

BIO-TECH TRAINERS WORKSHOP

“From natural to engineered ecosystems”

Green roof as Solution for the mitigation of Urban Heat Island and Urban Water Management Issues

Dr. Séré Geoffroy



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LABORATOIRE SOLS ET ENVIRONNEMENT

Introduction



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Structure and Aims of the Lecture

1. Define and describe the causes and consequences of 2 main environmental urban issues: Urban Heat Island & Urban Water Management
2. Present some French political responses at different levels (State, Municipality) => *not presented here*
3. Describe the emergence and development of green roof technologies
4. Assess the contribution of green roof to the mitigation of the above-mentioned issues
5. Evocate the impact of GR ageing on the performances
6. Visit of experimental green roofs => *tomorrow morning*

All Scales matter!



Urban environmental Issues:

Urban Heat Island (UHI)

Urban Water Management (UWM)



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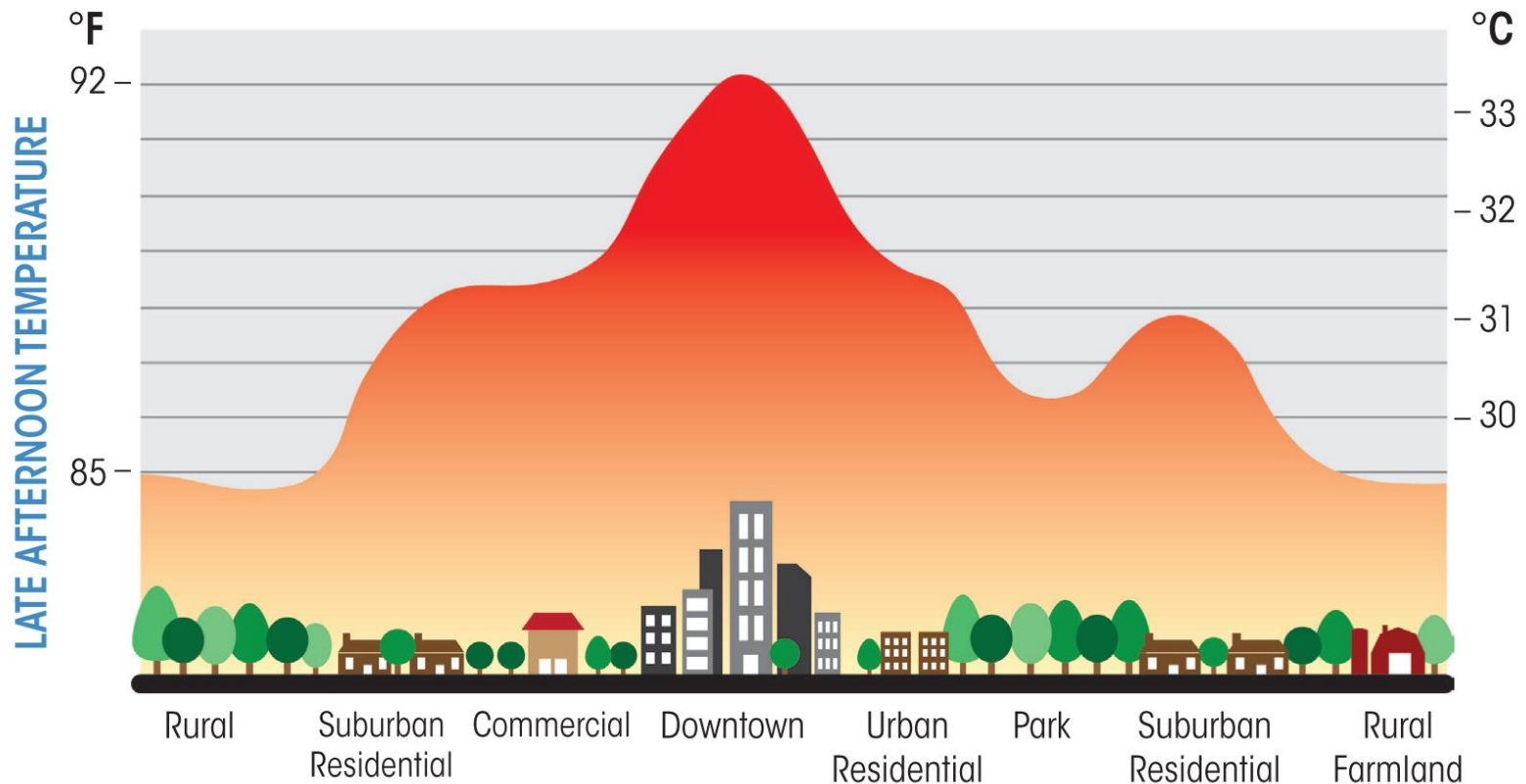
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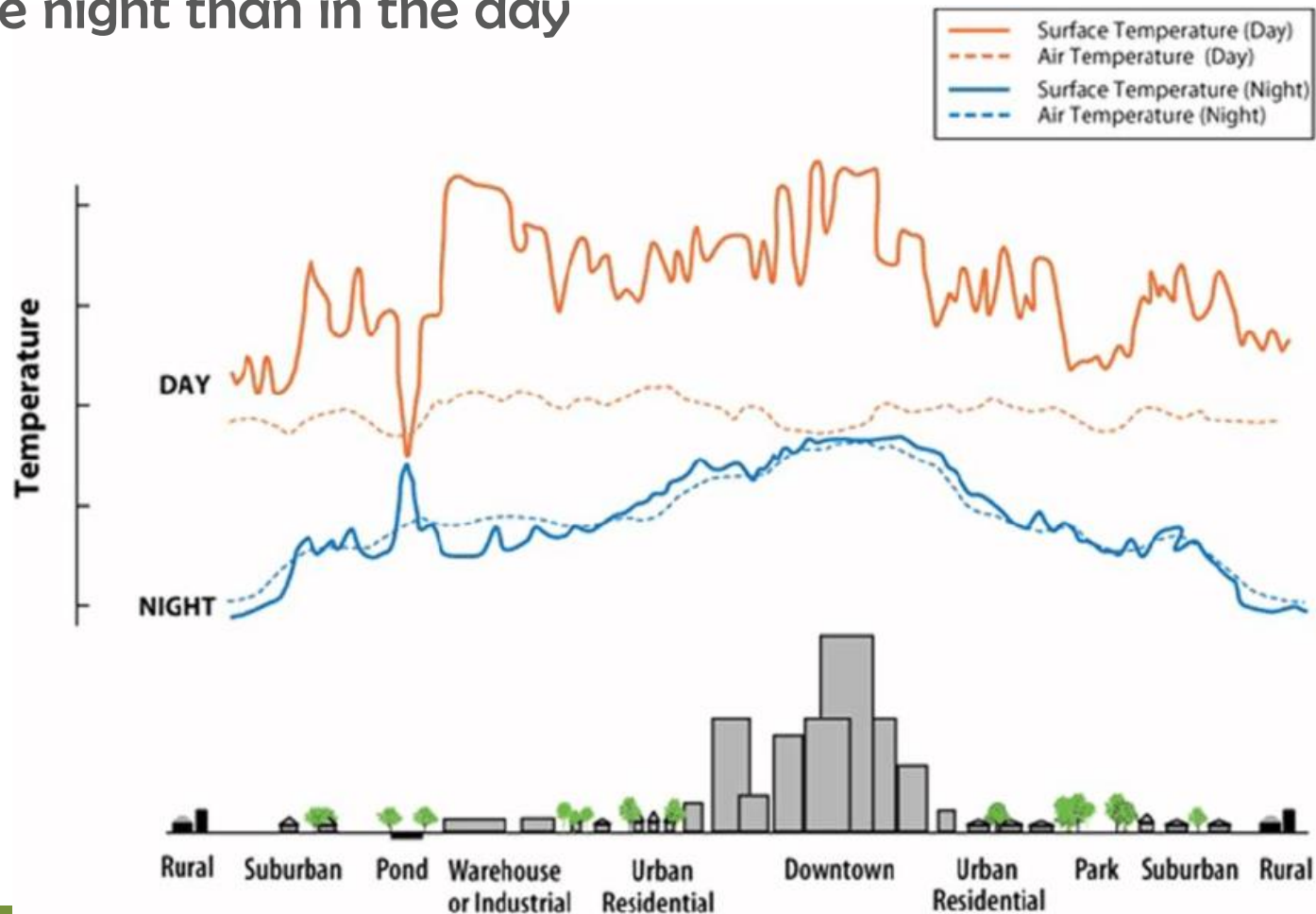
Description of UHI

- Urban Heat Island is an urban area or metropolitan area significantly warmer than its surrounding rural areas due to human activities



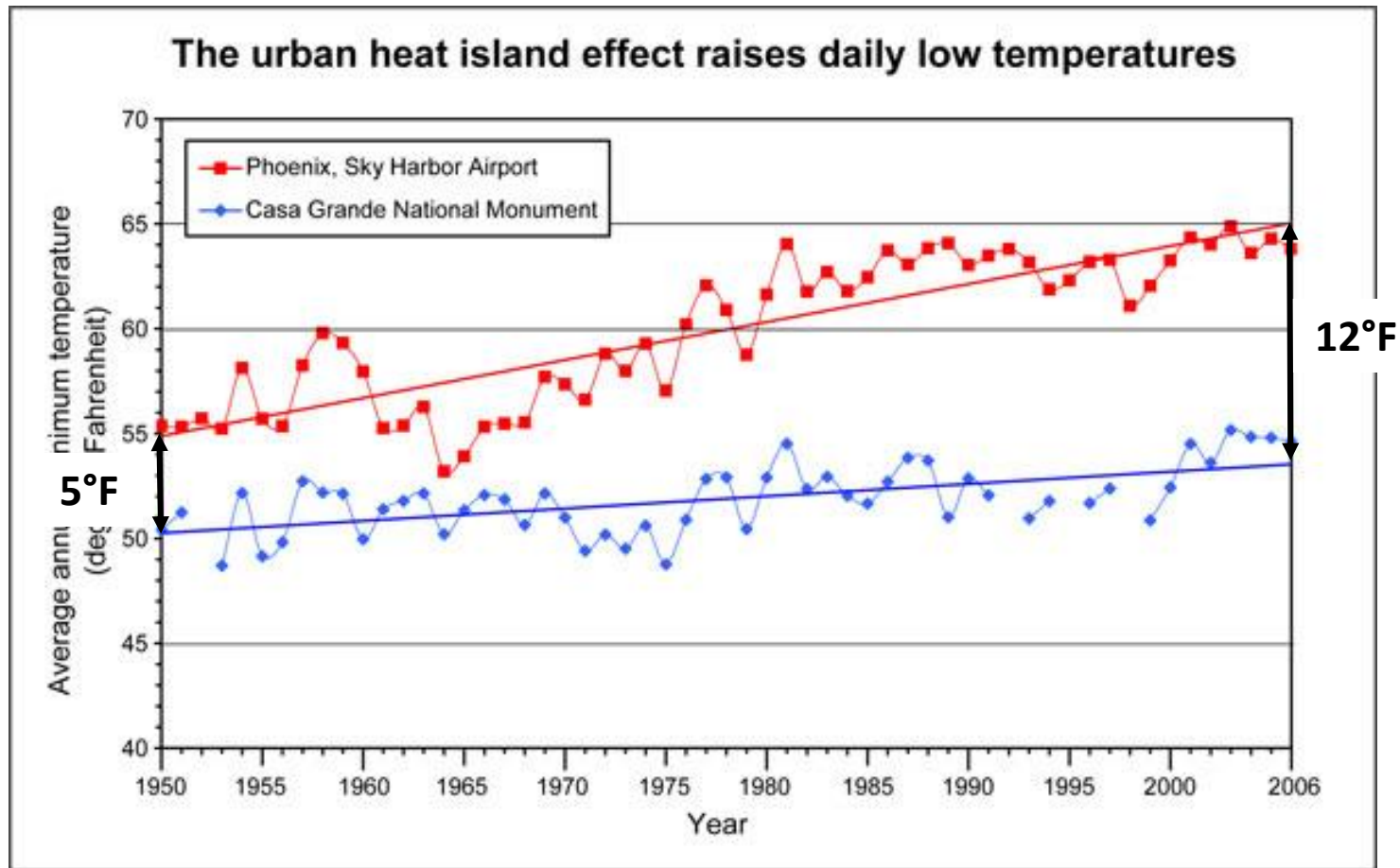
Description of UHI

- UHI, as expressed by air temperature, is more pronounced in the night than in the day



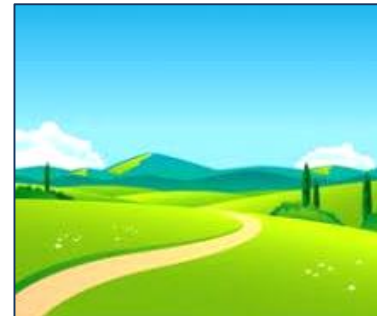
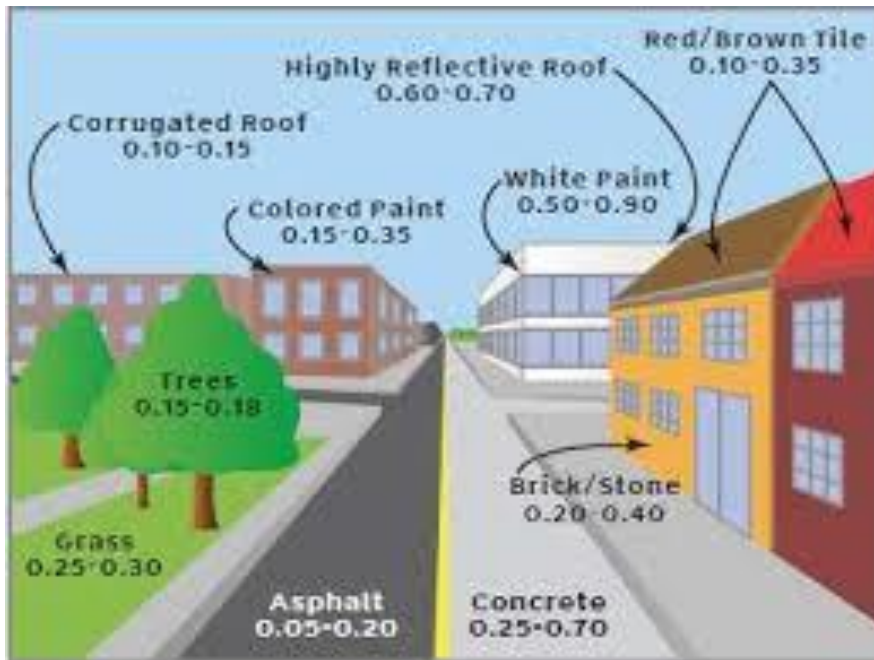
Description of UHI

- Increasing tendency of UHI over the years



Causes of UHI

- Albedo: proportion of the incident light or radiation that is reflected by a surface
- Lots of cities materials (*e.g.* asphalt, bricks) have low albedo
=> urban areas store heat during the day



$$\alpha = 0.2 - 0.3$$



$$\alpha = 0.1 - 0.2$$

Causes of UHI

- Urban morphology: shape of cities in terms of their form, function, and layout
- High buildings and narrow streets => poor ventilation + trapping effect

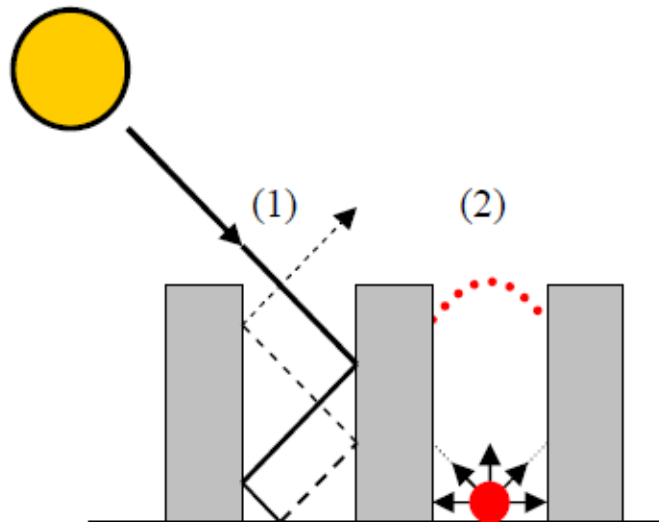
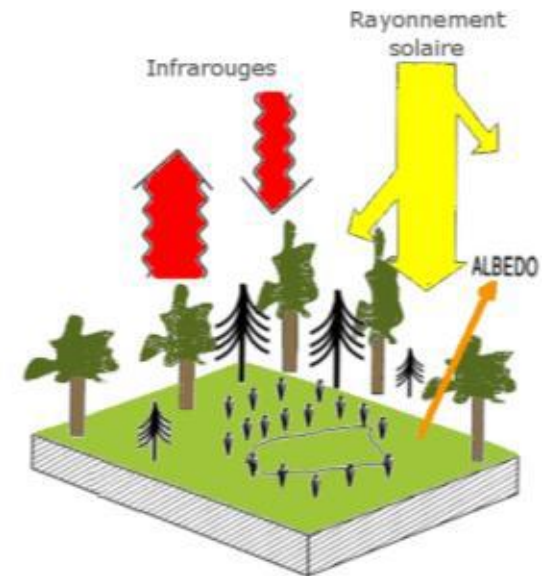
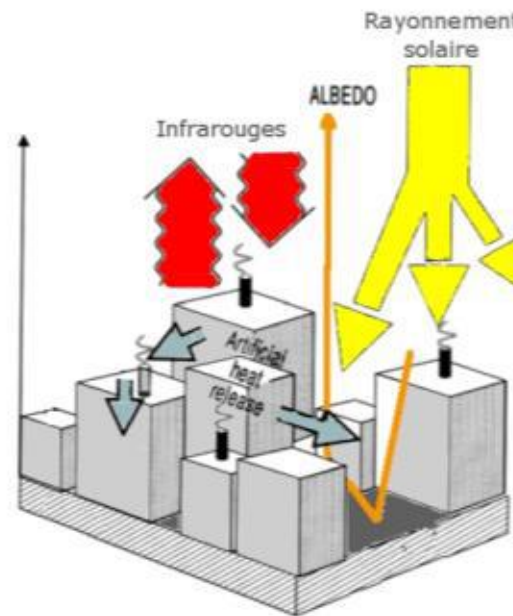


Fig.4 : Effet de Trapping
(UV et IR)

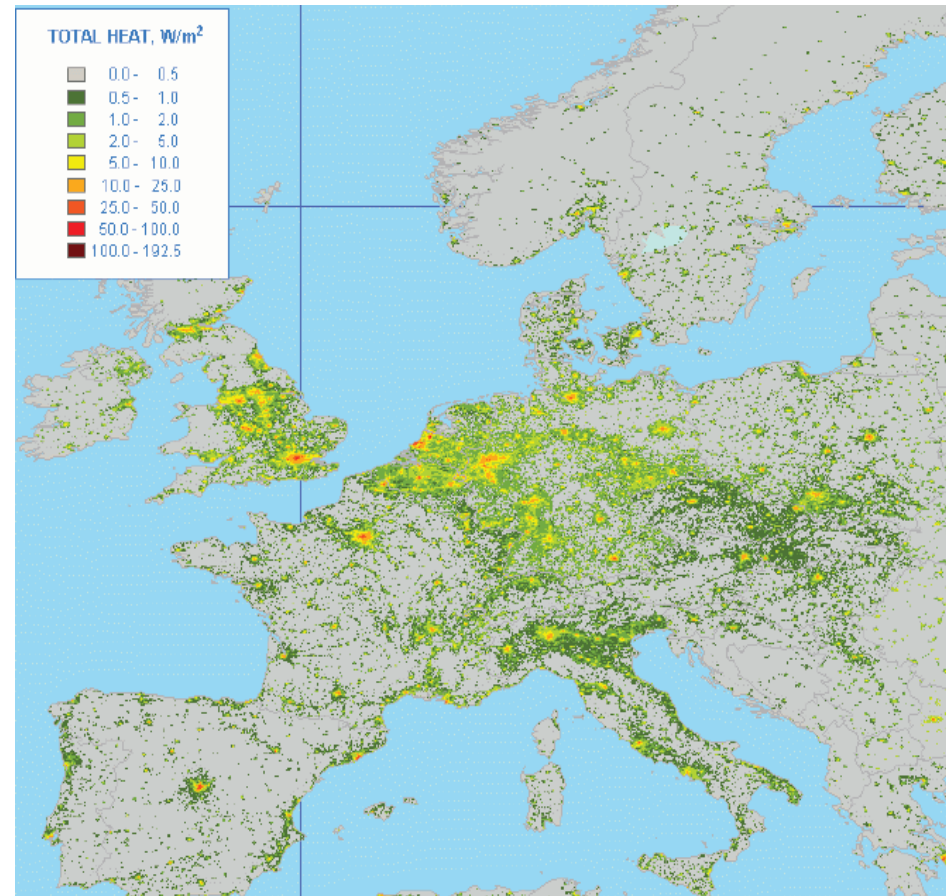


Causes of UHI

- Anthropogenic heat rejection: consequence of human activities (e.g. car, heating, air-conditioning)



Heat loss form private building



European heat rejection mapping

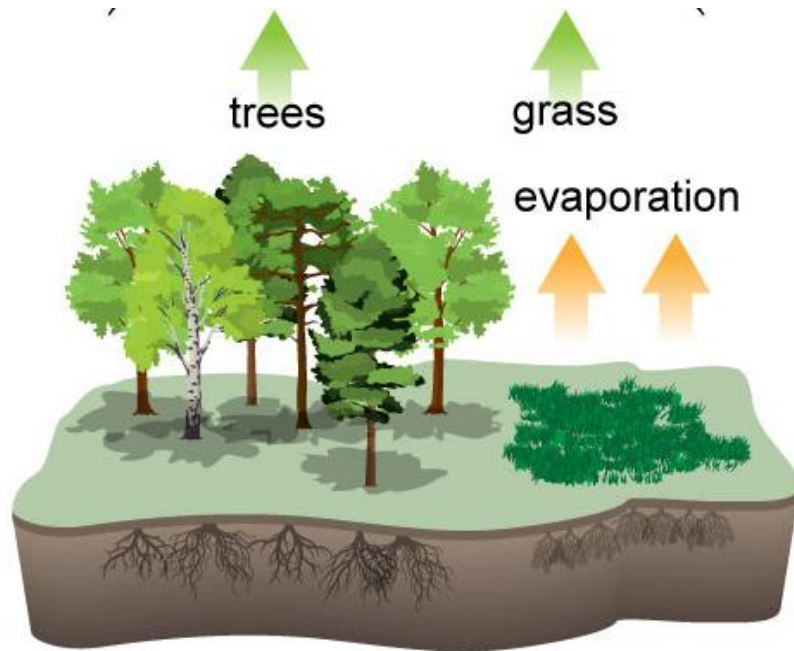
Causes of UHI

- Greenhouse-gases and fine particles emission: different sources (*e.g.* car, heating, industrial processes) from human activities
- They generate a local greenhouse effect by transforming solar radiation into infrared emissions that cause T°C increase



Causes of UHI

- Lack of vegetation: Urban areas are still sparsely vegetated
- Vegetation contributes to cooling effect through evapotranspiration and shadowing



Consequences of UHI

- Disturb urban microclimate (*e.g.* altering of local wind patterns, development of clouds and fog, rates of precipitation)
- Compromise human health and comfort (*e.g.* troubles due to extreme heat, respiratory diseases)
- Increase energy consumption (*e.g.* air conditioning increase)
- Impair water quality (by heating it)



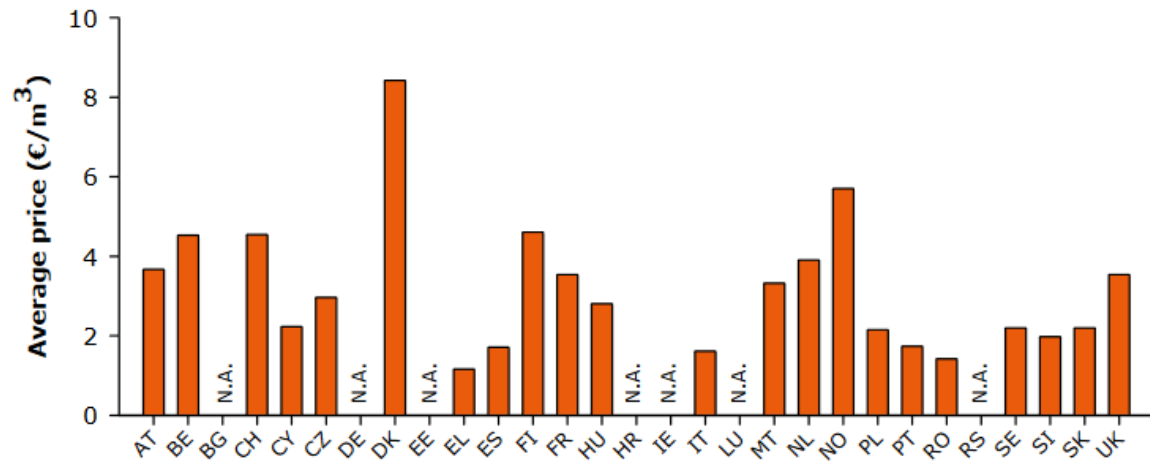
Description of issues with UWM

- Urban flooding is the result of heavy rainfall and the consequence of the saturation of drainage systems and/or rivers/coast overflowing
- “The economic costs associated with these extreme events exceeded \$110 billion in the year 2012 alone” (Neal, 2014)



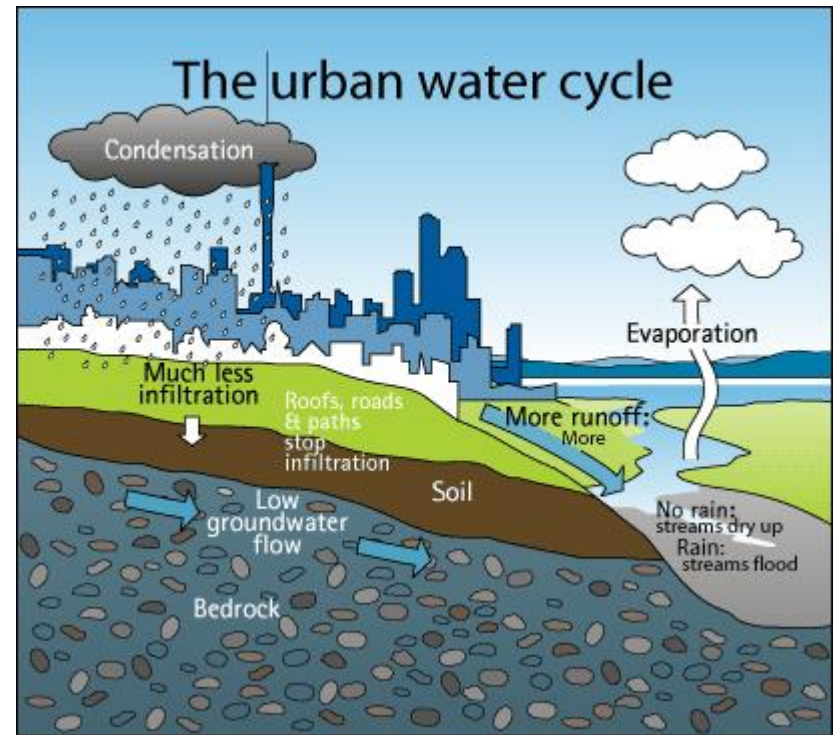
Description of issues with UWM

- Decline of water quality is the consequence of the contamination of water by trace elements and organic pollutants through runoff
- Drinking water - *i.e.* surface or ground water treated in order to be drinkable - has various prices among countries:
1.6 € m⁻³ (Spain) up to 8.3 € m⁻³ (Denmark)



Causes of issues with UWM

- Soil sealing: covering of the ground by an impermeable material
- It prevents water from infiltrating and cleansing through the soil



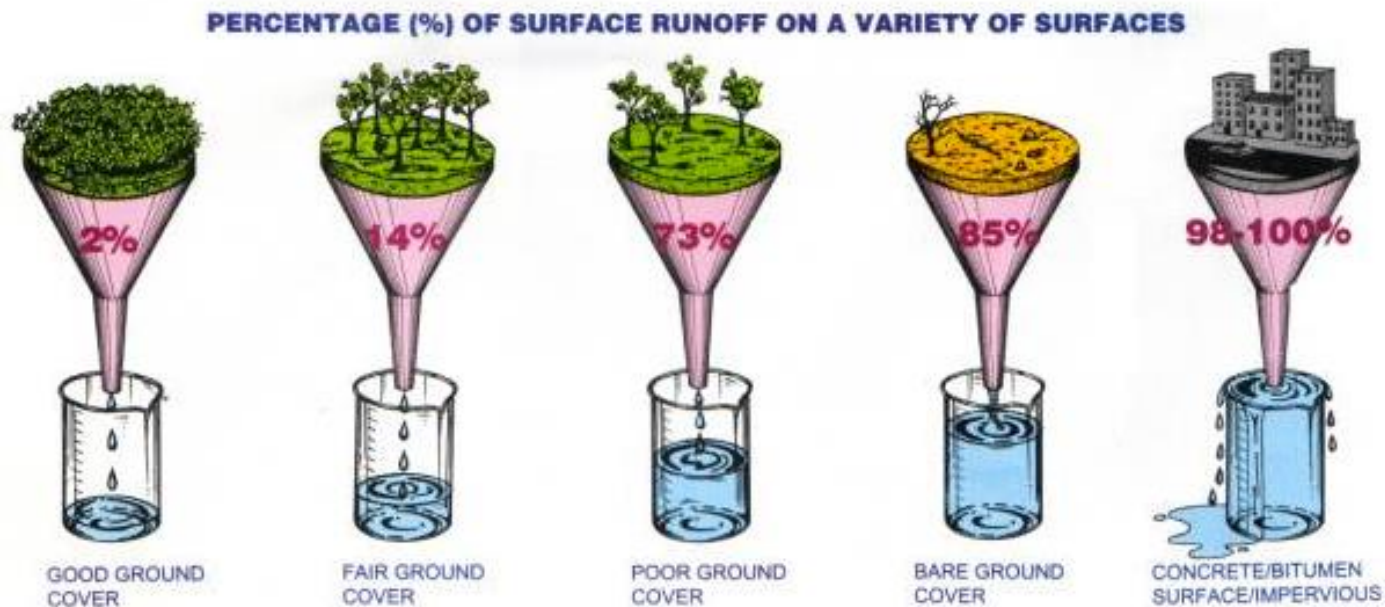
Causes of issues with UWM

- Urban runoff: Urbanization increases the variety and amount of pollutants (organic contaminants, trace elements, viruses & bacteria, pesticides, road salts) carried into streams, rivers, and lake
- It increases the pollutant loads



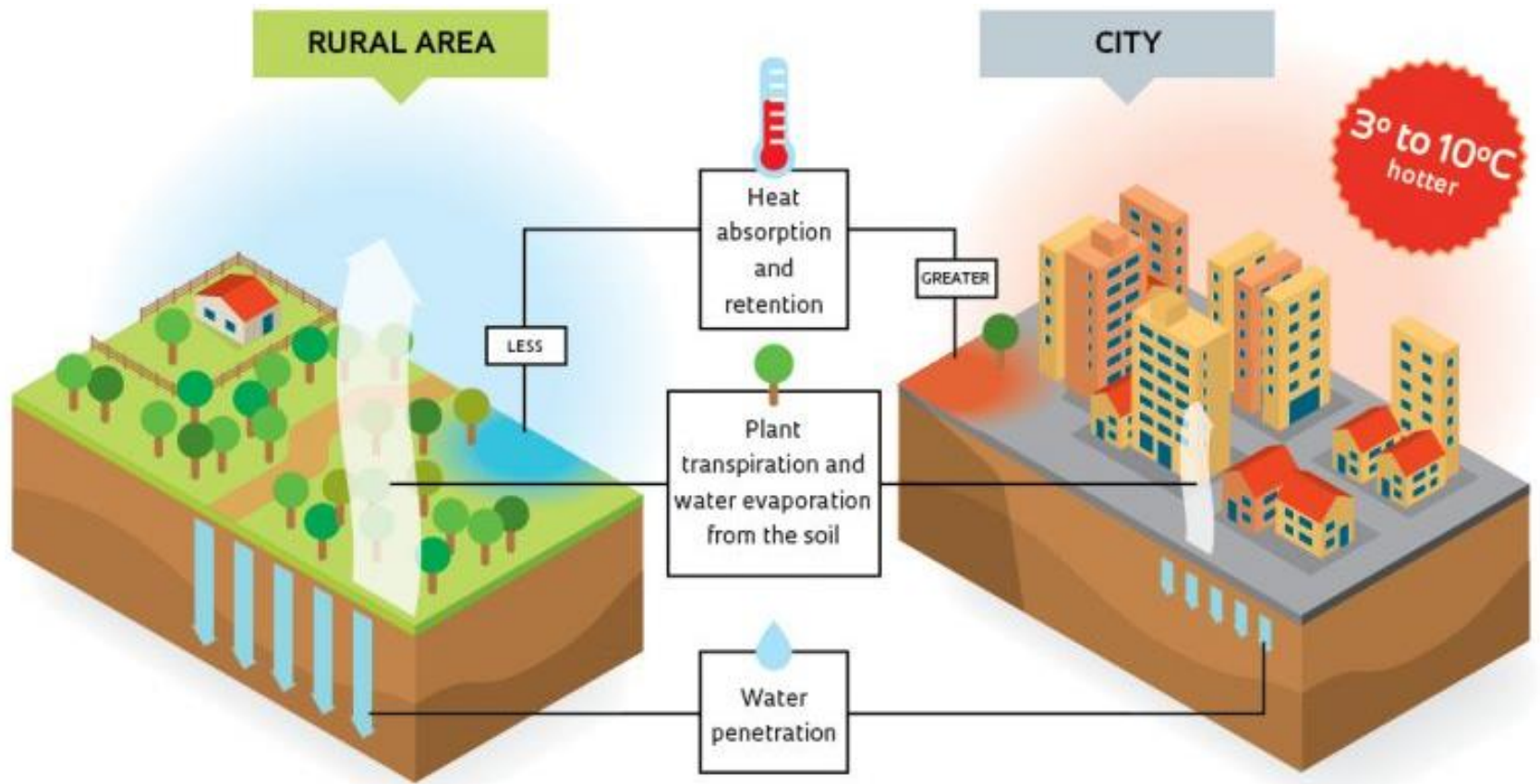
Causes of issues with UWM

- Lack of vegetation: Urban areas are still sparsely vegetated
- Vegetation needs infiltrating soils and contributes to water cycle through evapotranspiration and filtering



UHI + UWM issues

- Analogous causes, synergetic effects



Urban sprawl

- Since the mid 1950s the total surface area of cities in the EU has increased by 78 %, whereas the population has grown by only 33 %



What is a green roof?



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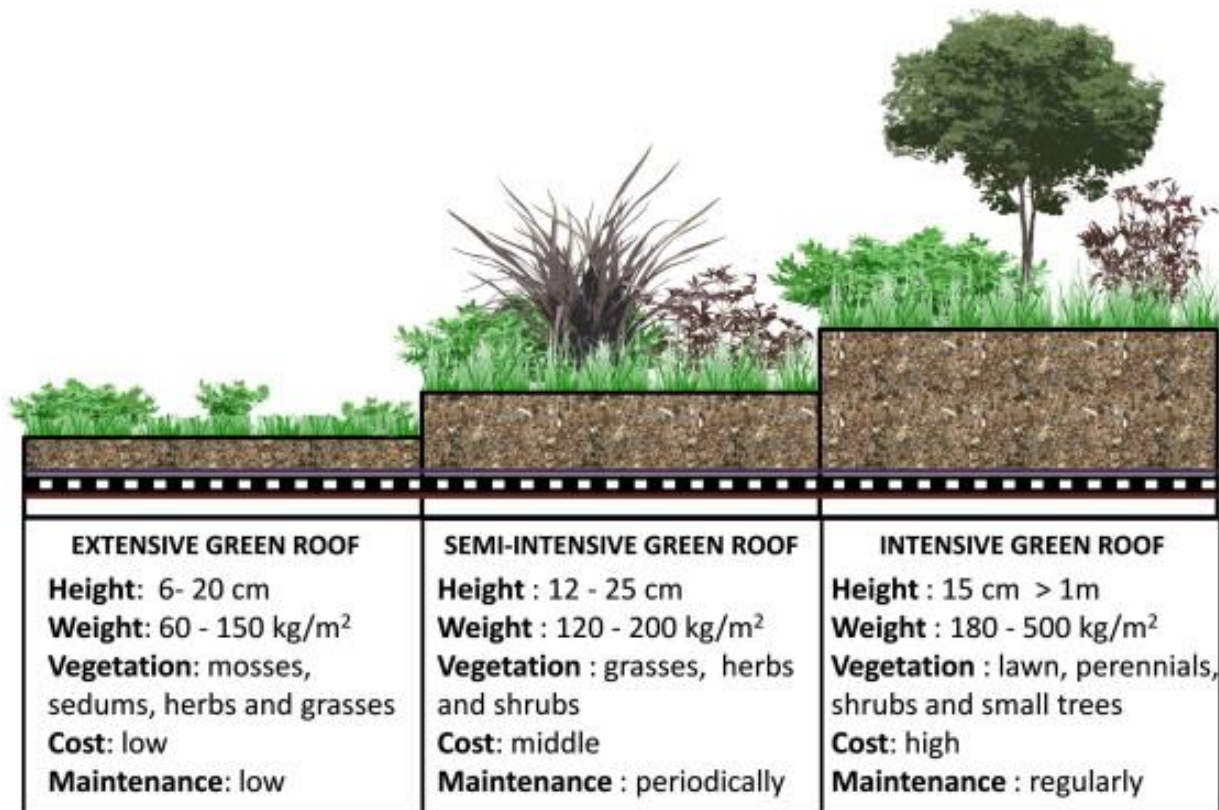
An ancestral technique

- Either for thermal insulation (Nearctic and Palearctic realms) or aesthetic purposes (Hanging Gardens) => Nature as a template



Three main types of green roof (GR)

- Classification – extensive / semi-intensive / intensive - as a function of their: depth, weight (required bearing capacity of the roof), vegetation, cost and maintenance



+ Rooftop vegetable garden

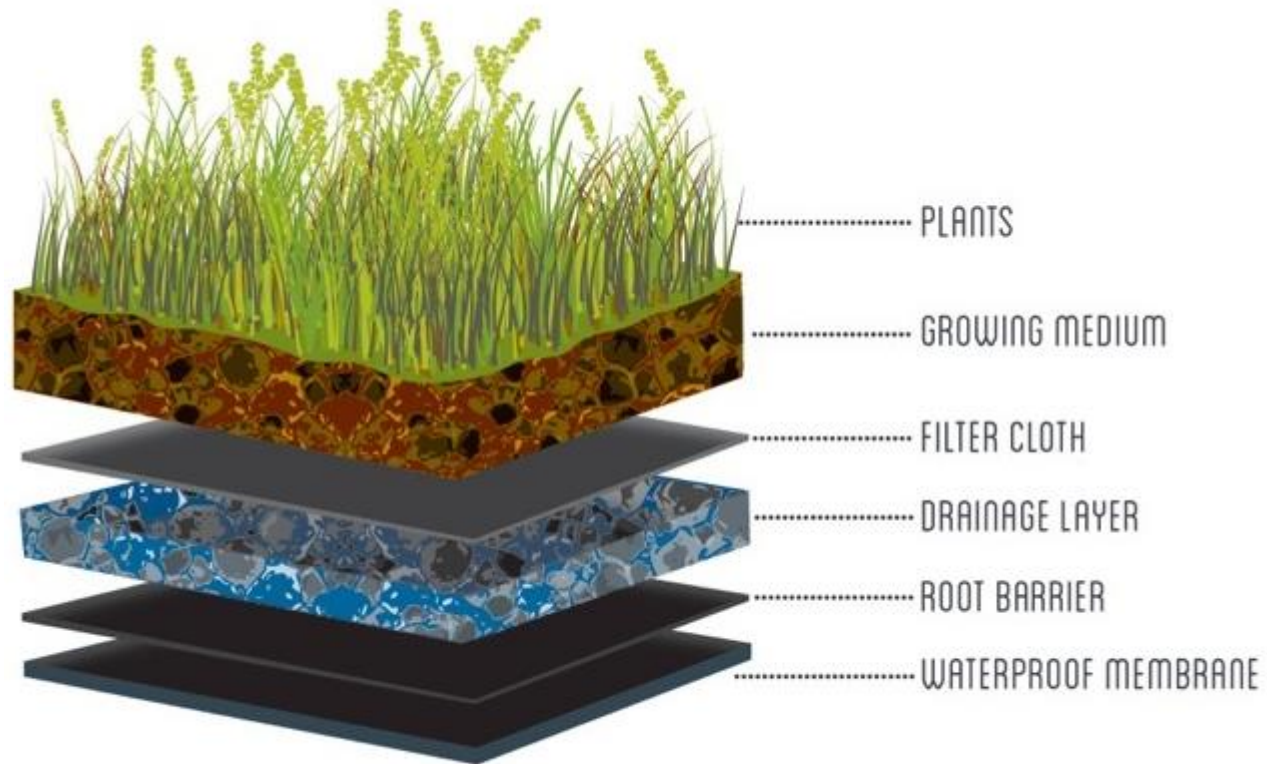
- Declination either as semi-intensive GR or growing containers



Montage d'une experimentation en toiture

Composition of an extensive GR

- Different layers with dedicated functions



GR's vegetation

- Plants adapted to dry & shallow soils that require low maintenance
- Various sedum species
- Ground cover (*e.g.* thyme, marigold)
- Blooming plants (*e.g.* armeria, iris)



sedum acre



sedum album



sedum floriferum



sedum hispanicum



sedum kamtschaticum



sedum reflexum



sedum sexanquale



sedum spectabile



sedum spurium



GR's substrate

- Mixtures of materials that shall be as light as possible, capable to provide nutrients and to store available water for plants
- Association of various proportion of organic (*e.g.* peat, compost, bark) and mineral (*e.g.* pozzolana, brick, expanded clay) products => depends on climatic conditions



Existing project

- Artem in Nancy = innovative extensive green roof that strongly limits the discharge of rainwater



Existing project

- Centre Robert Doisneau in Paris = a rooftop therapeutic garden dedicated to persons with reduced mobility



Ongoing project

- L'Hospitalité = green walls, rooftop vegetable garden, housing



Ongoing project

- Ôm at Issy-les-Moulineaux = a feng-shui architectural project that combines hanging trees, green roof, housing and commerces



Ecosystem services provided by green roof



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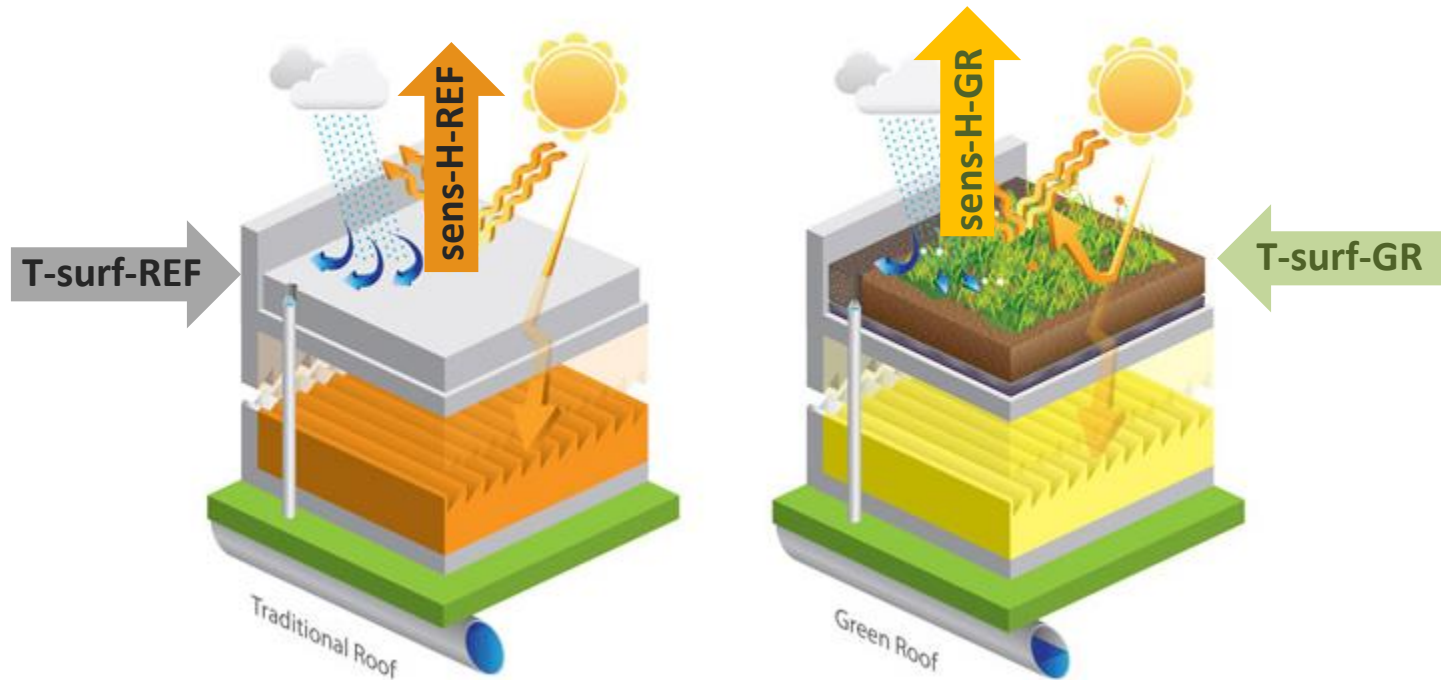


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Mitigation of UHI

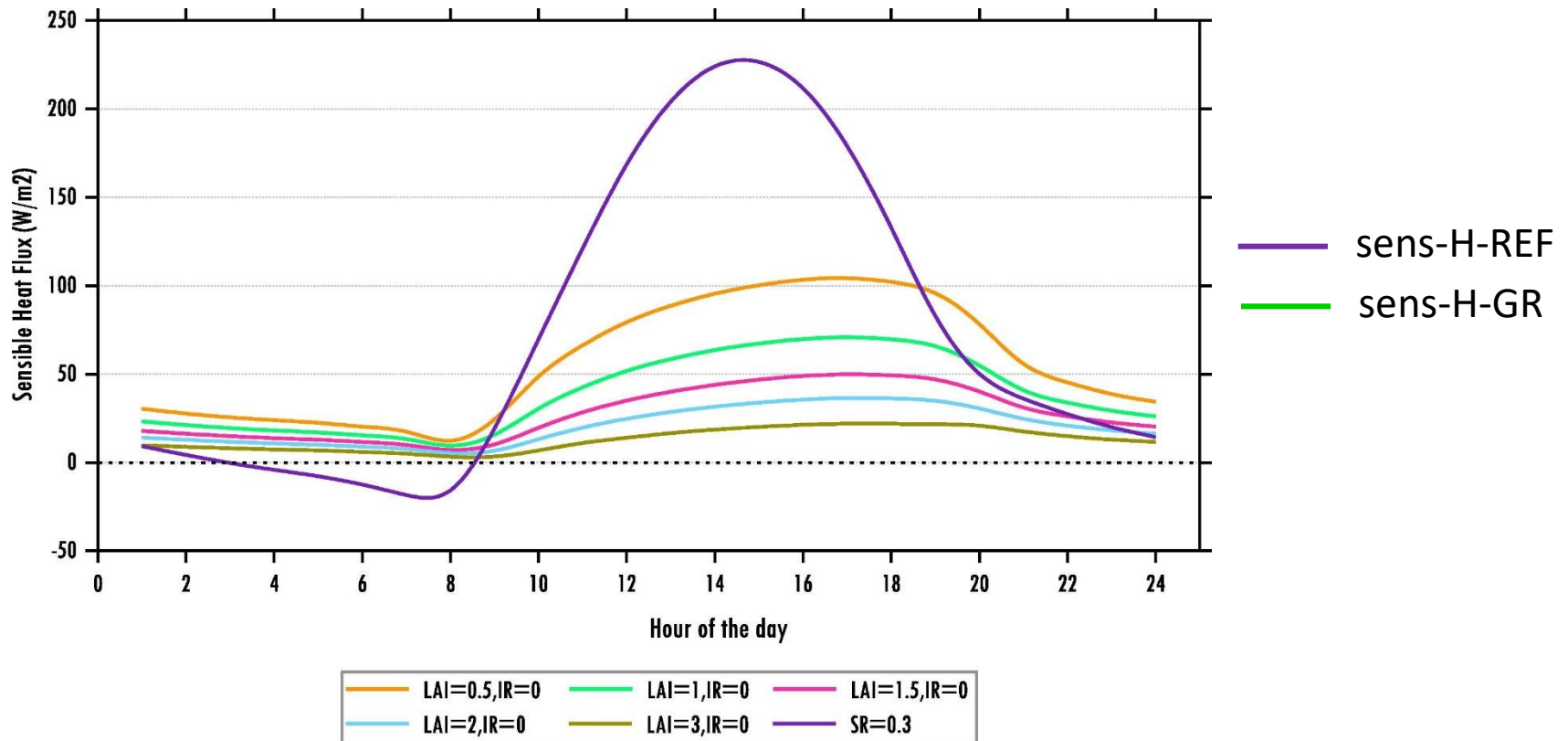
- Sensible heat flux + surface temperature

Green Roof Comparison



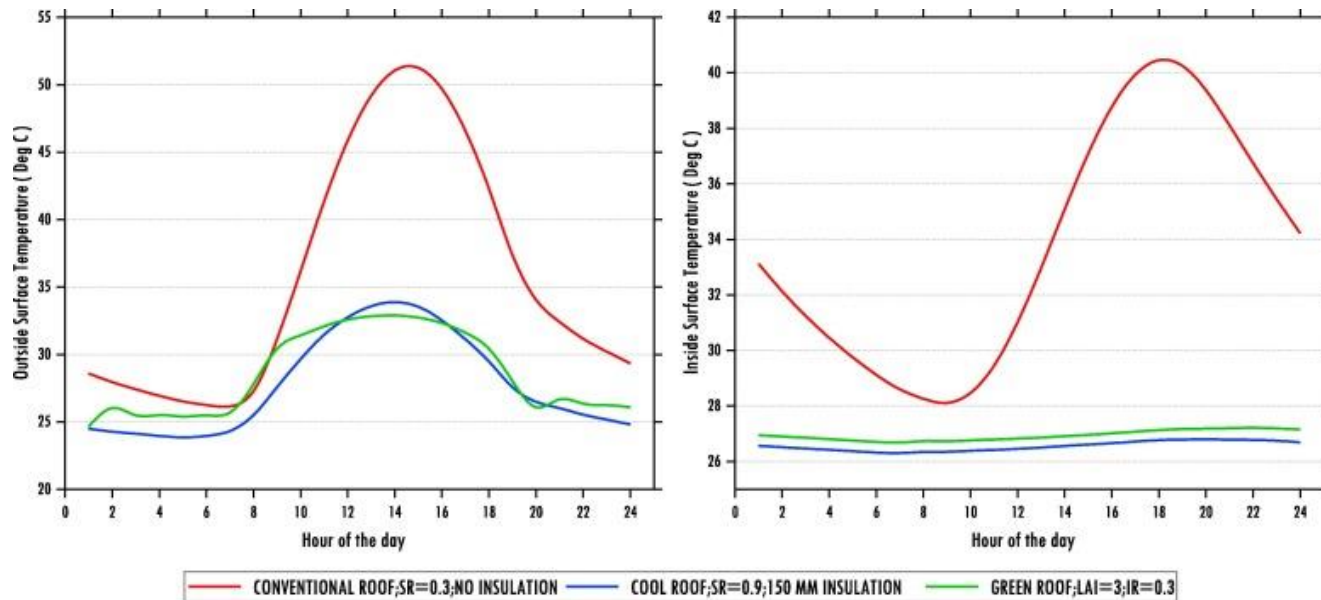
Mitigation of UHI

- Decrease of the sensible heat flux



Mitigation of UHI

- Reduction of the surface temperature

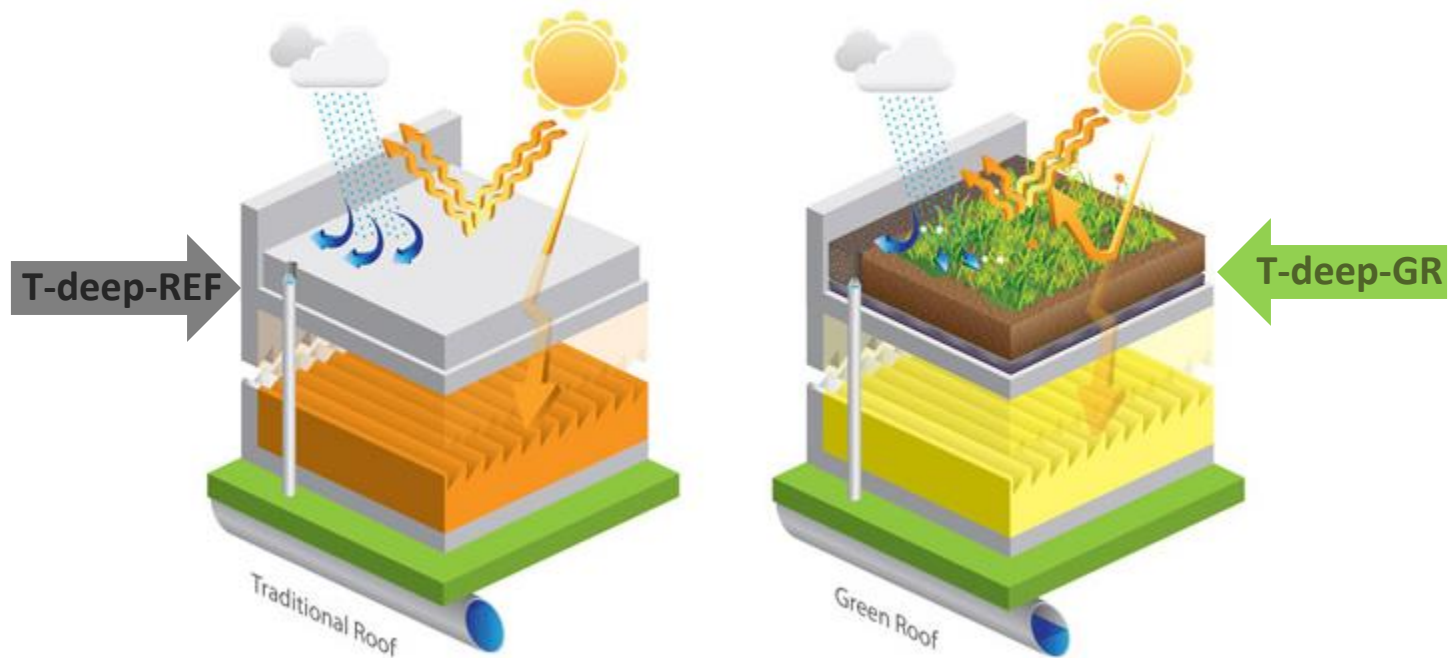


— T-surf-REF
— T-surf-GR

Thermal insulation of the building

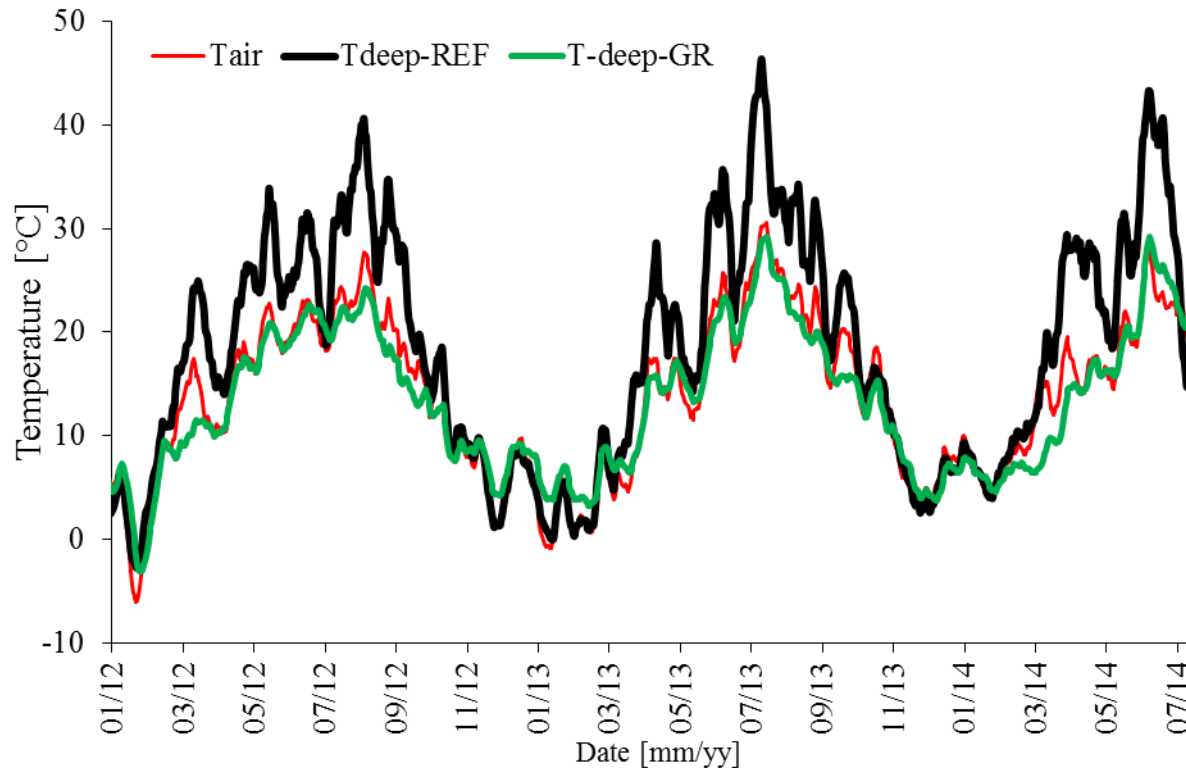
- Deep temperature

Green Roof Comparison



Thermal insulation of the building

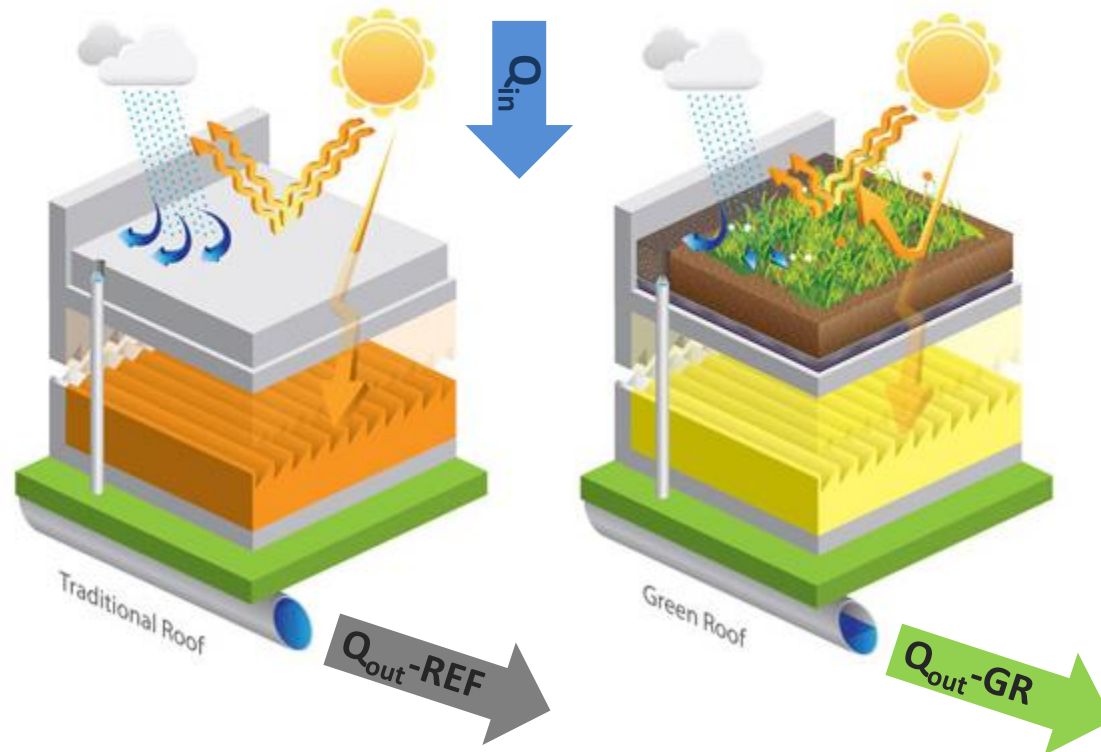
- Mitigation of the daily temperature variation thanks to GR



Retention / detention / evapotranspiration of water

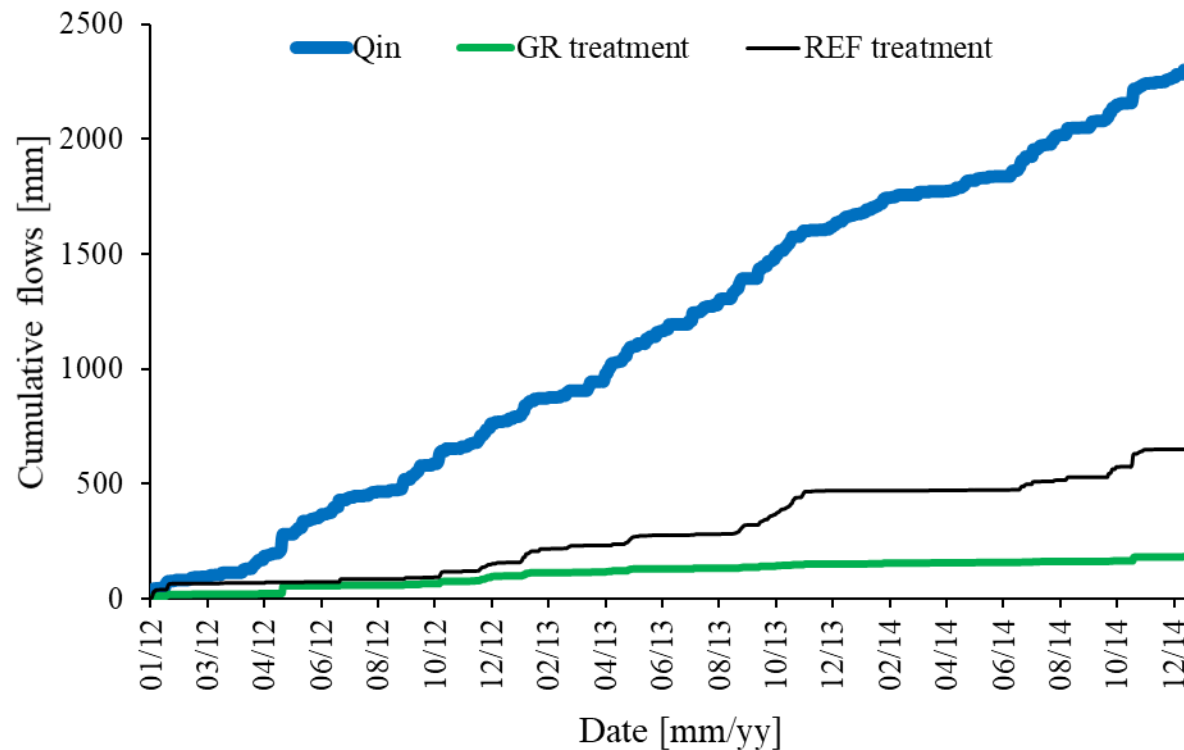
- Water fluxes

Green Roof Comparison



Expected contributions of GR to major stakes

- Measurement at the GR's scale



Influence of GR ageing on performances



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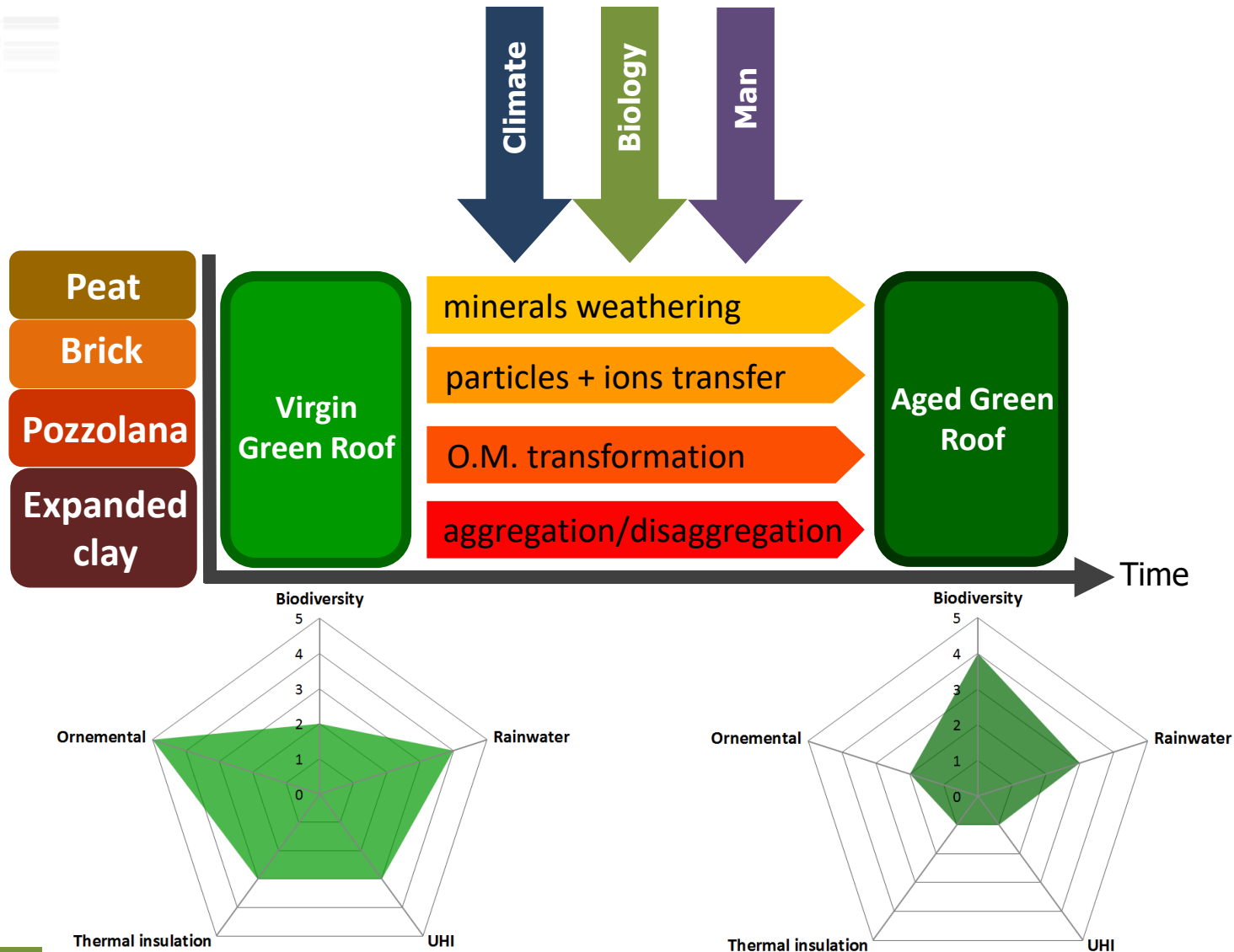
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Question

- Sustainability of green-roofs' performances?



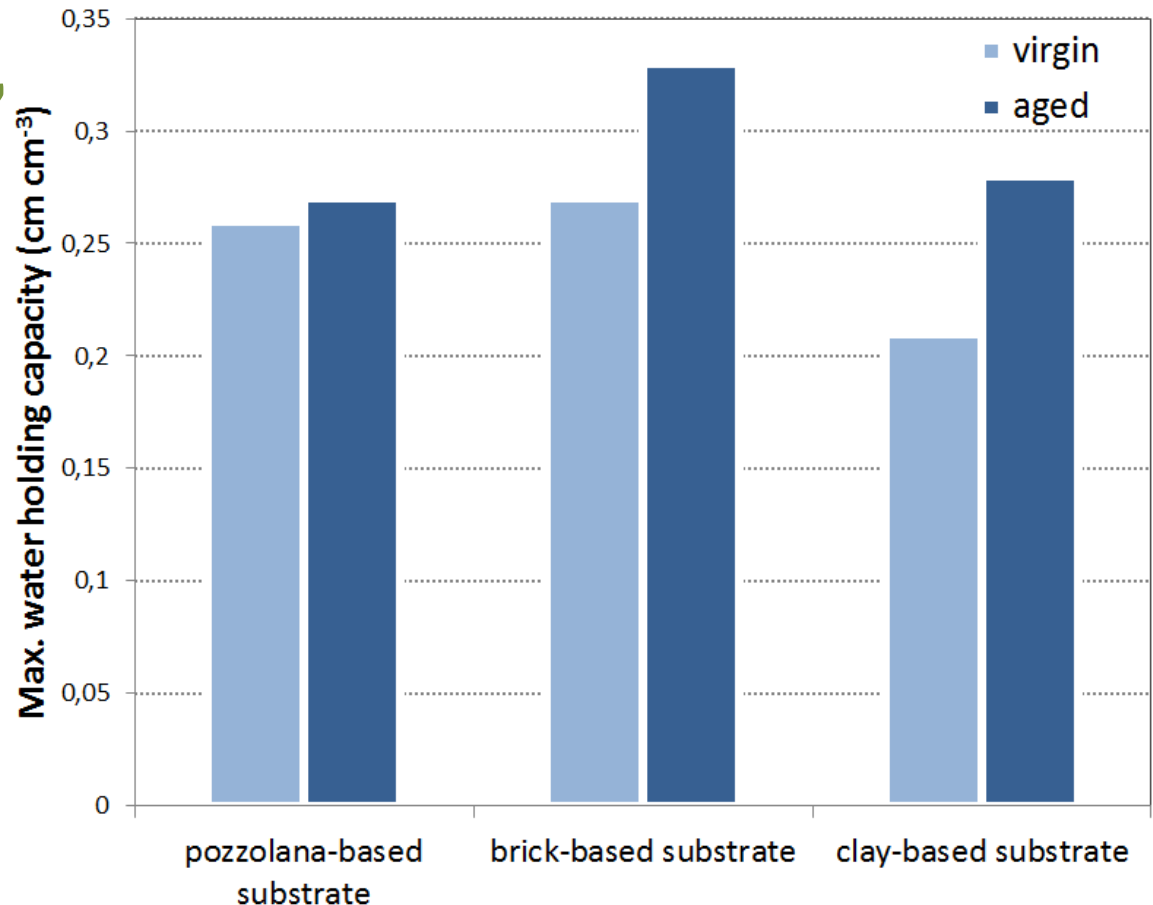
Scientific question



Maximum water holding capacity

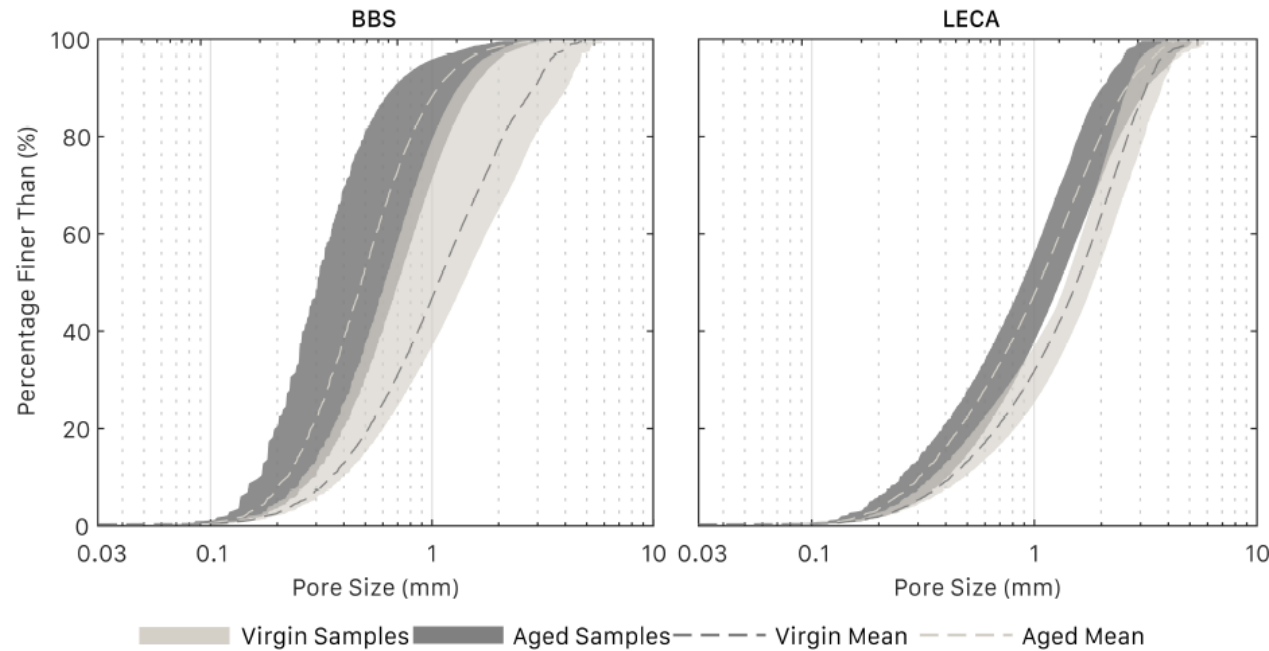
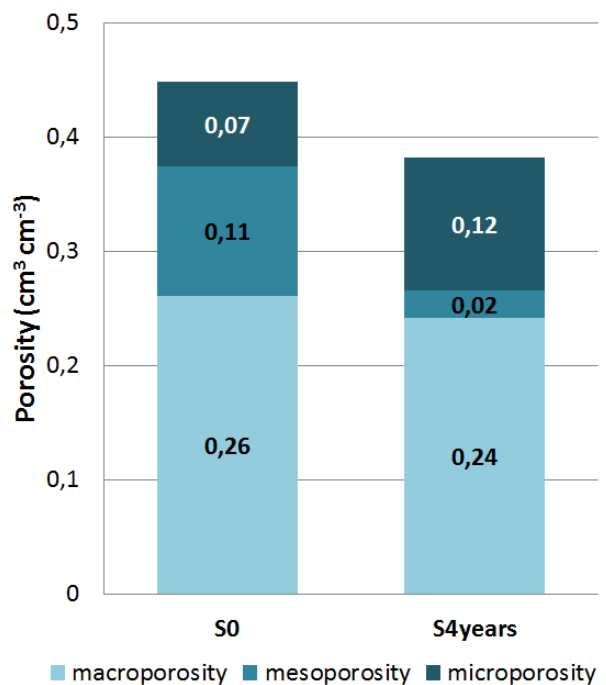
- Comparison of virgin and aged (3 to 5 years) substrates

- Increase of the max. water holding capacity in all cases,
- despite some decrease of bulk density...
- ... complex evolution of the poral architecture



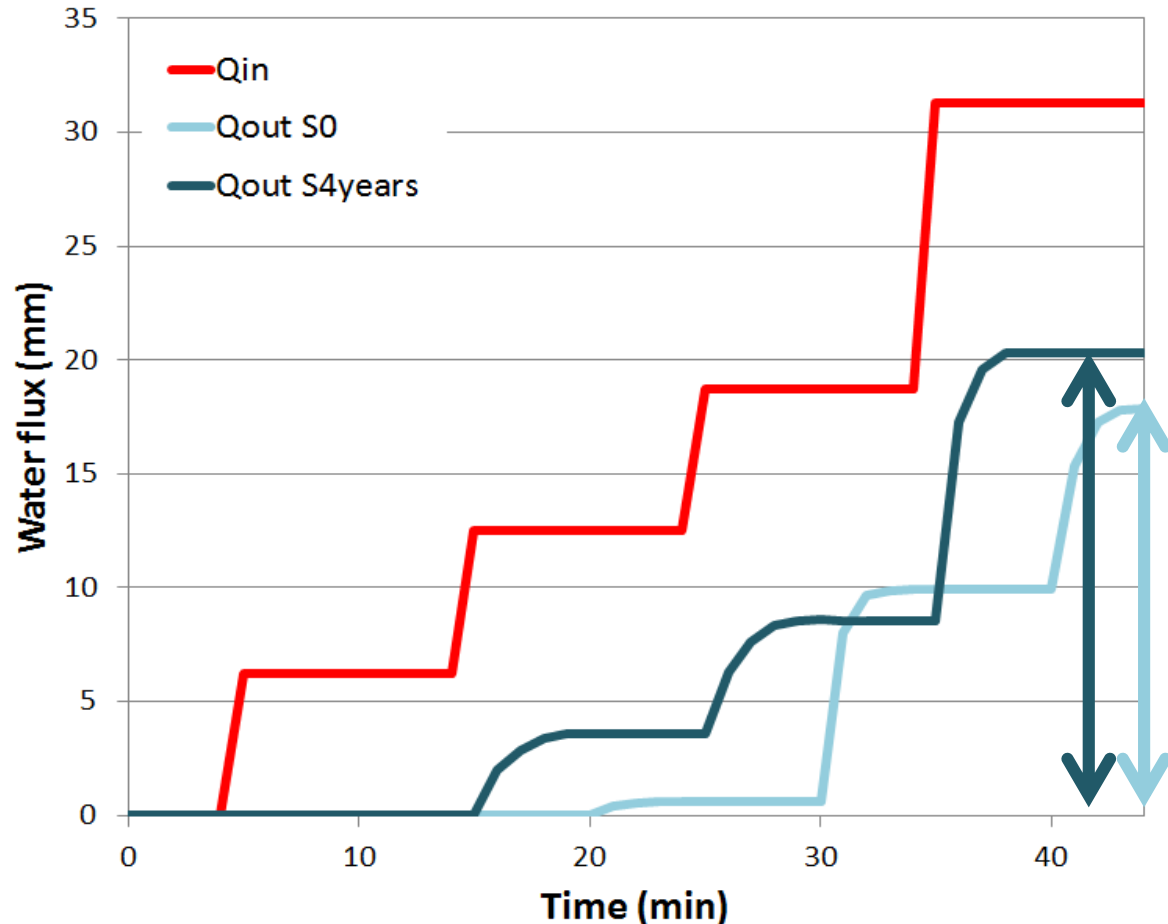
Poral architecture

- Comparison of virgin and aged (3 to 5 years) substrates
 - Significant increase of microporosity over time
 - Variable decrease of macroporosity and mesoporosity



Hydrological performances

- Lab experiment
 - The virgin substrate retain more water (15 mm) than the aged one (11 mm)
 - The detention time of the aged substrate (15 min) is smaller than the virgin one (20 min)



Take Home Messages



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Conclusions

- Urban areas concentrate specific environmental issues (UHI + UWM)
- Green roof is a Nature Based Solution
- that could provide valuable ecosystem services and contribute to the mitigation of UHI and UWM
- But green roofs are living systems that are submitted to an early pedogenesis which may affect their performances



