MOSS LAB 2.0

“What is the effect of plant properties and plant arrangements on acoustics in a hybrid office space?”

Makers
Of
Sustainable
Spaces.

Plants are the center point of every decision we make. We make cities resilient, livable, healthy and enjoyable again, from grey to green. We connect people with living green, landscapes and edible products to enrich and feed the city.

WHO IS MOSS?

Our vision is a world where people, plants, and animals live in harmony.

Amsterdam team

Architecture, Design, Product, Plant specialism, Ecology, Research, Art

Nina Sickenga

Tessa Duste

Kelai Diebel

Tessel Pool

Jagrit Vij

Caterina Fagiolari

Eirini Trachana

Mawee Pornpunyalert

International team

Business Developers / Local Agents / Research & Design

Melanie Ryan (USA)

Madelon van de Ven (ASIA)

Monica Daley (AUS)

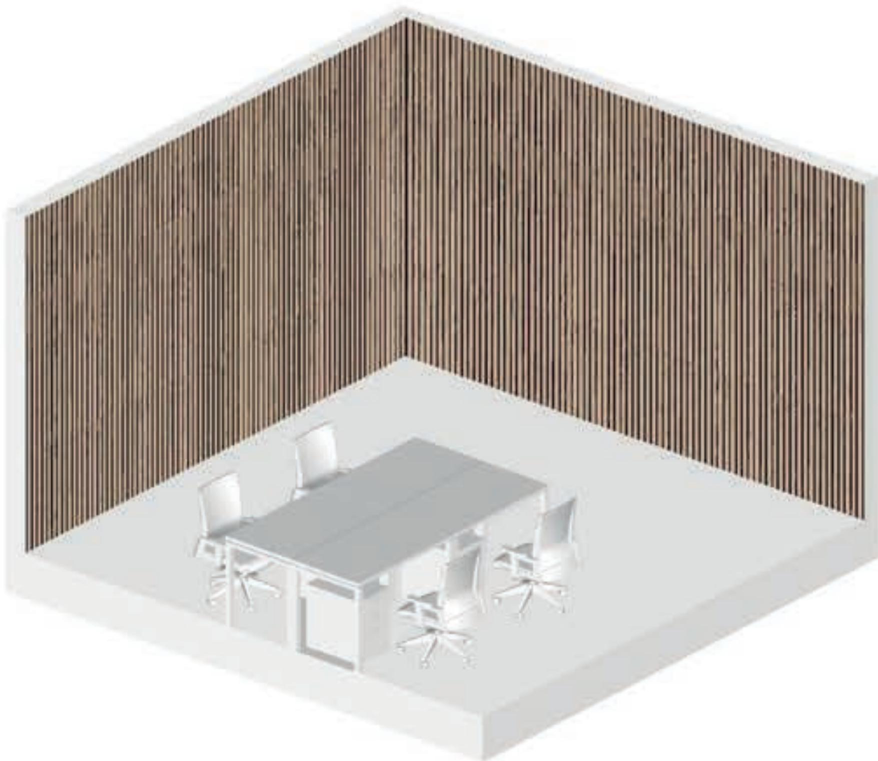
For cities, for life, for our future. We design and create green oases in and on top of buildings!

WHY ARE WE INTERESTED?

“Noise issues in the office are a concern for 56% of employees when considering returning to the office ”

(Poly, 2021)

CAN PLANTS BE OUR NEXT ACOUSTIC SOLUTIONS?



STAKEHOLDERS

MOSS
ADVISORY

RESEARCH TEAM
CONDUCTORS OF STUDY/
WRITERS OF FINDINGS

ACT COACH
COACH

COD
REAL ESTATE DEVELOPER

KGG
KONINKLIJKE GINKEL GROEP
GREEN CONTRACTOR

PHYSEE
SUSTAINABLE TECHNOLOGY
DEVELOPER

SORAMA
SOUND TECHNOLOGY
DEVELOPER

WHO ARE THE RESEARCHERS?

MOSS teamed up with 6 Master's students of Wageningen University to design a study that explores the effect of plant properties and plant arrangements on acoustics in a hybrid office space. They have worked to find how a study could be designed to investigate the way indoor green affect the acoustics.

MANAGER

Elena Ungureanu-Tangerman

Master Plant Biotechnology (Molecular Plant Breeding and Pathology)

SECRETARY

Leonie Nijs

Master Biology (Ecology)

CONTROLLER

Luc Buvelot

Master Plant Biotechnology (Molecular Plant Breeding and Pathology)

MEMBER

Nan Wang

Master Plant Science (Greenhouse Horticulture)

MEMBER

Ilva van Dam

Master Plant Science (Plant Pathology and Entomology)

MEMBER

Ilse Biemond

Master Plant Science (Greenhouse Horticulture)

SORAMA

Sorama assists product developers reduce and optimise the sound level of their products through patented technology to visualise the sound field around and vibrations on manufacturers' products. The researchers worked collaboratively with the sound experts from Sorama to conduct the experiment.

EXPERIMENT CONDUCTOR

Vishnu Thamaraikannan

Vibro-acoustic Engineer

EXPERIMENT CONDUCTOR

Achiel Schuurmans

Acoustic Consultant

SORAMA CAM1K

Sound measurement system that converts noise and vibration data into easy-to-interpret visual information.

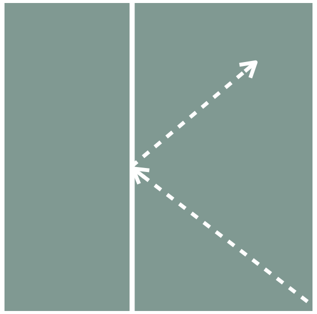
SORAMA CAM IV64

A sound level meter and acoustic camera that shows visualises where sound comes from.

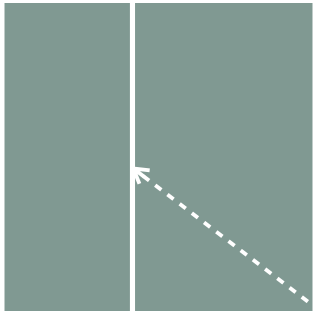
SOUND PATH

There are different ways in which sound can move through a space. Sound in offices mostly travels via air. However, objects in the room can have several effects on the sound waves.

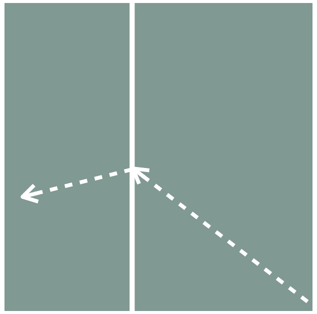
*Sound absorption depends on the material **thickness**, **porosity**, **density**, **position**, **airflow resistivity**, and **air gap thickness***



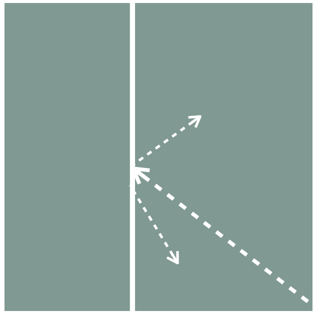
Reflection *of sound is the 'bouncing back'. The reflection of one sound wave can result in multiple reflected sound waves.*



Absorption *is the measure of the removal of energy from the sound wave when it passes through a material*



Refraction *of sound is the bending of the sound path*

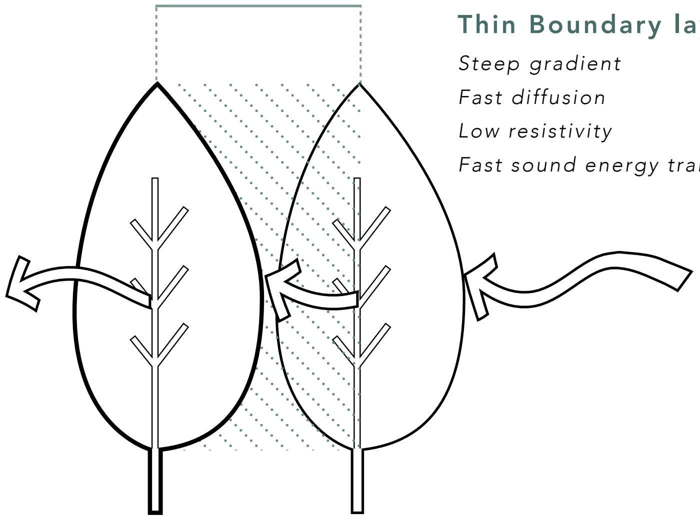


Diffusion *is the scattering of sound is the 'breaking' of the sound wave into different directions*

AIR GAP THICKNESS & SOUND ABSORBING ABILITY

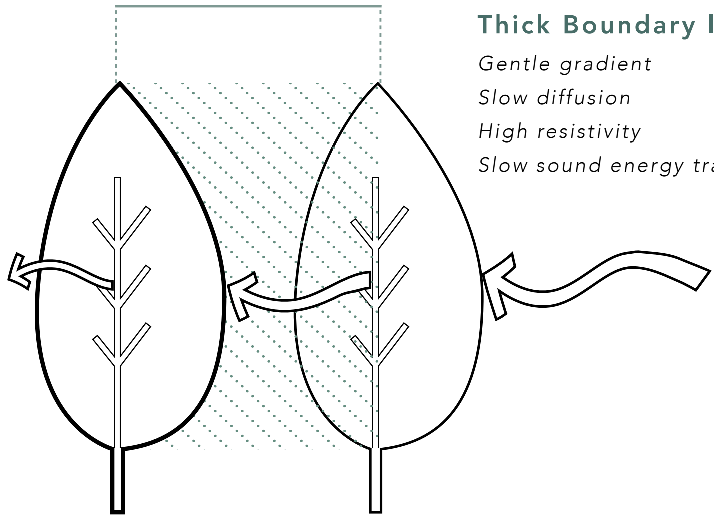
Having an air gap between "rows" of insulation material results in higher sound absorption. A thicker air gap will be able to trap the air moving through it for a longer period, thereby increasing sound absorption. Such air gaps between insulation materials, consisting of a still air layer with increased air density are very sound absorbent. Since plants are also covered in a layer of unperturbed air, called the boundary layer, this characteristic is believed to be of major importance for the sound absorption properties of plants

*The **thicker** the air gap (boundary layer), the **higher** the sound absorption*



Thin Boundary layer

Steep gradient
Fast diffusion
Low resistivity
Fast sound energy transfer



Thick Boundary layer

Gentle gradient
Slow diffusion
High resistivity
Slow sound energy transfer

PLANT PROPERTIES INFLUENCING ACOUSTICS

DENSITY
Compact

TEXTURE
Fuzzy

ORIENTATION
Angles

SHAPE & WEIGHT
Big

ROLE OF SUBSTRATE

Soil can absorb up to 80% of incident acoustic energy.

(Asdrubali et al., 2014).

The main determinant of the sound absorption ability of the soil is its porosity. Higher soil porosity linearly correlates with more sound absorption. Topsoil was found to absorb sound better than sandy soil or a mixture of sandy soil and leaf mold (D'Alessandro et al., 2015). In addition, a mixture of 30% perlite and 70% coconut fibres was proven to absorb sound well (Asdrubali et al., 2014).

PLANT COMBINATION AS A SOLUTION

*Combination of **dense**, **coarse**, **big** leaves with **dominant angle***

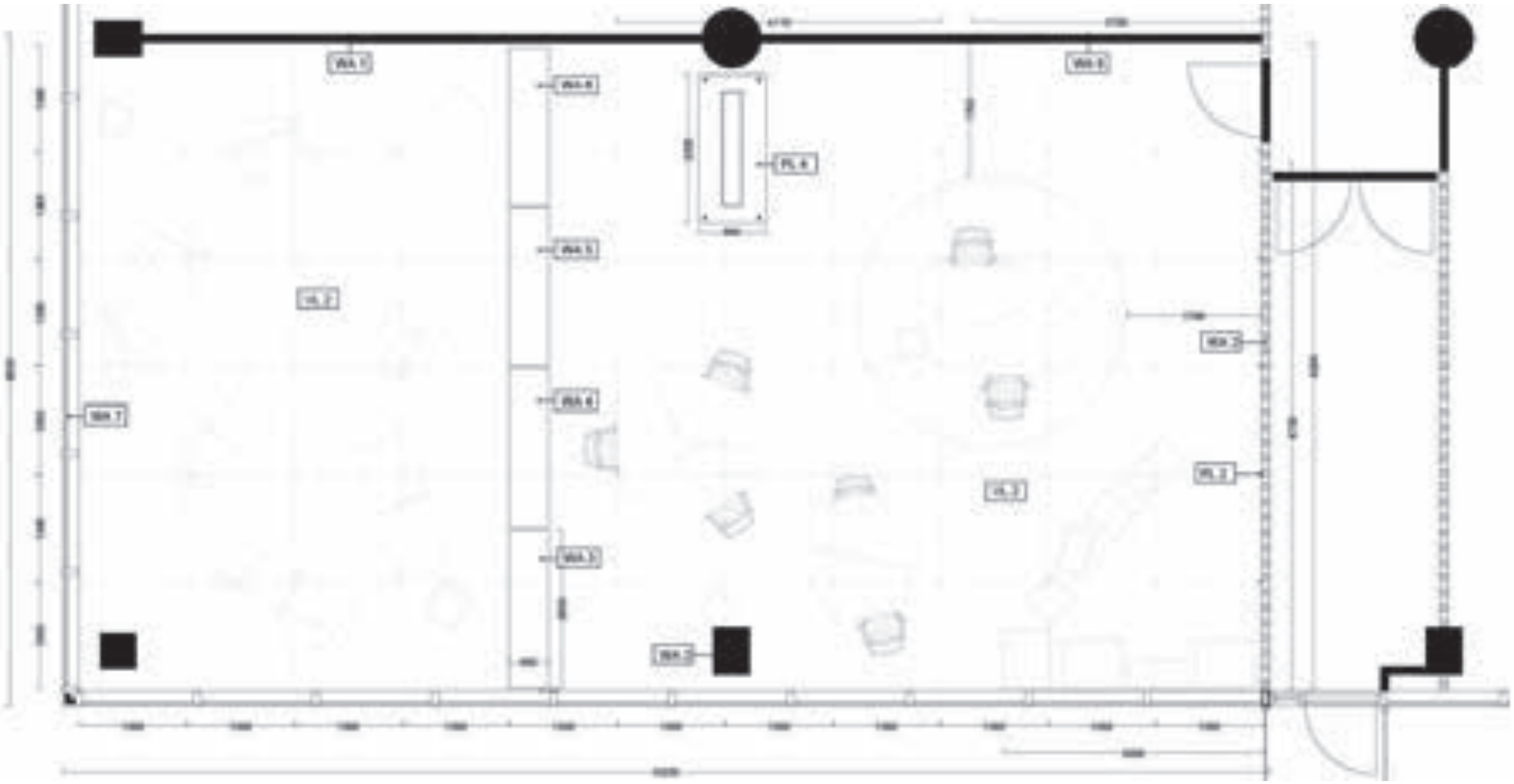
*Mixture of 30% **perlite** and 70% **coconut fibres***

HYPOTHESIS

In a room, plant arrangements should be of mixed species composition and be scattered at the perimeter of the room to absorb sound optimally.

B.BRIGHT LAB

B.BRIGHT LAB



Total Surface Area:

129.60 m²

EXPERIMENT PLANTS

RHAPIS EXCELSA

FICUS LYRATA

CARYOTA MITIS

SCHEFFLERA ARBORICOLA

KENTIA HOWEA

SCHEFFLERA AMATE

FICUS BENGAMINA

ASPIDISTRA ELATIOR

PLANT INVENTORY

BRIGHT LAB PLANT INVETORY						
Plant name	Height (cm)	Foliage W (cm)	Volume (m3/pc)	Amount	Total Surface (m2)	Total Volume (m3)
Kentia Howea	150	70	1,05	7	4,9	7,35
Kentia Howea	40	40	0,16	2	0,8	0,32
Kentia Howea	20	10	0,02	1	0,1	0,02
Ficus Lyrata	150	50	0,75	3	1,5	2,25
Ficus Lyrata	25	20	0,05	1	0,2	0,05
Caryota Mitis	140	50	0,7	2	1	1,4
Caryota Mitis	40	30	0,12	3	0,9	0,36
Raphis Excelsa	90	50	0,45	7	3,5	3,15
Aspidistra Elatior	30	20	0,06	2	0,4	0,12
Ficus Bengamina	100	40	0,4	3	1,2	1,2
Schefflera Amate	80	40	0,32	3	1,2	0,96
Schefflera Amate	60	30	0,18	1	0,3	0,18
Schefflera Aboricola	80	40	0,32	3	1,2	0,96
Schefflera Aboricola	50	30	0,15	2	0,6	0,3
				40	17,8	18,62

Note: This percentage does not meet the benchmark set in MOSS LAB 1.0 (8%).

BRIGHT LAB SCOPE			
Description	Surface (m2)	Height (m1)	Volume (m3)
Bright Lab Scope	129,6	3,5	453,6
Green (current)	17,8	0,75	18,62
Green (proposed)	37,95	0,87	37,04

SUMMARY CURRENT INVENTORY	
Description	Amount
Green m2 (%)	0,1373
Green m3 (%)	0,041

EXPERIMENT EQUIPMENT

OMNI-DIRECTIONAL SPEAKER

Speakers in a sphere configuration to distribute sound evenly. All speakers are connected in a series-parallel network.

SORAMA CAM1K

Sound measurement system that converts noise and vibration data into easy-to-interpret visual information.

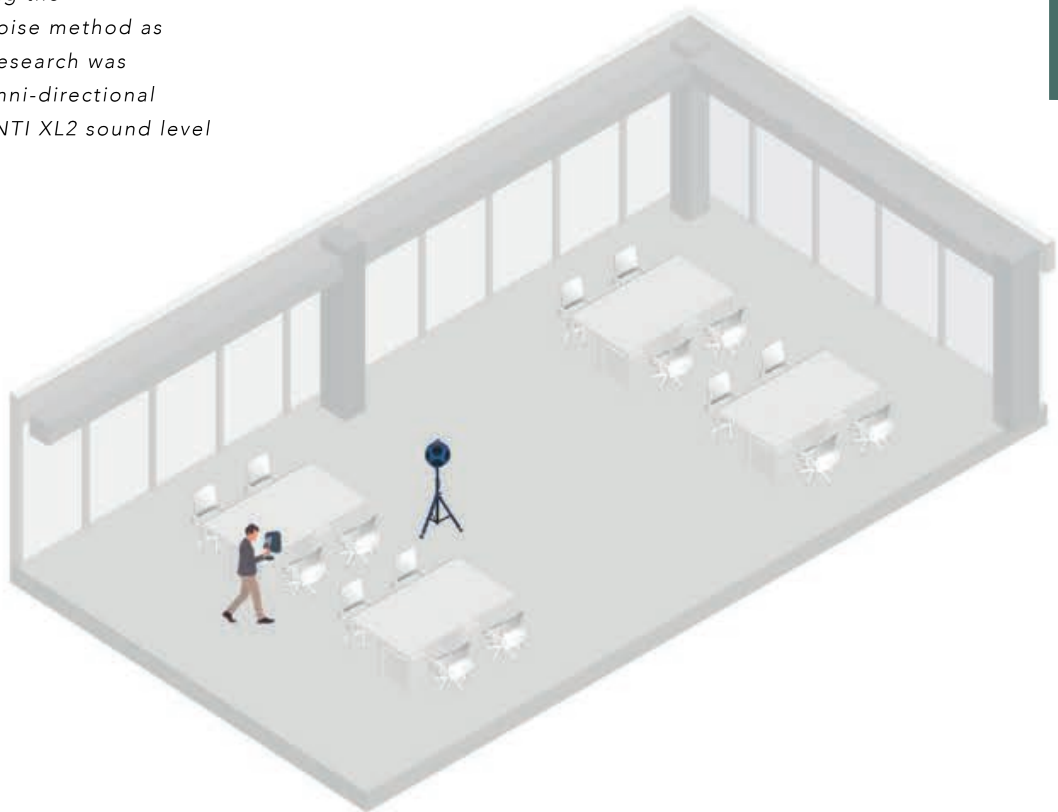
SORAMA CAM IV64

A sound level meter and acoustic camera that shows visualises where sound comes from.

EXPERIMENT: REVERBERATION TIME

*The time is measured which it takes for a broadband sound source to **decay** with 60 dB after switching off the sound source. The strategy that was used during the measurements follows the interrupted noise method as described in NEN-EN-ISO 3382-2. This research was conducted using the Looking DS-303 Omni-directional speaker, the Sorama CAM iV64 and the NTI XL2 sound level meter.*

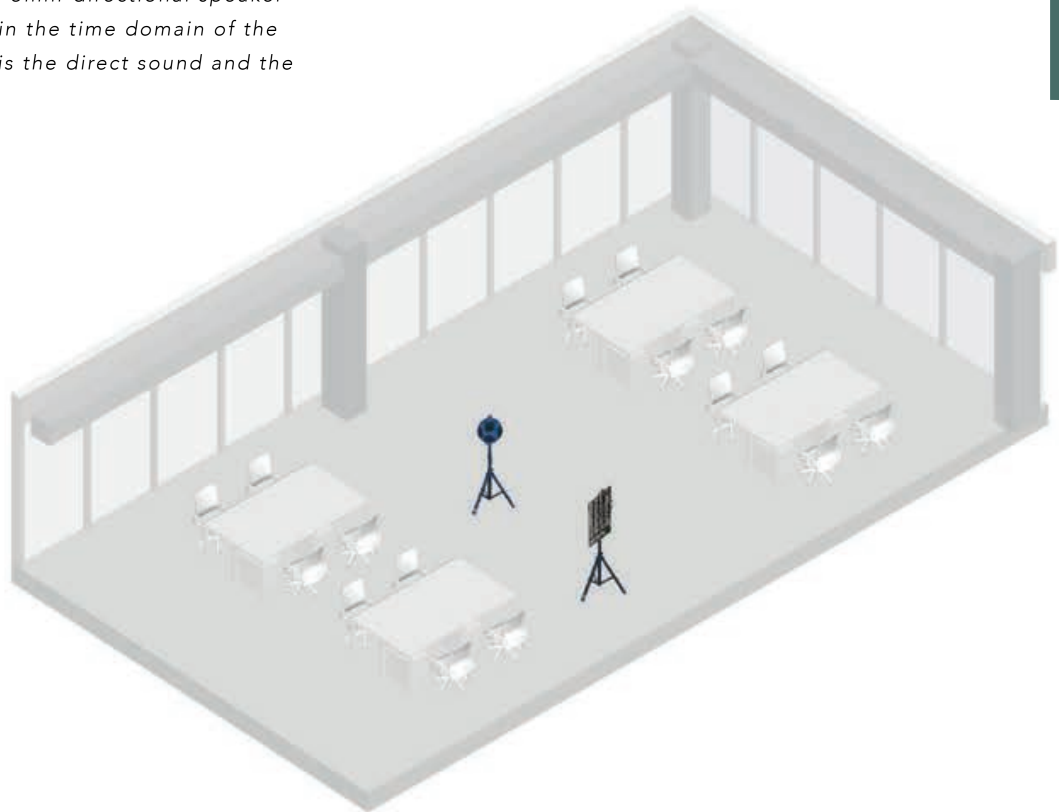
The reverberation time is a parameter that describes how absorptive or reflective a room is.



EXPERIMENT: LOCATION OF REFLECTION

*The second research focuses on finding the specific **location of reflections** using the Sorama CAM1K acoustic camera. The Sorama CAM1K was positioned on 4 sides of the omni-directional speaker which played a burst sound signal. Within the time domain of the measurement, it can be identified what is the direct sound and the reflections.*

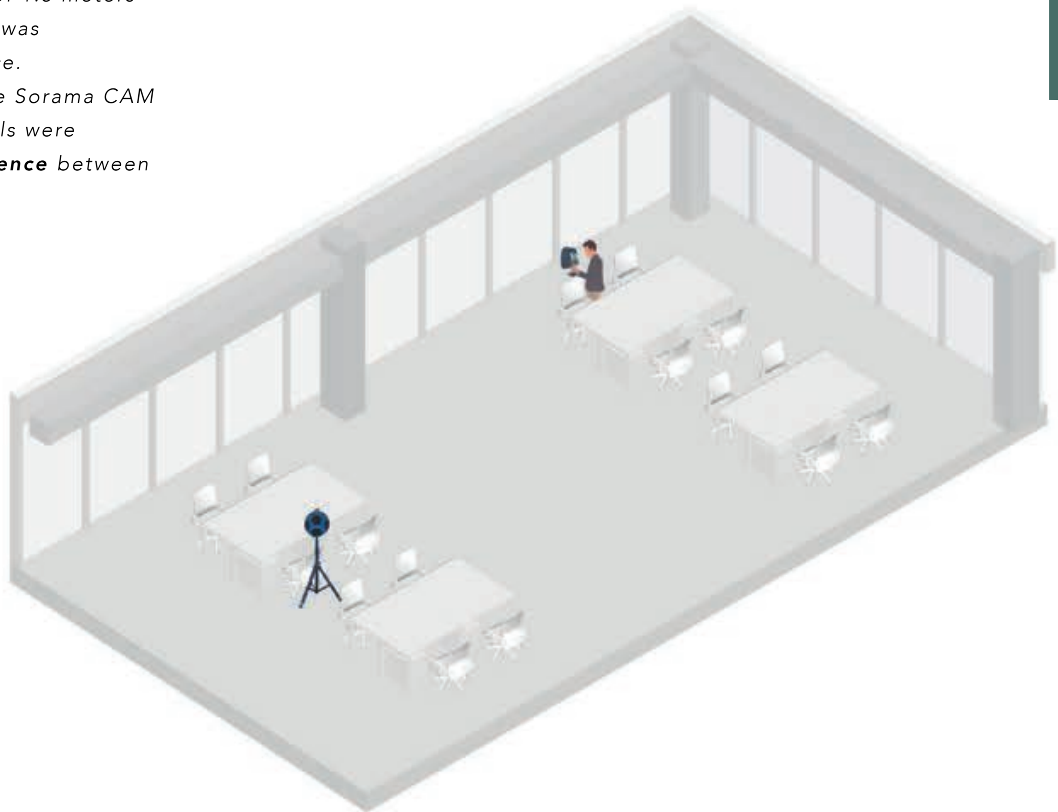
*Identifying which **planes** in the lab space contribute most to the measured reverberation time.*

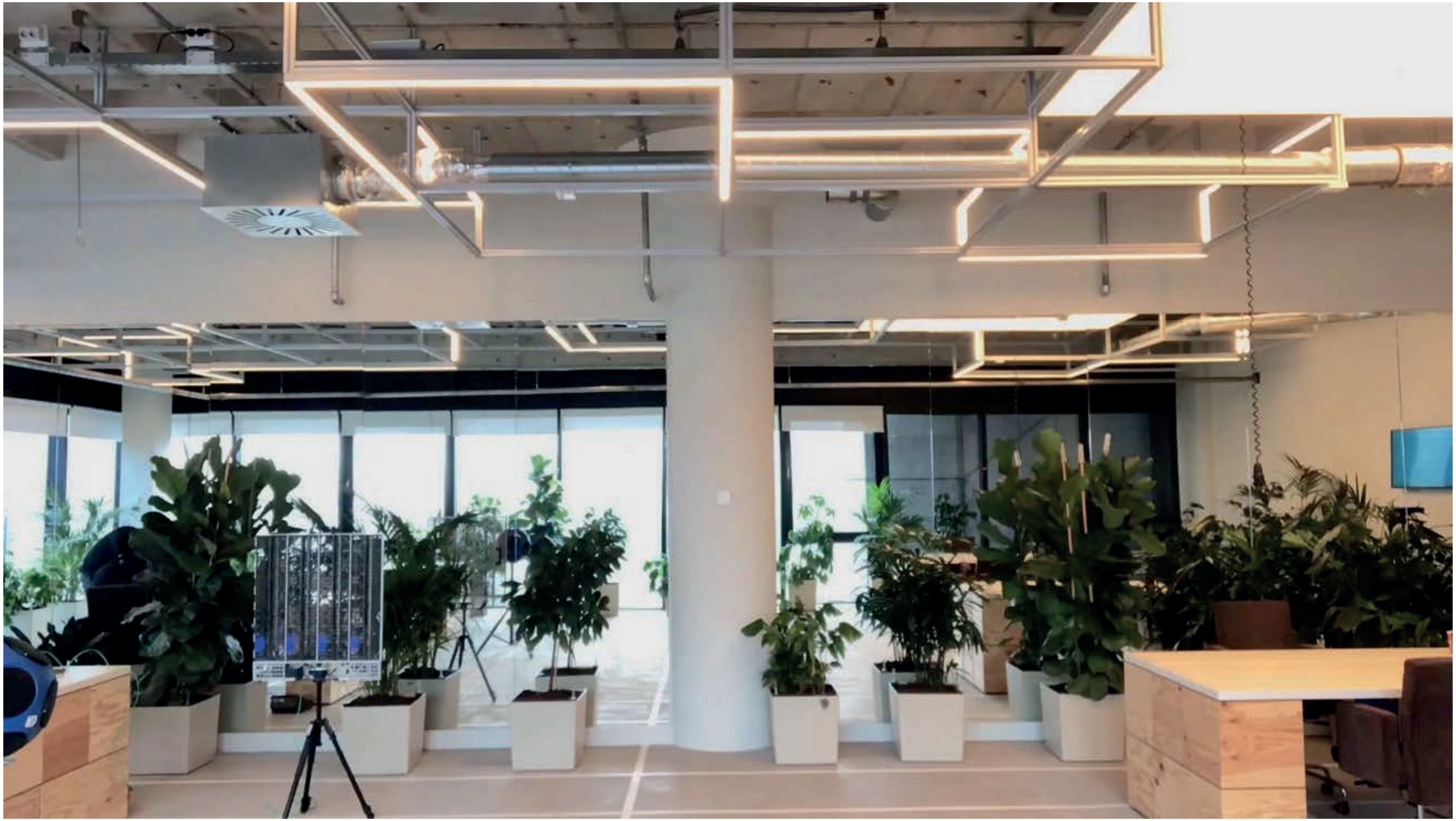


EXPERIMENT: LEVEL DIFFERENCE

*The omni-directional speaker is placed on the location of the **sender**. The sound pressure level of the sender was measured at a distance of 1.5 meters from the speaker. The **receiver** location was positioned on the other side of the space. Measurements were performed using the Sorama CAM iV64. The measured sound pressure levels were averaged over time and the **level difference** between the sender and receiver was calculated.*

*Indicating the airborne **sound reduction** between 2 locations where the sound pressure level is measured.*





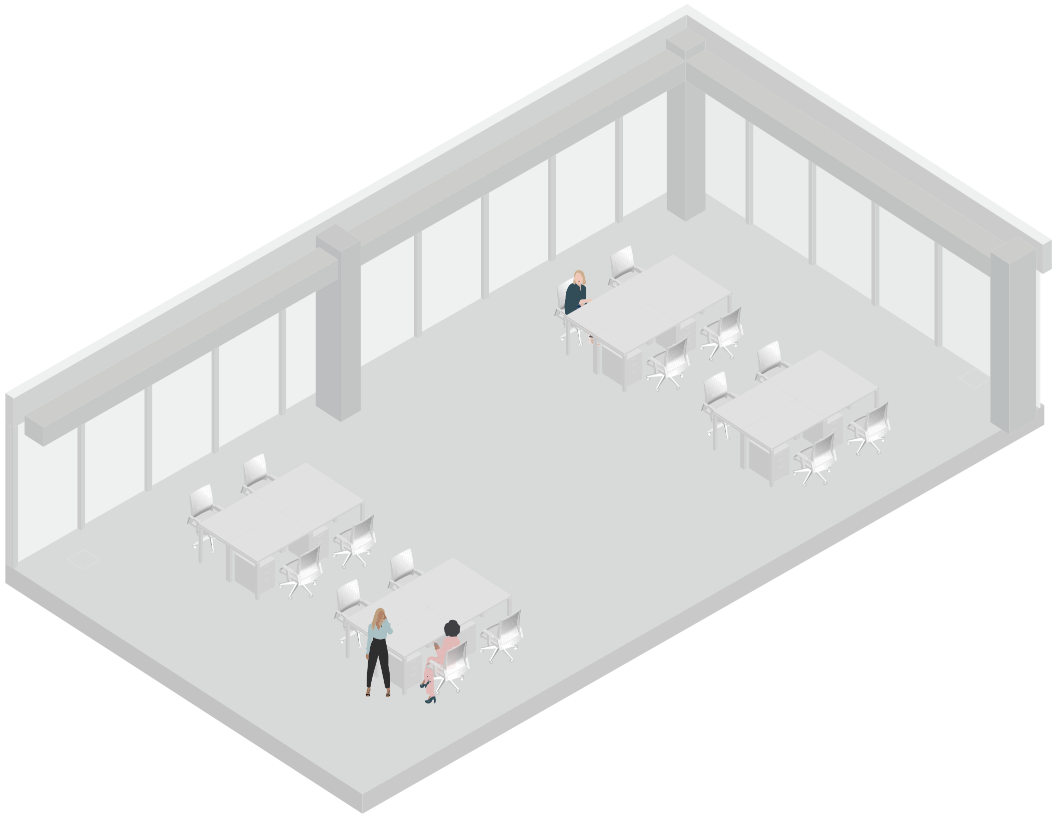
EXPERIMENT 1: PERIMETER

EXPERIMENT 2: SCATTERED

EXPERIMENT 3: DIVIDER

EXPERIMENT 4: CIRCULAR

EXPERIMENT 5: NONE



RESULT: REVERBERATION TIME

CONFIGURATION	REVERBERATION TIME (s)
1 (Perimeter)	1,54
2 (Scattered)	1,52
3 (Divider)	1,56
4 (Circular)	1,56
5 (None)	2,07

*The **configuration 2** (scattered) shows the shortest reverberation time*

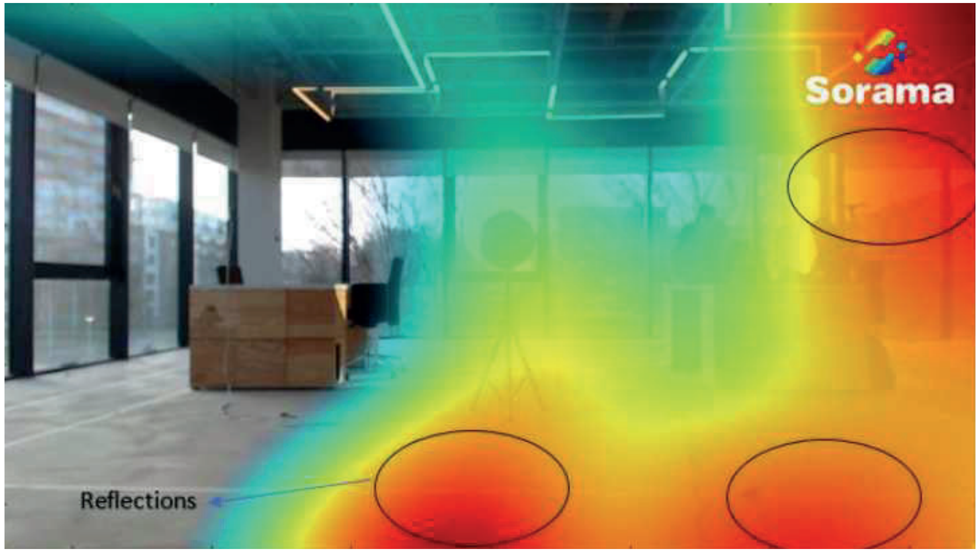
The experiment shows that the set up with no plants yield the highest reverberation time. Therefore, the addition of plants in the lab space has an effect on the reverberation time . Between the different set-ups with plants, there is only a small difference shown. The scattered set-up shows the shortest reverberation time, but more research is needed to show a clearer difference. This was as expected since literature states that plants in corners and edges of the room showed the biggest effect on the acoustics.

RESULT: LOCATION OF REFLECTION

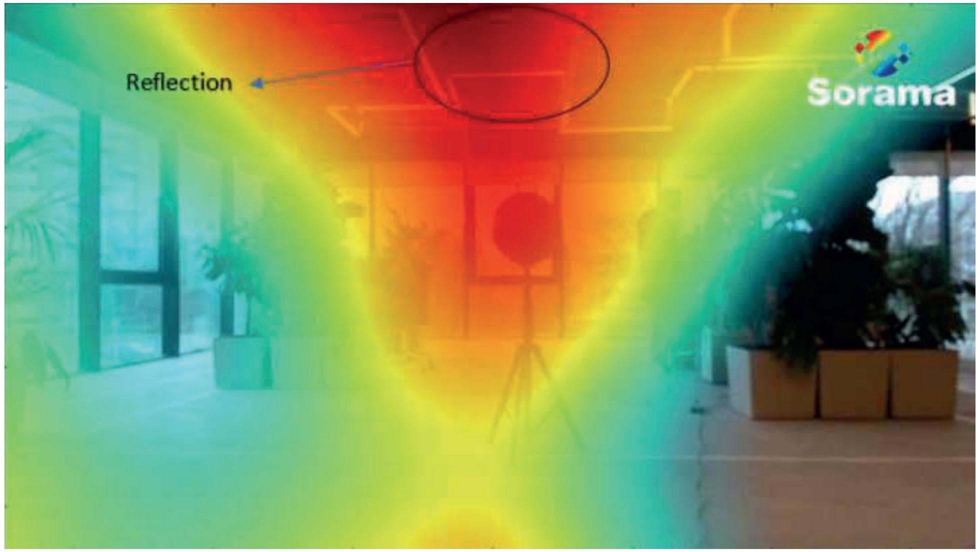
POSITION 1

Comparing empty room with the scattered set-up, can be observed that there is a sound reflection throughout the empty room, while in the scattered set-up the reflection is mostly concentrated at the ceiling area as plants redistribute the energy.

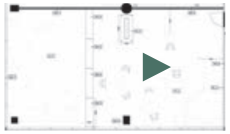
*The indoor plants **redistribute** the energy in differed directions*



CONFIGURATION 5 - NONE



CONFIGURATION 2 - SCATTERED

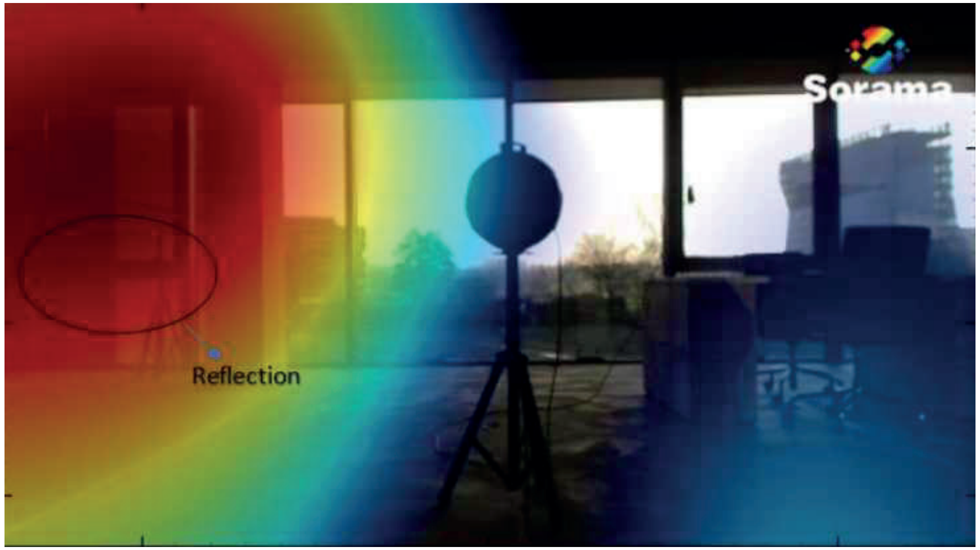


RESULT: LOCATION OF REFLECTION

POSITION 2

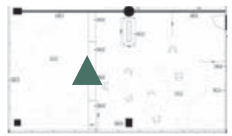
The difference between the reflections in the empty room and the divider set-up is visible. Without a divider, there are clear reflections present on the left side of the room. However, with the presence of plants in the divider setup, the reflections remain mainly present on the right side and the energy is more distributed over the space.

The indoor plants ***redistribute*** *the energy in differed directions*



CONFIGURATION 5 - NONE

CONFIGURATION 3 - Divider



RESULT: LEVEL DIFFERENCE

CONFIGURATION	LEVEL DIFFERENCE (dB)
1 (Perimeter)	2,3
2 (Scattered)	3
3 (Divider)	3,1
4 (Circular)	3,1
5 (None)	1,4

*Placing plants **directly in this path** might create the best results in sound reduction. Hence, **configuration 3 & 4** perform the best.*

The set-ups including plants showed a clearly bigger level difference in sound (in dB) than the empty room. Most likely, the plants increase the absorption of sound in the space. The divider and circle set-ups showed the most effect in level difference. These set-ups have plants placed directly between the sender and the receiver, which might mean that placing plants directly in this path might create the best results in sound reduction. This is as expected because in literature it was found that the position of isolation in the direct path of speech had the biggest effect.

RESULT: SUMMARY

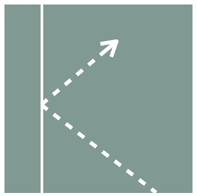
From the pilot experiment, clear indications were found that potted plants can help to reduce noise and thus improve acoustics. Configuration 2 has the best acoustic design due to the reverberation time which closest approaches the guidelines of the open office reverberation time, it seems to distribute reflections on other locations compared to an empty space, and the level difference between the two sides of the lab space is almost the highest with minimal differences to the highest level differences.

Lowest

1.52

Reverberation time

Effective



Redistribution

High

3

Level Difference

***Configuration 2** has the best acoustic design*

CALL TO ACTION

This being said it is still worth investigating why the reverberation times of the first 4 configurations do not have many differences, further experimentation is essential to study which of the spatial arrangements are most effective in reducing noise in this experimental environment.

Increase to

8%

Green Volume

Since the pilot experiment was conducted using a relatively low plant density of 4.2%, no solid conclusion can be drawn yet. By increasing the green volume to 8%, as suggest by the result of MOSSLAB 1.0, the effect of the plant arrangements will be enlarged, thus leading to more reliable results on which plant arrangement is most suitable for improving acoustics.

Selection of

Plant Species

The plant characteristics that were found to be most important for attenuating office noise are: high leaf density, coarse and pubescent leaf texture, perpendicular leaf orientation, large and elliptic leaves and high leave weight. Some plants that carry multiple of these beneficial traits are the furry feather calathea (Calathea rufibarba) and the felt bush (Kalanchoe beharensis).

Imitate

Office Environment

During the pilot experiment, the office remained rather empty. While in a more realistic office environment, office equipment (PCs, phones, etc.) would be present which would affect the sound. The emptiness, high amount of concrete, and open ceiling in Bright Lab may therefore have led to a distorted picture of how sounds are reflected in the office.

Better Cities
Better Life

5-25 minutes spent
in a biophilic environment
can elicit positive
restorative responses.

MOSS
Makers of Sustainable Spaces
www.moss.amsterdam

Danzigerbocht 55
1013 AM Amsterdam, The Netherlands

Kelai Diebel
kelai@moss.amterdam
+31(0)6 33 89 02 59