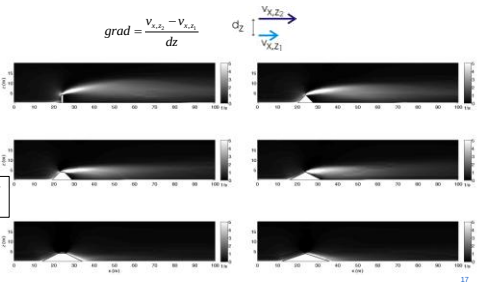
## NATURAL BERMS

$$grad = \frac{v_{x,z_2} - v_{x,z_1}}{dz}$$



Van Renterghem et al., *Landscape and urban planning*, 2012

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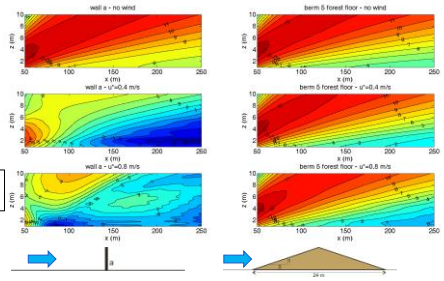


Van Renterghem et al., *Landscape and urban planning*, 2012

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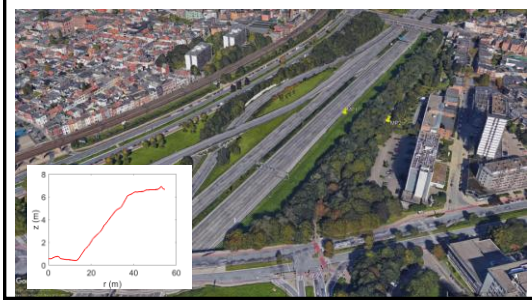


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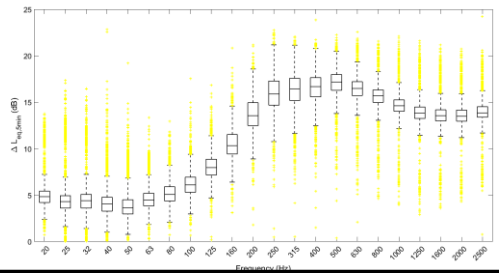
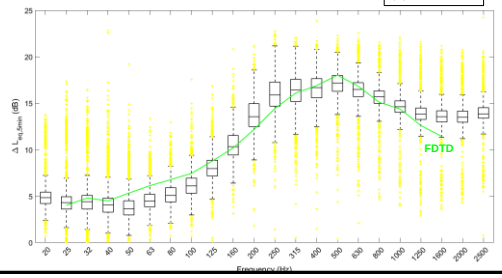
## NATURAL BERMS



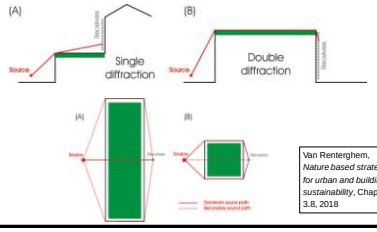
## NATURAL BERMS

Van Renterghem et al., *Environmental modelling and software*, 2018




## BUILDING ENVELOPE GREENING

- Enhancing quiet side
- Dominant sound path interacting with green roofs




Van Renterghem, *Nature based strategies for urban and building sustainability*, Chapter 3.8, 2018

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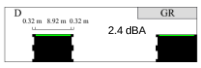
## BUILDING ENVELOPE GREENING

- Flat roofs

Van Renterghem et al., *Building and Environment*, 2011

Van Renterghem, *Nature based strategies for urban and building sustainability*, Chapter 3.8, 2018

| | case number | Substrate depth | Propagation path length interacting with green roof | Vegetation cover | Green roof road traffic noise insertion loss (30-70 km/h, 5 % heavy traffic): Low microphone position | High microphone position |
|---|---|---|---|---|---|---|
| single diffraction cases | 1 | 20-30 mm | 8 m | > 75 % (sedum + mosses) | 4.1 dBA | 1 dBA |
| | 2 | 50-60 mm | 2.5 m | < 5 % (sedum shoots) | 2.3 dBA | -2.4 dBA |
| | 3 | 180 mm | 4.5 m | 50 % (grasses) | 5.5 dBA | 2.1 dBA |
| double diffraction cases | 4 | 30-40 mm | 25 m | > 90 % (sedum) | 3.1 dBA | 2.2 dBA |
| | 5 | 80-100 mm | 25 m | < 5 % (sedum shoots) | 3.4 dBA | 5.1 dBA |




2-4 dBA re rigid roofs

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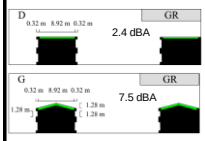
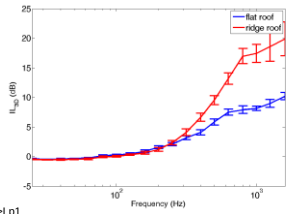
## BUILDING ENVELOPE GREENING

- Non-flat roofs





Van Renterghem et al., *Building and Environment*, 2013

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## BUILDING ENVELOPE GREENING

– green roofs vs solar panels

?

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## BUILDING ENVELOPE GREENING

– green roofs vs solar panels

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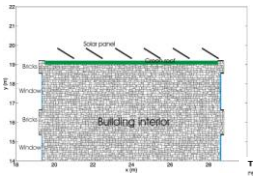
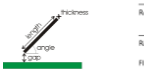
## BUILDING ENVELOPE GREENING

– green roofs vs solar panels




Van Renterghem, *Building Acoustics*, 2018

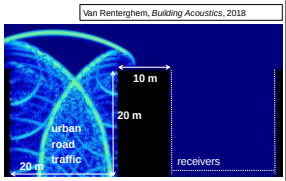



**Table 1.** Predicted solar panel insertion losses (dBA) for various panel inclinations, averaged over all receivers in the shielded canyon, for urban road traffic.

| Reference situation | | Solar panel inclination | | | | | |
|---|---|---|---|---|---|---|---|
| | | −45° | −30° | −15° | 15° | 30° | 45° |
| Rigid flat roof | Gap | 0.9 | −0.3 | 0.0 | 0.0 | −0.1 | 0.9 |
| | No gap | 2.6 | 1.4 | 0.5 | 0.7 | 1.7 | 3.9 |
| Flat limestone green roof | Gap | 0.9 | 0.4 | −0.3 | −0.3 | 0.3 | 0.9 |
| | No gap | 5.6 | 4.1 | 1.8 | 1.8 | 4.2 | 5.7 |

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## NOISE PERCEPTION AND GREEN

– "*A significant number of respondents indicated that vegetation was a **viable alternative to noise walls***" and "*it was claimed that their **experience** with vegetation supported this contention*" (Perfater, 1979).
– "***90%** of the subjects believed that landscape plants contribute to noise reduction*" (Yang et al., 2011).
– A cycling path exposed to 70 dBA highway noise (but covered in green) lead to 45% of the respondents still considering this zone as **"calm"** (opposed to "busy") (Aletta et al., 2018).
– …

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## SOURCE VISIBILITY

- "Attention focussing" : seeing a source will increase annoyance
- "Audio-visual congruency" : "you should see what you hear"
- Contradicting conclusions (Watts, 1999 vs Zhang et al., 2003)

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## NATURAL SOUNDS

- Masking potential
- Highly appreciated by humans

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## RESTORATIVE POTENTIAL

- Environmental noise exposure
  - occupies part of the workload of the human brain
  - induces stress reactions
- Potential explanation by
  - Attention Restoration Theory (Kaplan et al., 1983)
  - Stress Recovery Theory (Ulrich, 1989)

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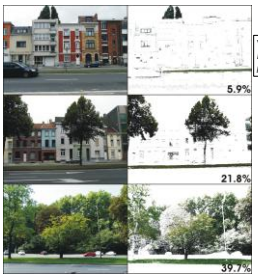
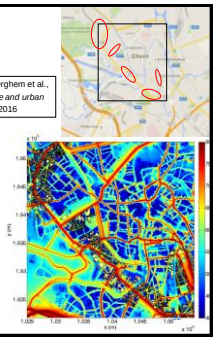
## RESTORATIVE POTENTIAL




Van Renterghem et al., *Landscape and urban planning*, 2016



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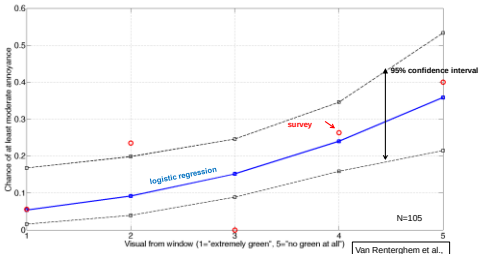
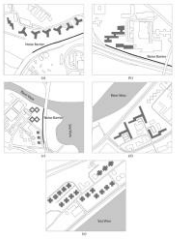
## RESTORATIVE POTENTIAL




Van Renterghem et al., *Landscape and urban planning*, 2016



## RESTORATIVE POTENTIAL

Leung et al., *Journal of Acoustical Society of America*, 2017



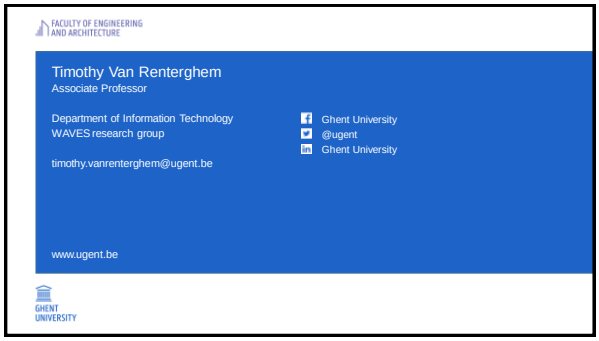
## PERCEPTION IMPROVEMENT

- Need for visible outdoor vegetation
- Importance of green quality
- Seems to work at high exposure levels
- Equivalent level reduction is strong
  - 15 dBA (Langdon, 1976)
  - 5 dBA (Lercher, 1996)
  - 10 dBA (Van Renterghem et al., 2016)
  - 11 dBA (Leung et al., 2017)



## CONCLUSIONS

- Can nature-based solutions be used to reduce decibels? Yes !
- Can vegetation be used to improve perception regardless of the exposure level ? Yes ! (strong effect)
- But must be well designed !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