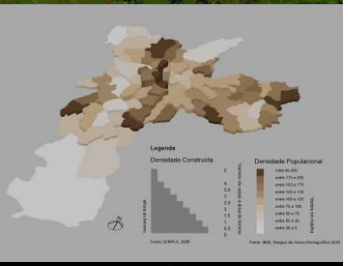
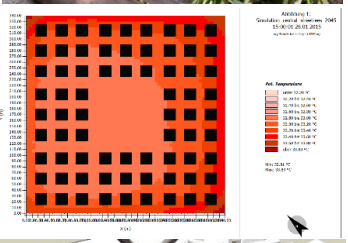



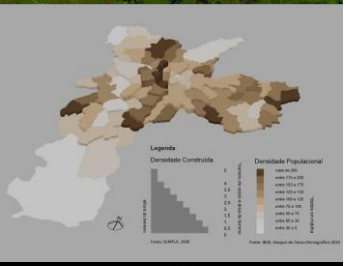


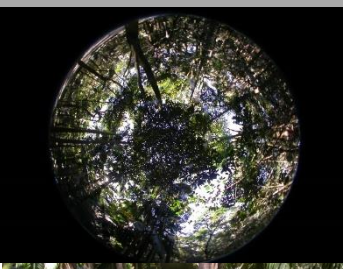


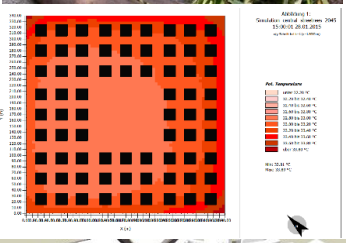

Vegetation and Urban Microclimate

AUT0225 – Conforto Ambiental em Espaços Urbanos Abertos

Prof. Dra. Denise Duarte, Prof. Dr. Leonardo Monteiro, Prof. Dra. Ranny Michalski






What a difference green makes

AUT0225 – Conforto Ambiental em Espaços Urbanos Abertos

Prof. Dra. Denise Duarte, Prof. Dr. Leonardo Monteiro, Prof. Dra. Ranny Michalski


ESTAÇÃO ALENCASTRO
OS 10 MANDAMENTOS


Jesus
3322-3960


Até aqui nos ajudou o Senhor. 1° SM 7.12b
Lindu
Bijoux Finos
CENTER BABY

Microclimate impacts of vegetation

Which are these effects?

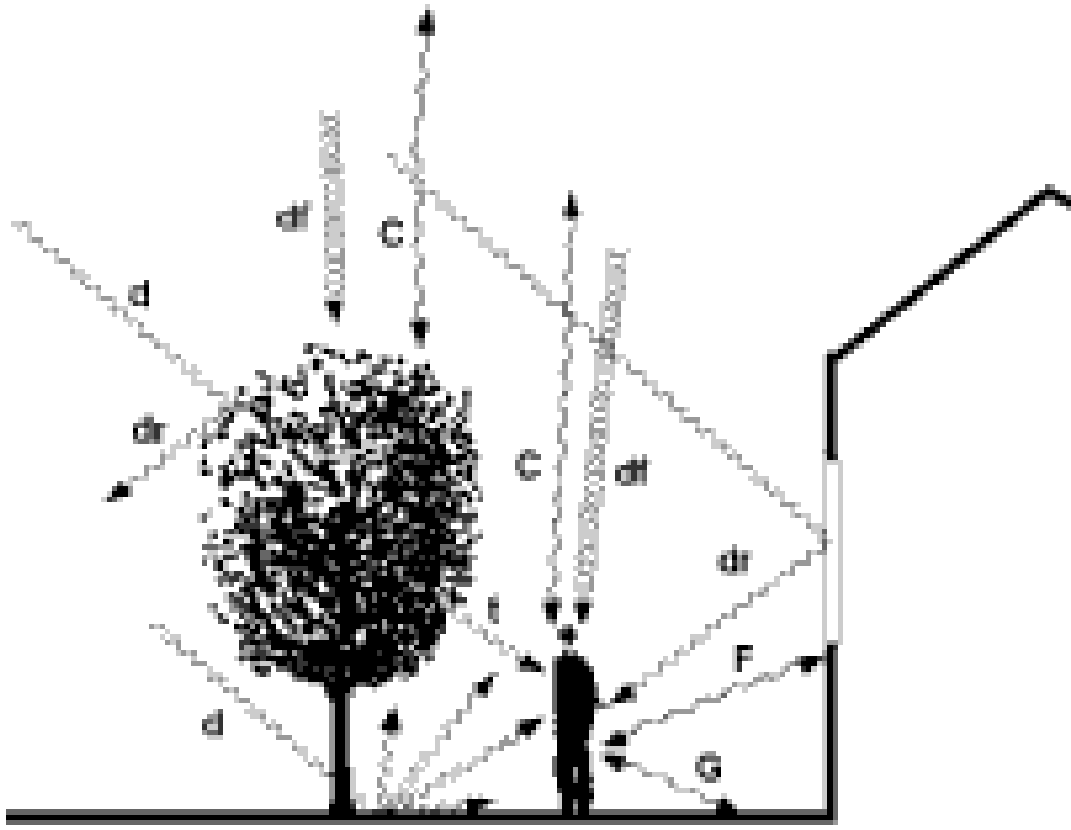
How big are these effects?

What is the spatial distribution of these effects?

How big is the influence of an urban park?

How far from the green areas could the microclimatic benefits be felt?

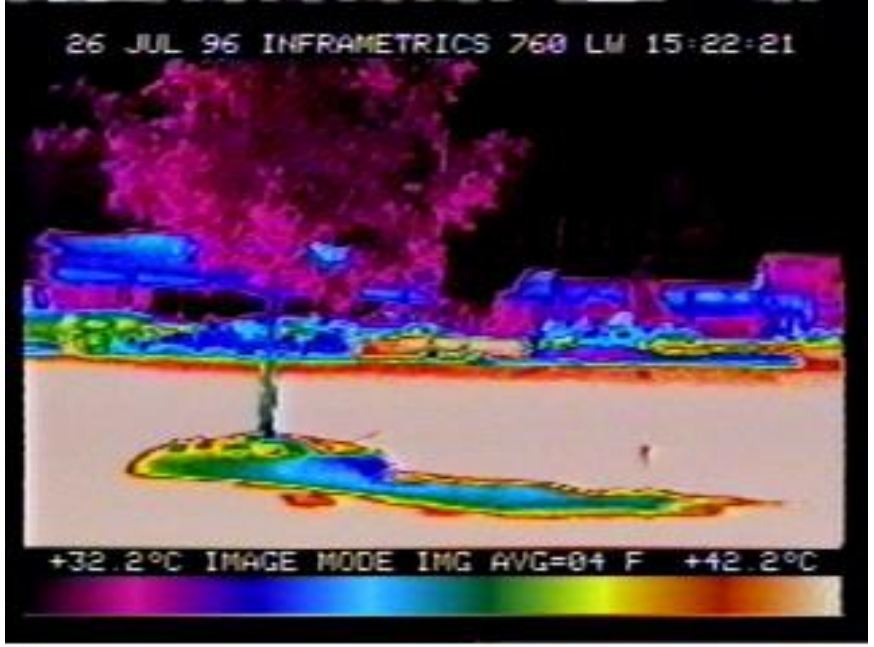
How to quantify the impact of shading, gap fraction, tree geometry and soil characteristics?



Vegetation Impacts

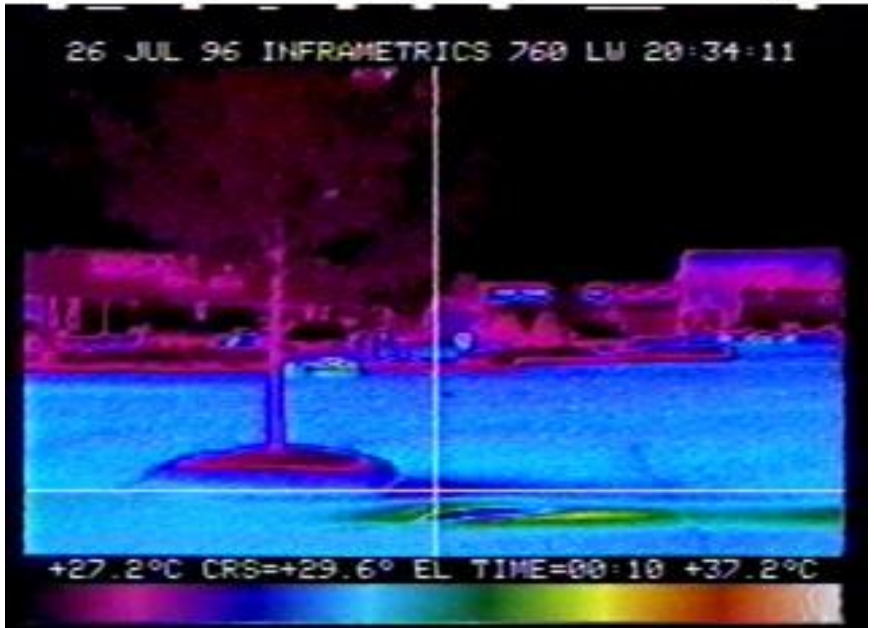
Differently from inert materials, energy process in vegetation happens by two mechanisms:

- physical
- biochemical (resultant from photosynthesis and CO_2 exchange)



Day

Night



Vegetation Impacts

The presence of vegetation influences two fundamental mechanisms to decrease urban heating:

- shading
- evapotranspiration through the leaves

besides other effects like:

- retention of particulate material (pollution)
- storage of atmospheric carbon, etc.

Vegetation Impacts

Vegetation mitigates urban warming not by cooling the air, but by warming the air less.

Vegetation is more efficient than the replacement of surfaces to lighter colour materials or with high reflection coefficients, because inert materials have the capacity to absorb and store heat, and even a white surface can reach 10ºC higher than air temperature

Paley Park, New York, summer 2018

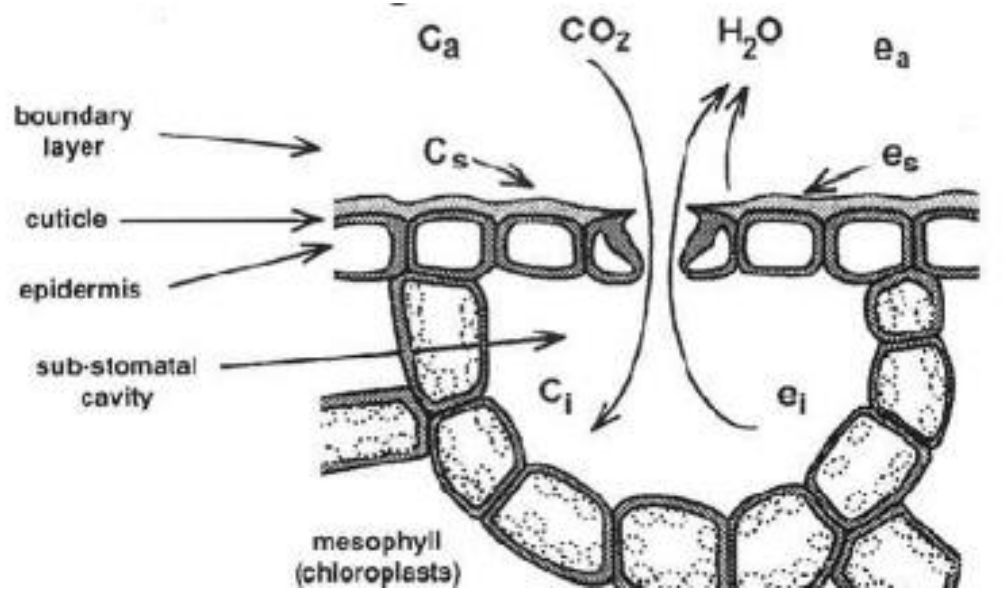
Central Park, New York, summer 2018

Evapotranspiration

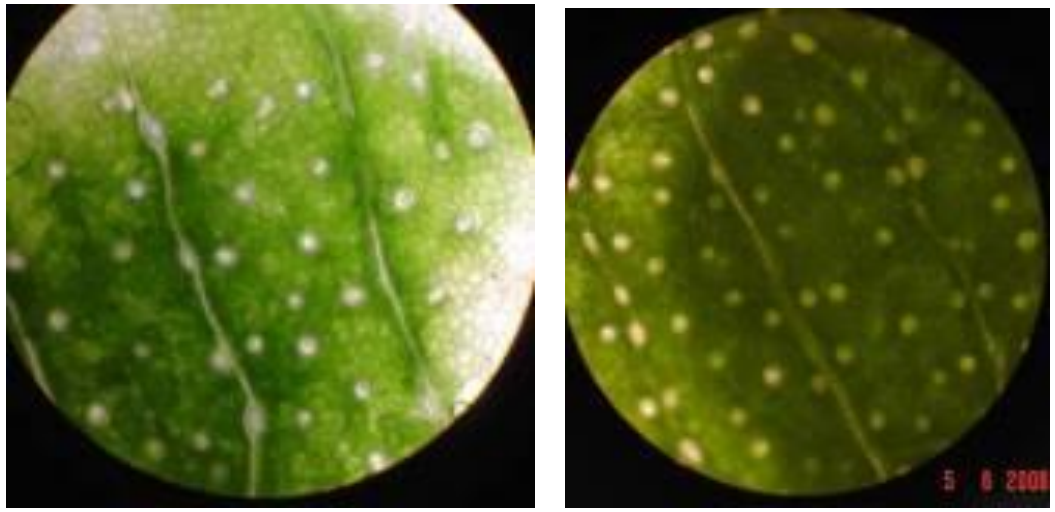
- Includes water losses occurring through the soil surface and by the plant's stomata transpiration; stomata are porous in the surface of leaves linking the atmosphere to the interior of the plants

- This transpiration is a consequence of photosynthesis, once during the day, stomata remain open to receive and eliminate CO_2, exposing, therefore, the humidity in its interior.

- In warm days, the trees act like a natural evaporative cooling system, and a bigger amount of absorbed radiation is dissipated as latent heat instead of sensible heat



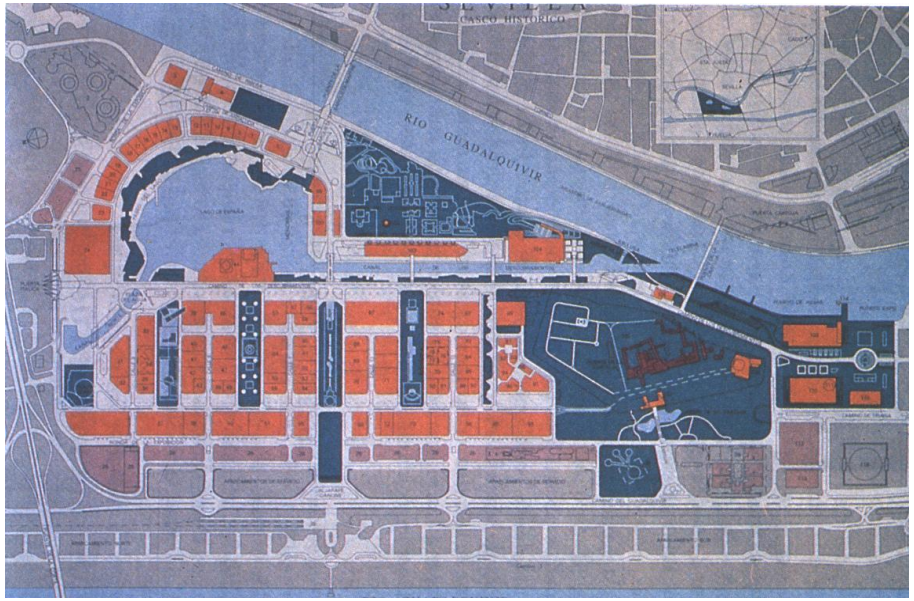
Gaseous exchanges by stomata at the leaf surface. Source: Oke (1978)

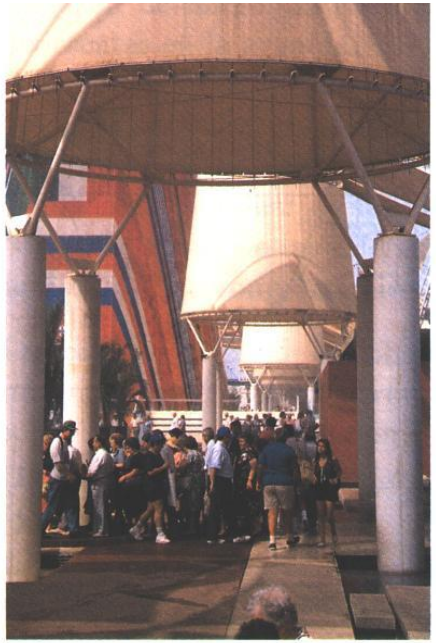


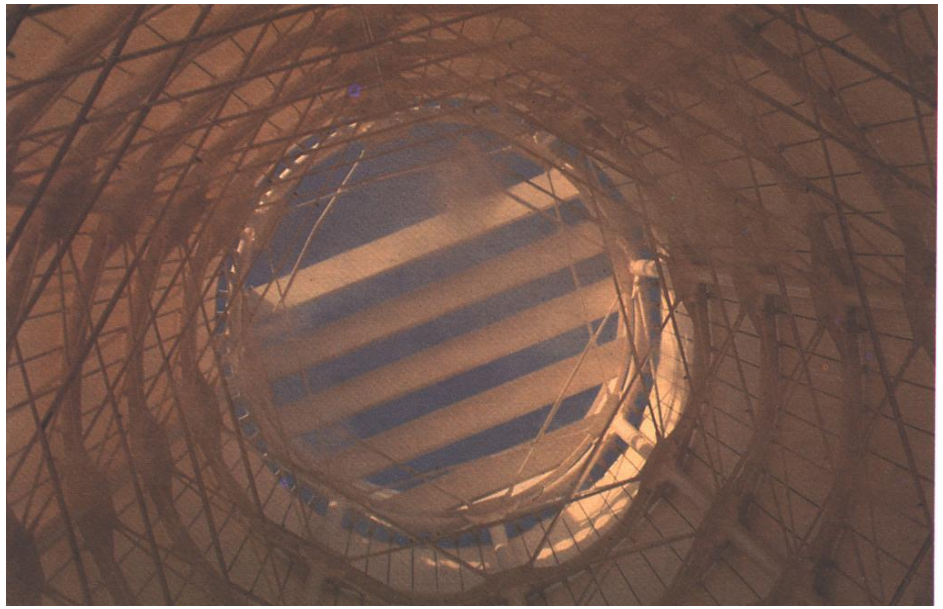
Stamata seen in a microscope (P. Shinzato)

Alhambra, Granada

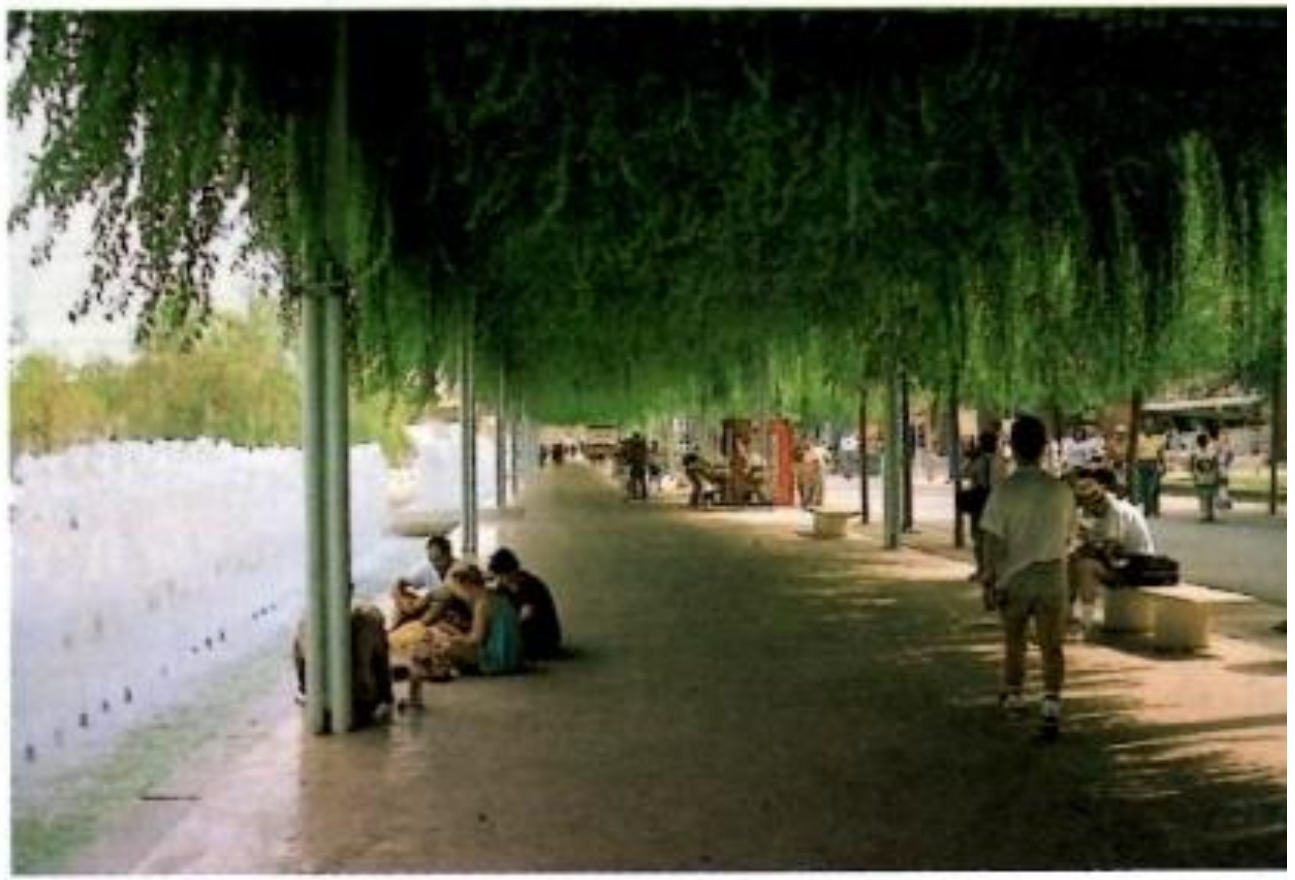
Estación Atocha, Madrid







Expo Seville’92



Expo Seville’92

Expo Seville’92

Place de la Republique, Paris

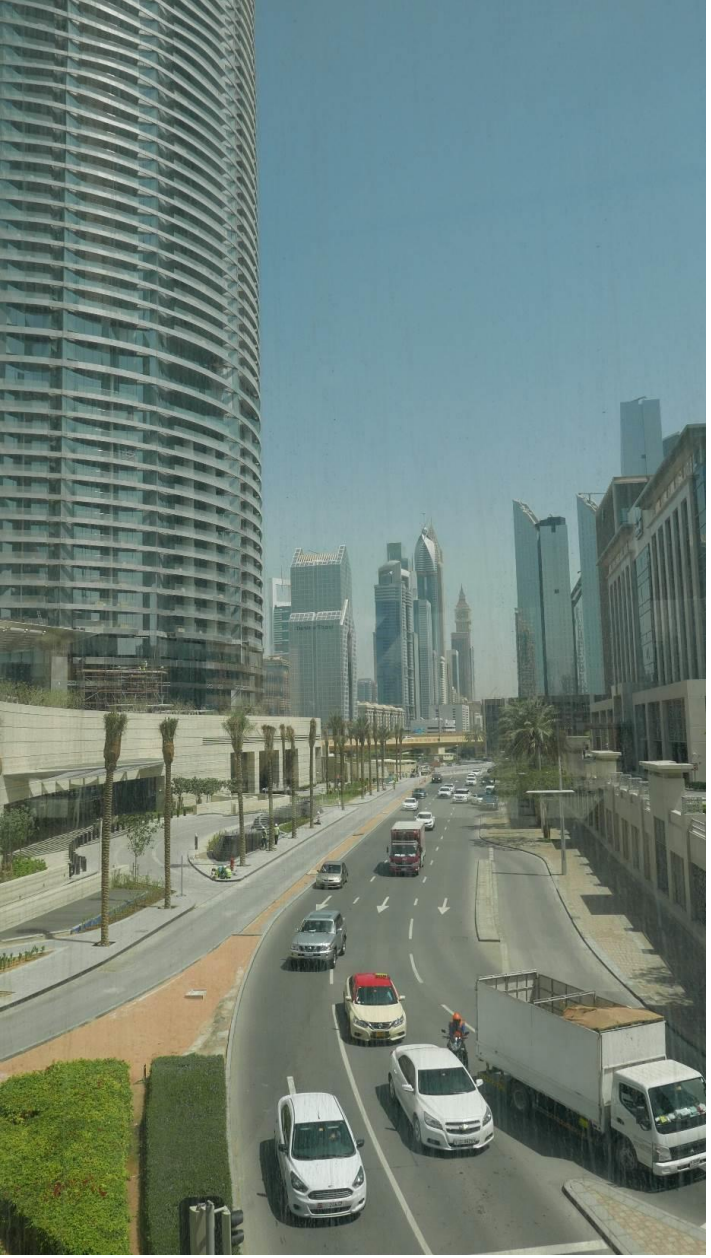
Harlem, NY, during the heatwave, in August 2018

But, some conditions are crucial.....

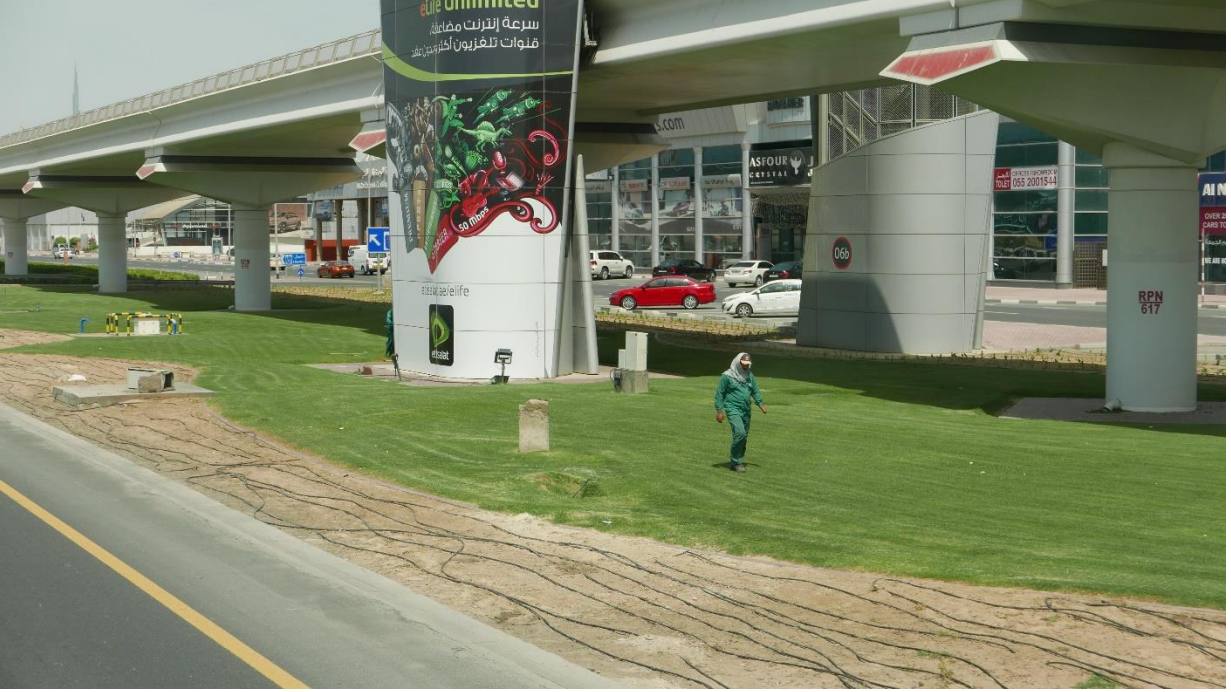
- The capacity of trees in modifying microclimate conditions in its surroundings is a function of season, regional climate, size of green area, kind of soil underneath and amount of leaves.

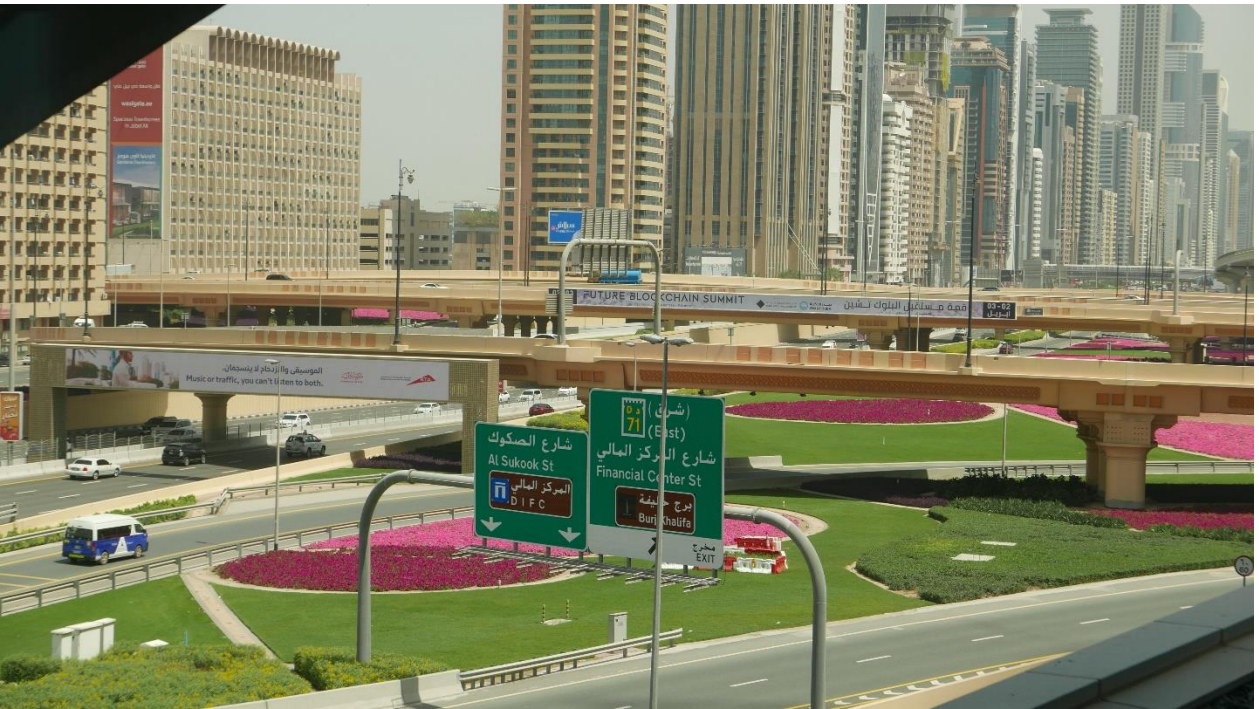
- Water availability is crucial to increase latent heat transfer trough vegetation

- Surface covered with vegetation is more efficient in transforming energy. Therefore, the bigger the exposed area of the leaves, the bigger the effect. In this sense, leaf area index – LAI has a direct relation with the amount of light energy and CO_2 consumption.



Dubai, UAE, April 2019


eLife Unlimited
سرعة إنترنت ومضاعفة
قنوات تلفزيون أكثر وبتغير
RPN
617


FUTURE BLOCKCHAIN SUMMIT
Music or traffic, you can't listen to both.
شارع الصكوك
Al Sukook St
المركز المالي
DIFC
(شرقي) (East)
71
شارع المركز المالي
Financial Center St
برج خليفة
Burj Khalifa
EXIT


LANDMARK GROUP

Energy balance of vegetated surfaces

$$\mathbf{Q^* = QH + QE + \Delta QS + \Delta QP} \ (\mathrm{W/m^2})$$

Q* = net all-wave radiation flux density

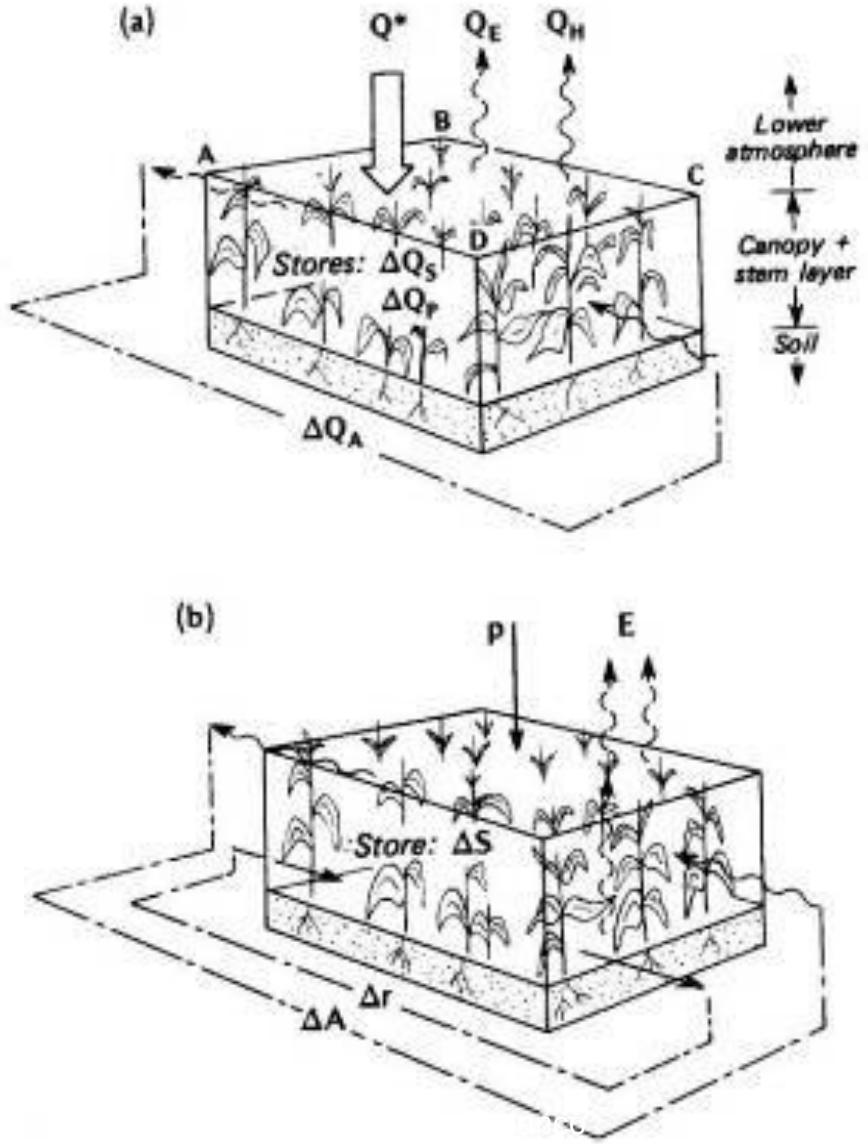
QH = turbulent sensible heat flux density

QE = turbulent latent heat flux density

Δ**QS** = net rate of physical heat storage by substances in the system

ΔQP = net rate of biochemical energy storage due to photosynthesis

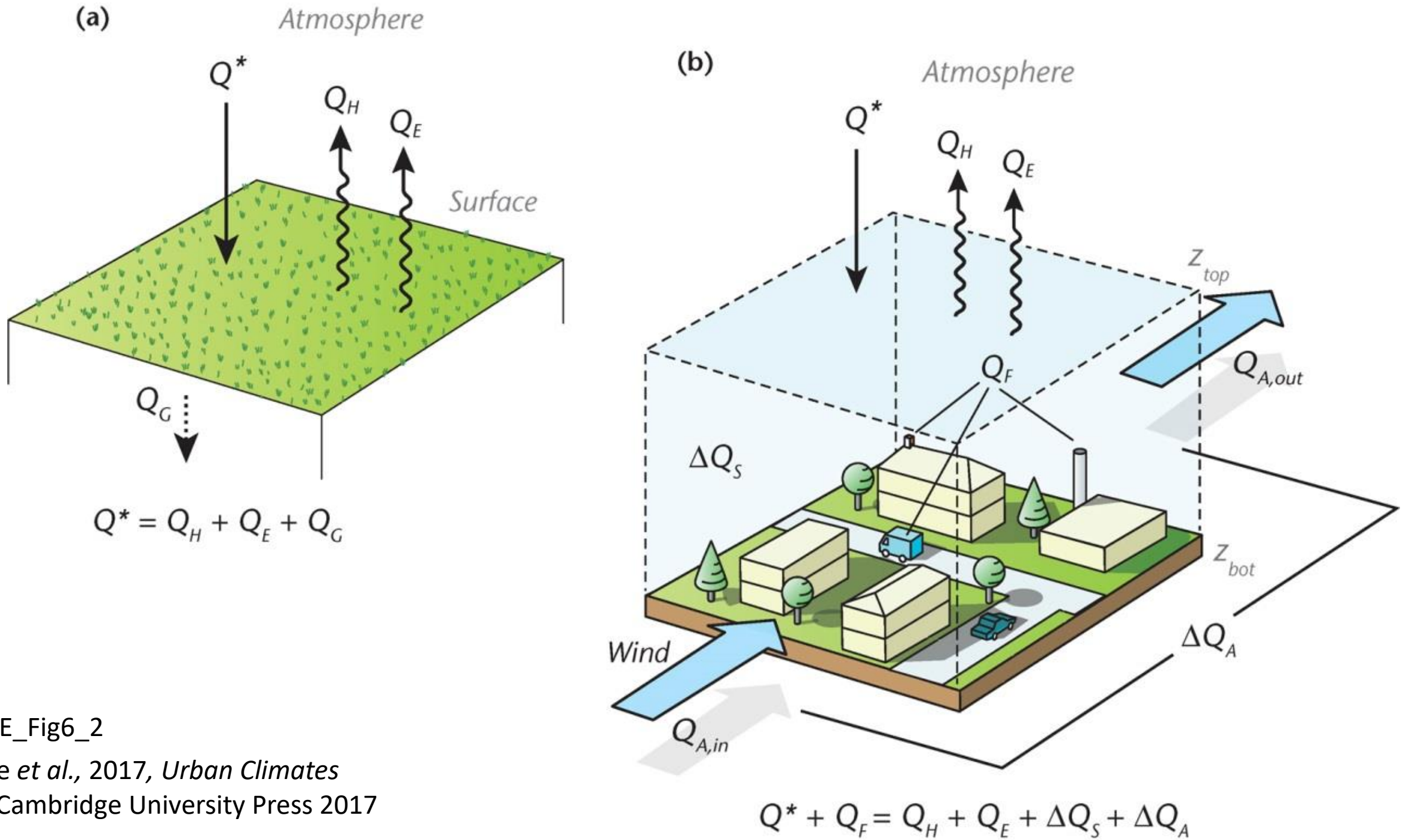
Besides energy balance, it is important to consider the water balance including all the water involved in soil, vegetation and atmosphere.



Schematic depiction of fluxes involved in (a) the energy and (b) the water balances of a soil-plant-air volume (Oke, 1987)

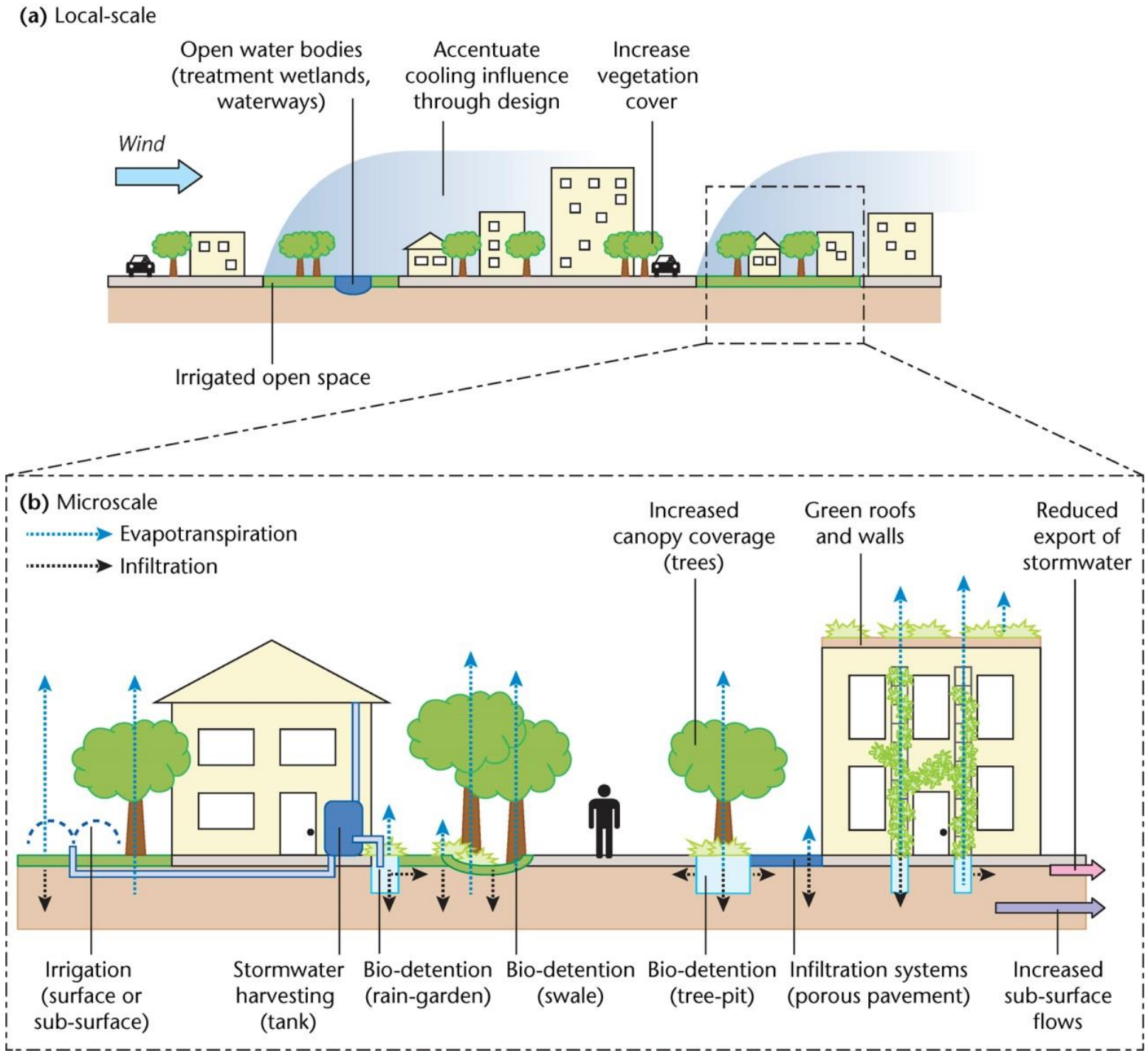
Sensible heat

Latent heat



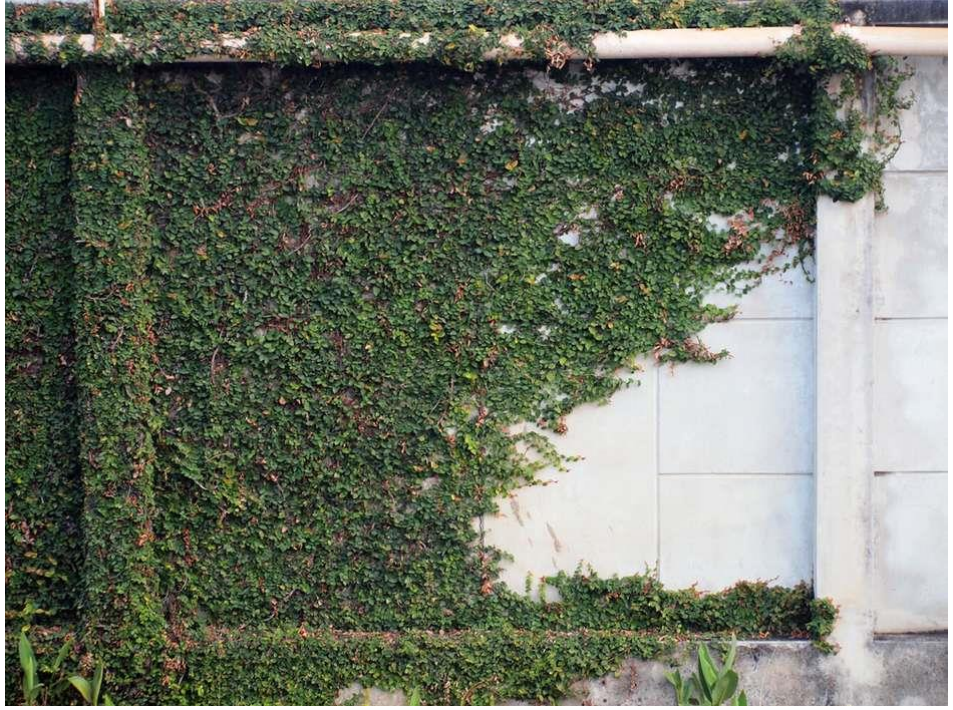
OKE_Fig6_2

Oke *et al.*, 2017, *Urban Climates*

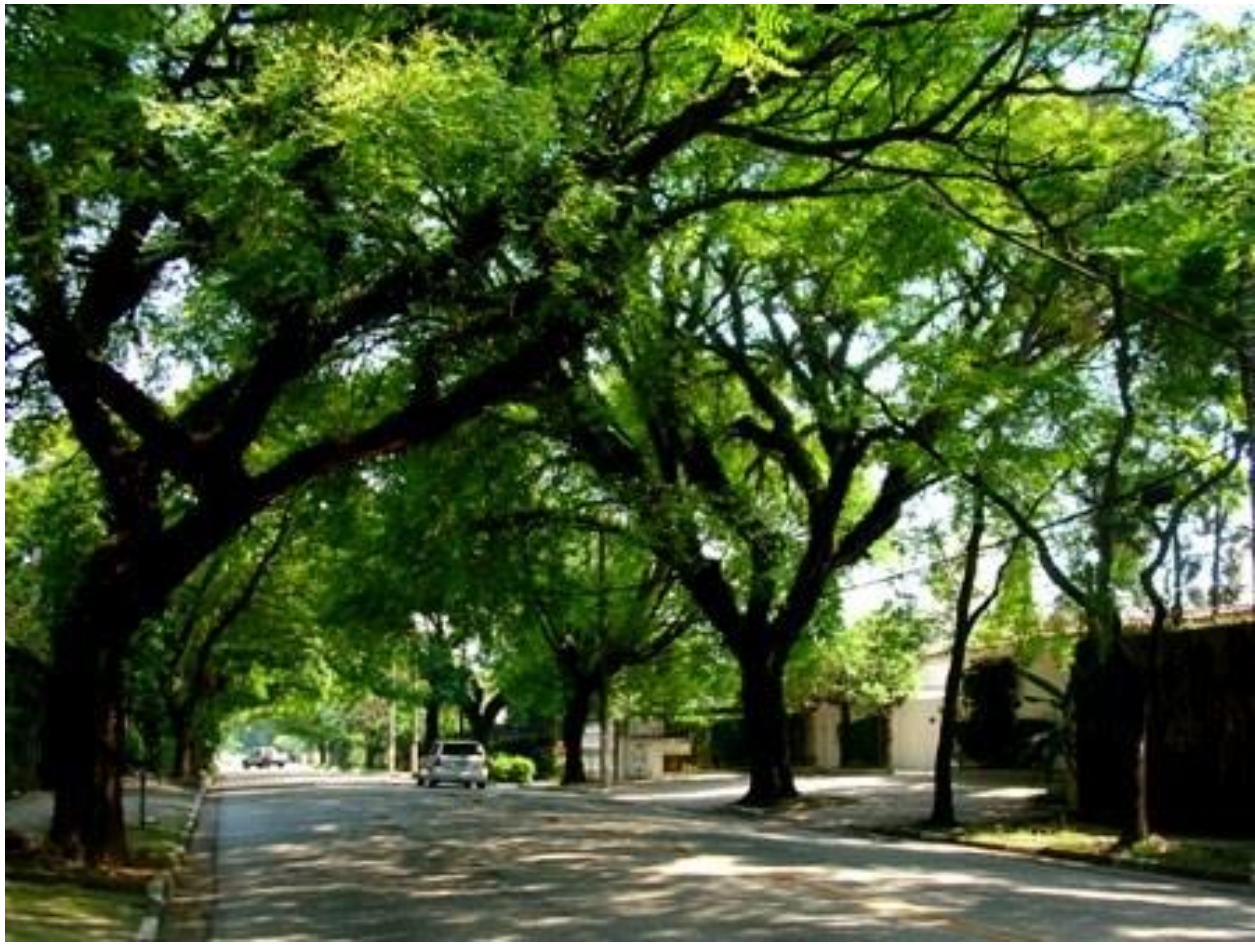


OKE_Fig15_29

Oke *et al.*, 2017, *Urban Climates*




21°
Campo Limpo
JARDINS VERTICAIS ESTÃO SEM MANUTENÇÃO
Moradores de prédios no Minhocão pedem a retirada dos murais verdes

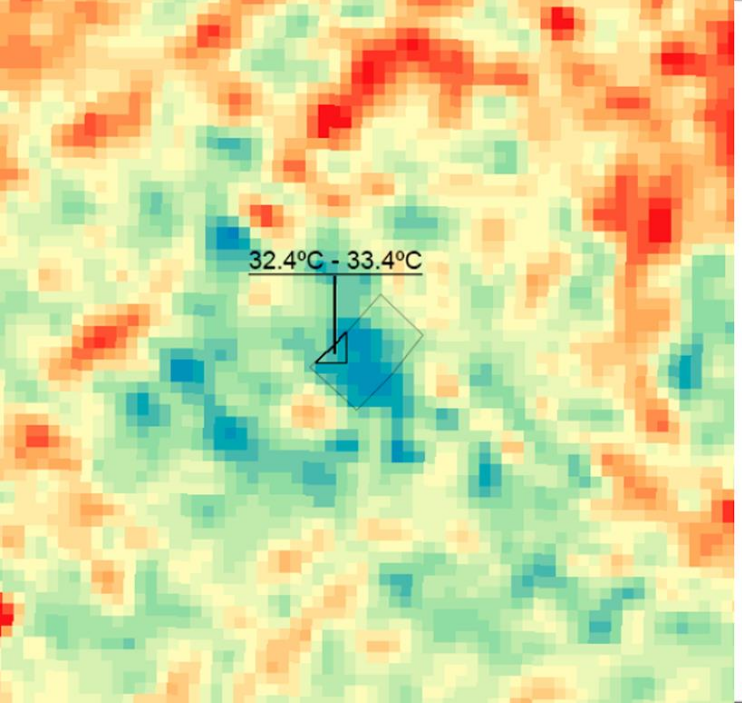



Fabibel

Local scale measurements

Field measurements can be carried out to raise local data for:

- Surface temperature, with a thermographic camera, sometimes simultaneous with Landsat schedules, for comparison;
- Leaf area index of individual trees and, in average, inside urban parks;
- Vegetation emissivity;
- Façade, pavements and vegetation surface temperature, to be verified with modelling results.



LEGENDA

Imagem Termal Landsat 7

Imagem com correção

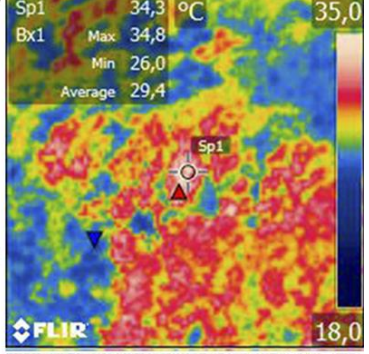
Data: 10 de Abril de 2016

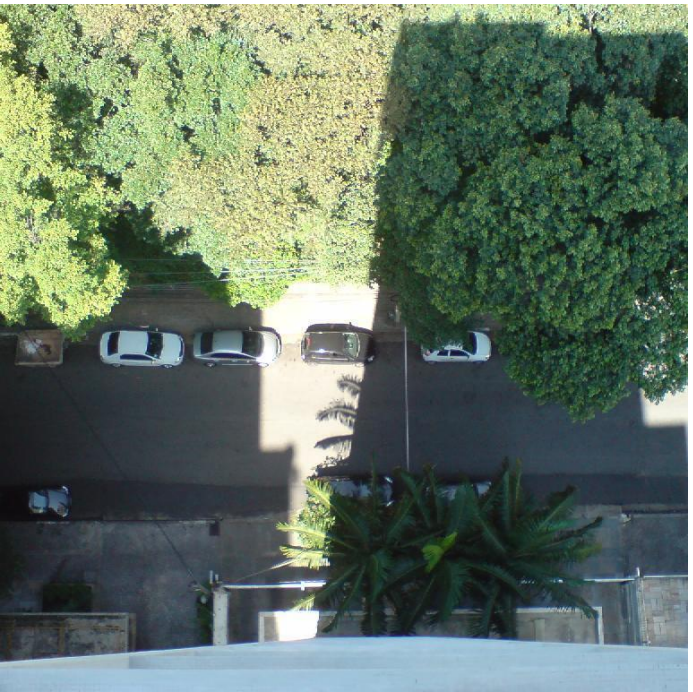
Parque Trianon

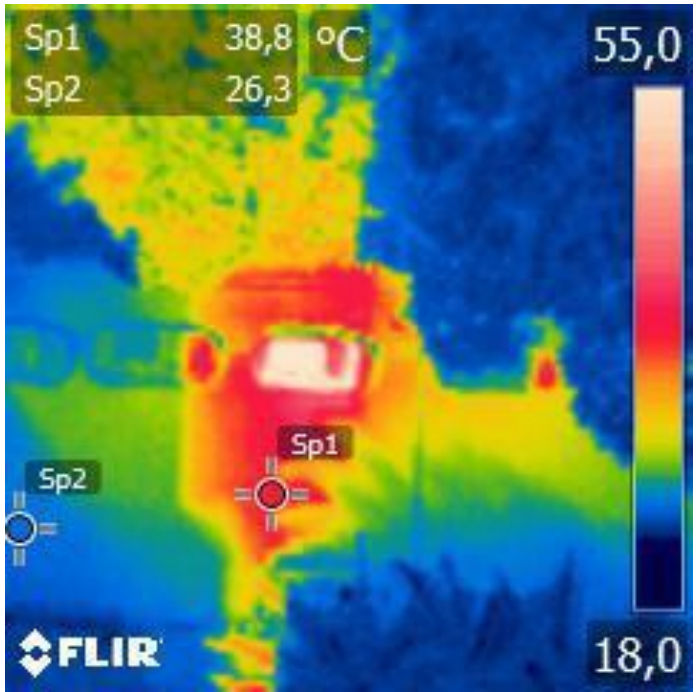
Área de medição em solo

Gradiente de temperaturas

32 ºC
33 ºC
34 ºC
35 ºC
36 ºC
37 ºC
38 ºC
39 ºC
40 ºC
41 ºC
41,6 ºC

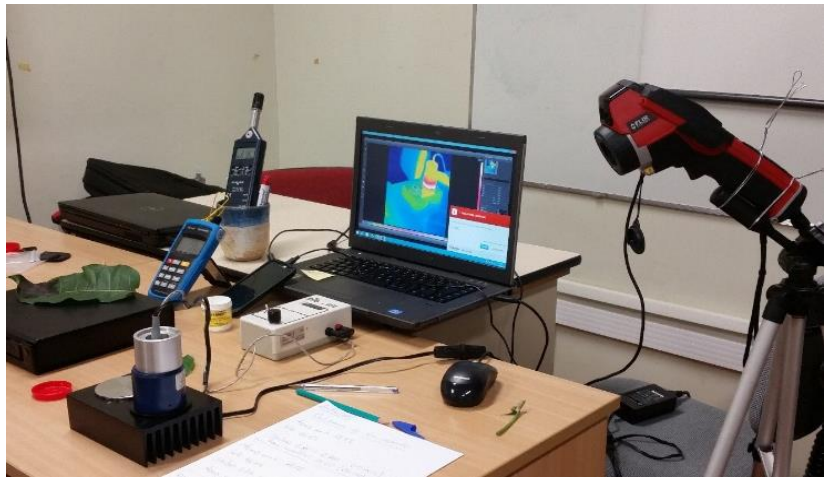






Emissivity of the leaves

No.	Folha	Valor de emitância	Características
1		0,722 2 folhas sobrepostas e dobradas ao meio = 4 camadas	Folhas grandes com aspectos próximos a folha no. 8, porém, mais espessa.
2		0,720 Sobreposição de várias folhas	Folhas finas, rugosas e 'aveludadas'.
3		0,844 2 folhas sobrepostas e dobradas ao meio = 4 camadas	Aspecto liso (como a folha 5), porém, não muito resistente e nem tão espesso.
4		0,761 2 folhas sobrepostas e dobradas ao meio = 4 camadas	Folhas de tamanho médio, leve rugosidade e lisa (como a folha 3).
5		0,813 2 folhas sobrepostas e dobradas ao meio = 4 camadas	A folha no. 4 é a mais espessa e firme dentre todas as analisadas. Além disso, é lisa e com aspecto 'encerado'.
6		0,757 As folhas foram destacadas e sobrepostas até cobrirem a área do cabeçote	Folhas pequenas, com características parecidas a da folha 5 (no entanto, menos espessas e firmes).
7		0,783 As folhas foram destacadas e sobrepostas até cobrirem a área do cabeçote	Aspectos semelhantes a da folha no. 4, contudo, suas folhas são menores.
8		0,777 As folhas foram destacadas e sobrepostas	Folhas pequenas (com aspectos parecidos a folha 3), no entanto, são mais finas.



Albedo of the leaves

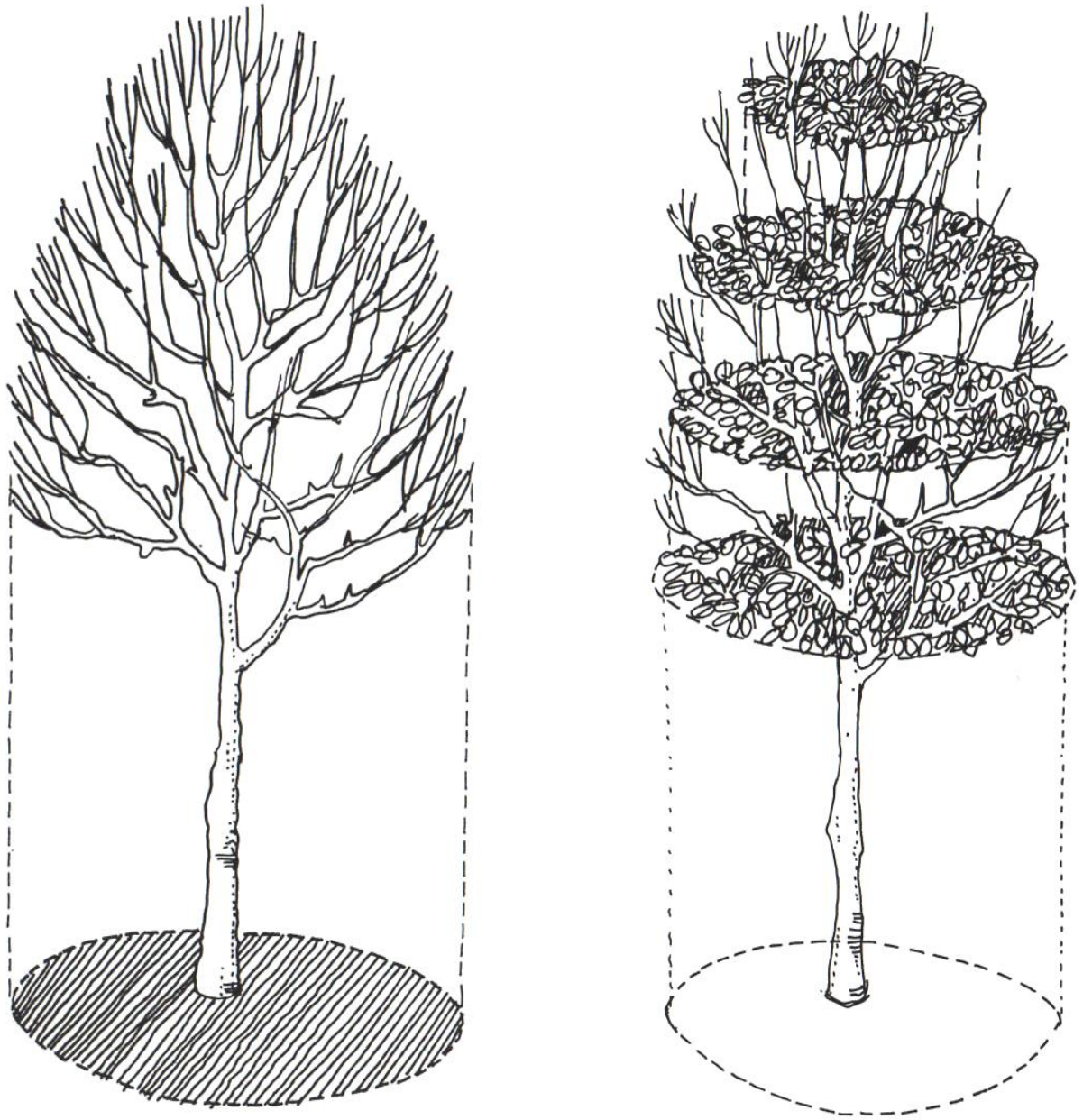
- High albedo decreases the amount pf solar radiation absorbed by any material, keeping the surface temperatures lower. The reduction of surface temperatures decrease the longwave emission to the atmosphere

- A new asphalt has an albedo between 0.05-0.10; the albedo of a grey cement is about 0.05-0.10; while a white cement is around 0.70-0.80

- The albedo of the leaves vary between 0.25 e 0.30

Leaf Area Index - LAI

LAI measures the amount of leaf material (photosynthetic tissue) in an ecosystem, which imposes important controls on photosynthesis, respiration, rain interception, and other processes that link vegetation to climate.

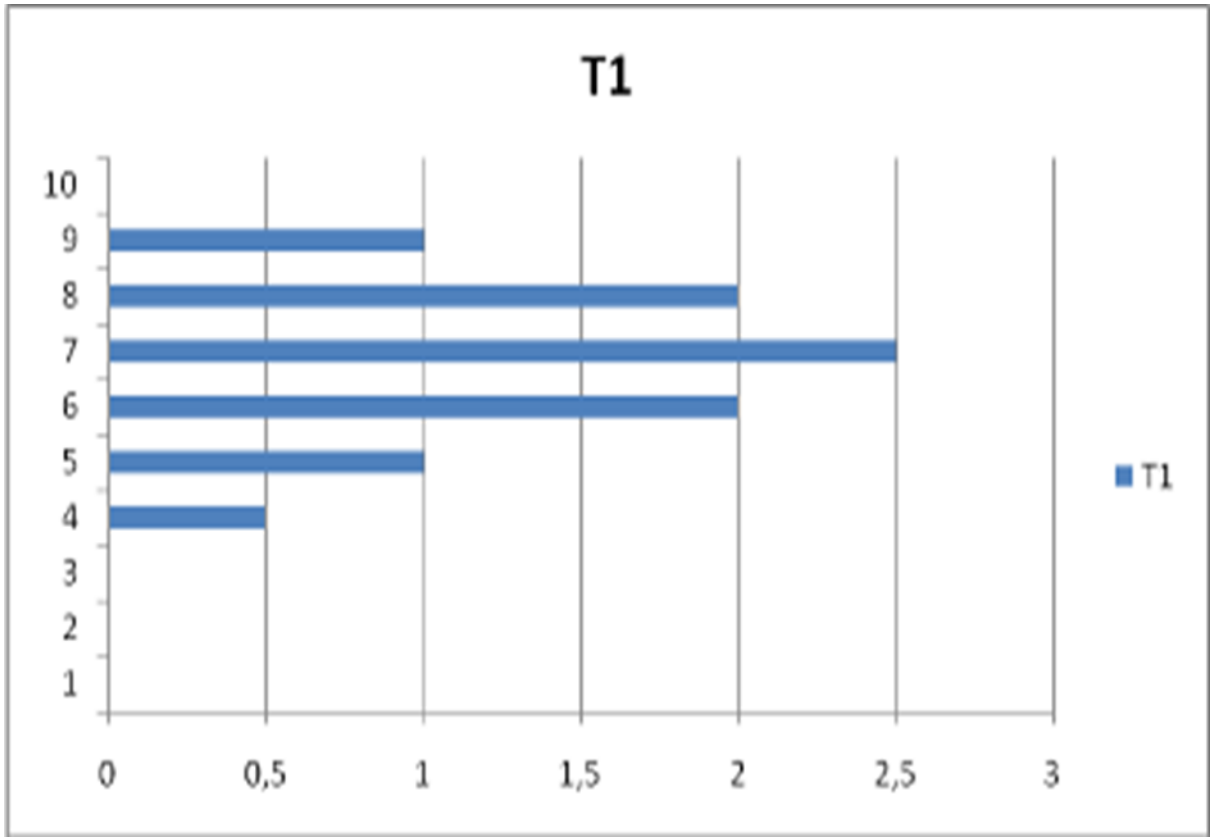


Leaf Area Index - LAI

- LAI is defined as half the total intercepting (non-projected) area per unit ground surface area (Chen and Black, 1992).
- LAI is a dimensionless number and a key parameter to determine a series of ecological and physiological process, such as photosynthesis and evapotranspiration
- A complete definition of a tree structure includes also:
  - leaf area density (LAD)
  - clumping index
  - tree height
  - shape

Leaf Area Density - LAD

- LAD is a parameter defined as the total one-sided leaf area (m^2) per unit layer volume (m^3) in each horizontal layer of the tree crown.
- Determined by the vertical distribution of the leaves in horizontal layers (spatial distribution);
- The spatial distribution of LAD is an important parameter in describing tree characteristics, which influences on its radiation balance and the mass and energy exchange with the atmosphere (Lalic and Mihailovic, 2004).

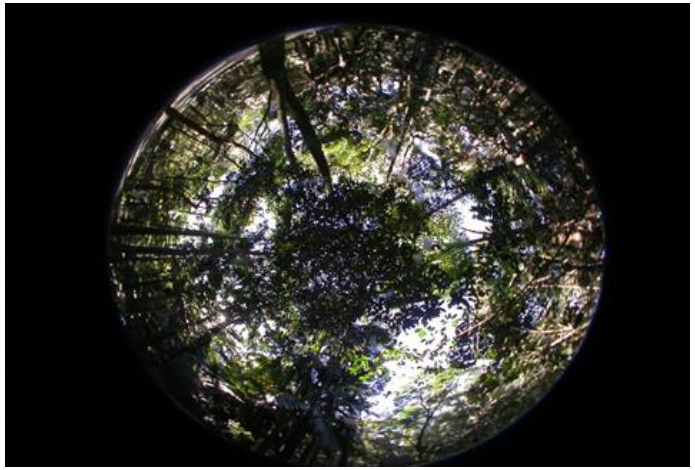


Methods to estimate LAI

LAI can be estimated using direct methods (destructive sampling or litter traps), whereas indirect method calculates LAI using measurements of canopy transmittance (Breda, 2003).

Direct methods: they are the most accurate, but have the disadvantage of being extremely time-consuming and as a consequence making large-scale implementation only marginally feasible. LAI can be assessed directly by using harvesting methods such as destructive sampling and the model tree method or by non-harvesting litter traps during autumn leaf-fall period in deciduous forests.

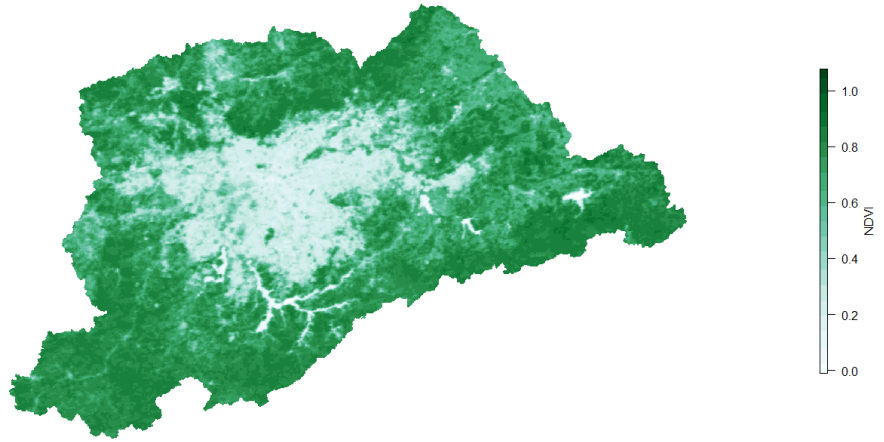
Indirect methods, in which LAI is derived from more easily (in terms of time, workload, technology) measurable parameters.



Indirect methods to estimate LAI

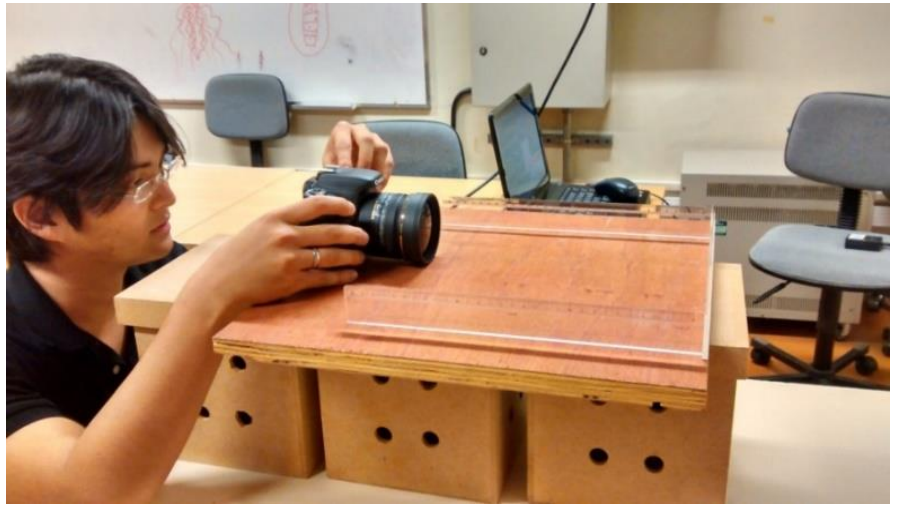
- Calculation regarding the radiation extinction trough the canopy, as a function of the geometric distribution of the gaps (Gap Fraction Distribution).
  - Hemispheric photos, under cloudy sky, to estimate the visible sky fraction in different angles
  - Canopy analyser
  - Sunfleck area estimated by a ceptometer. Sunflecks are the bright areas under the canopy where direct beam solar radiation penetrates without attenuation by the canopy.

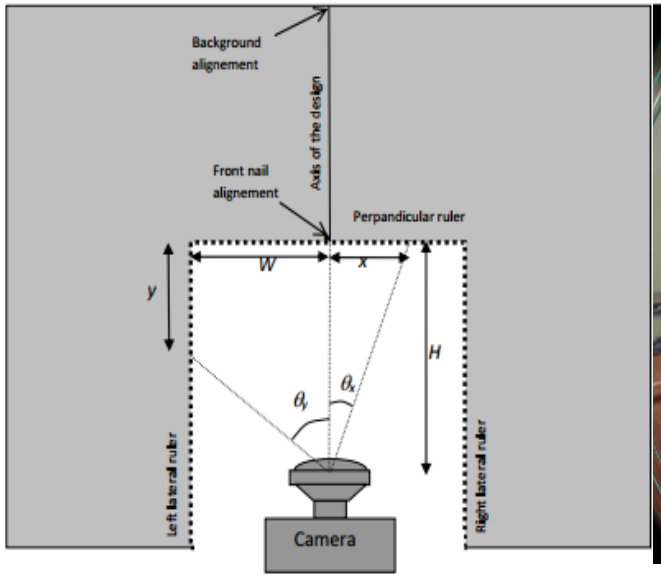
- Remote sensing: NDVI = normalized difference vegetation index (ratio between spectral surface reflectance to red and near infrared), can be used as a measure of vegetation cover or to estimate LAI

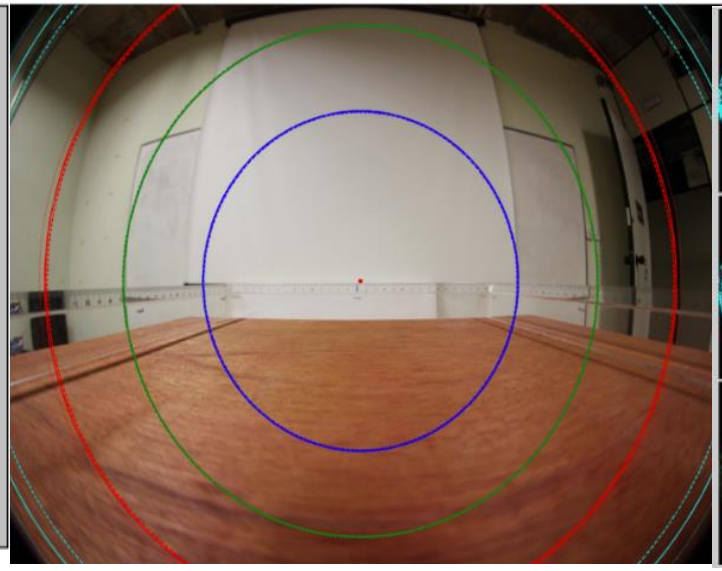


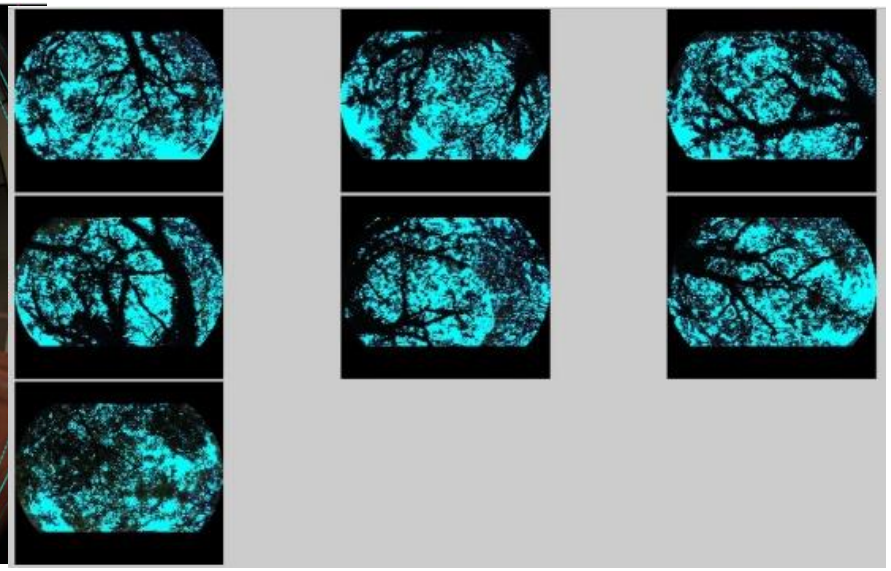
LAI estimation

hemispheric photos / Can-Eye software calibration



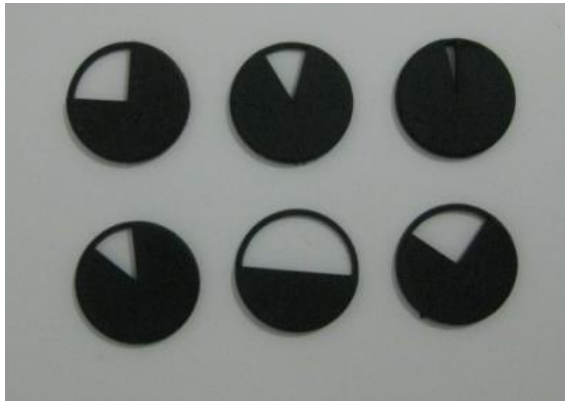






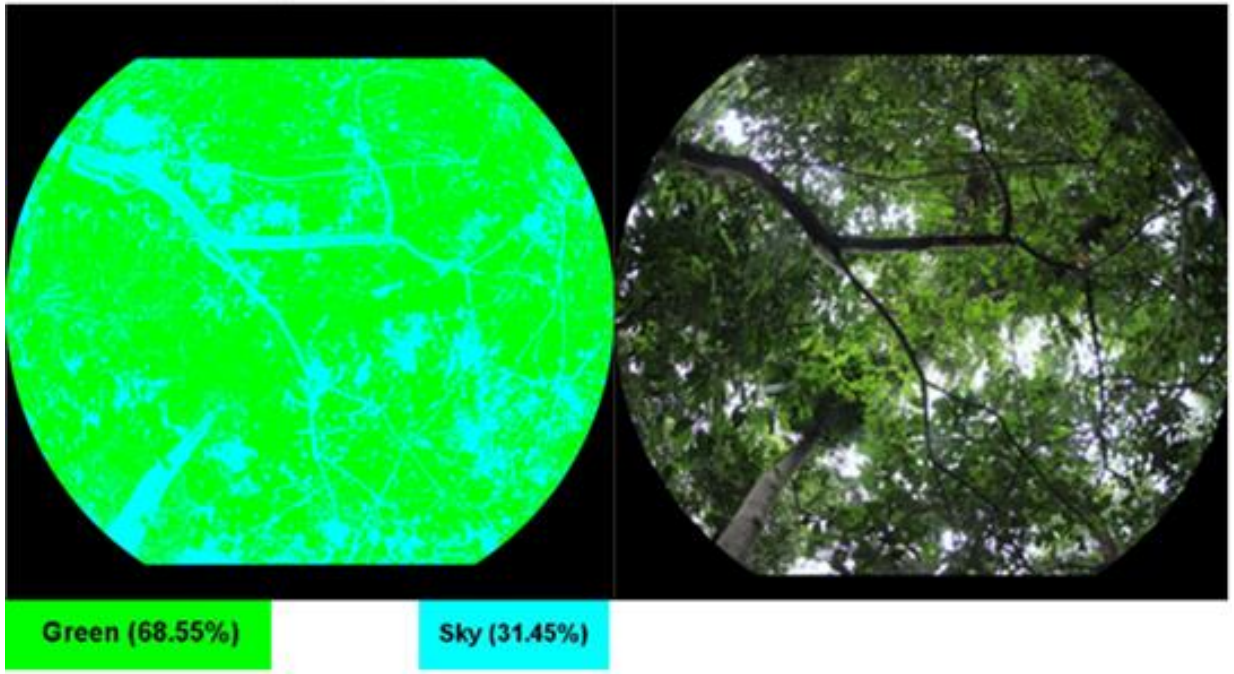
LAI estimation

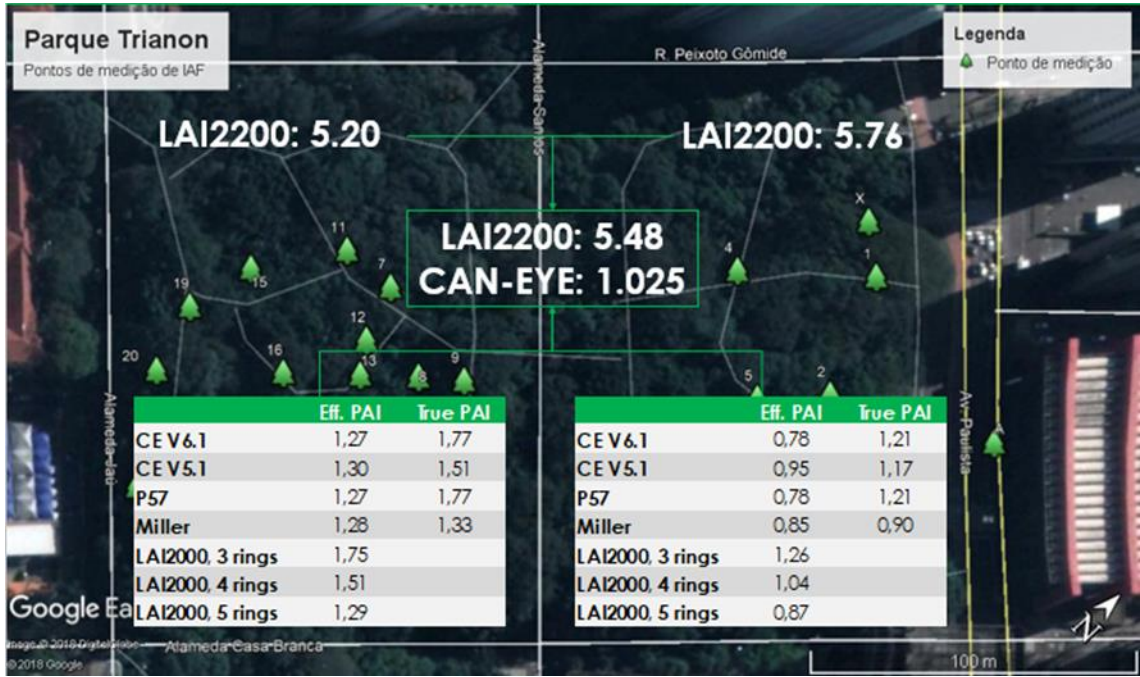
LAI 2200 Plant Canopy Analyser



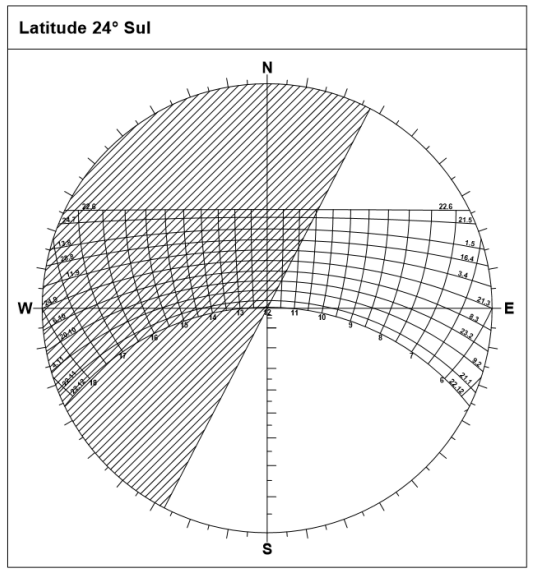
LAI estimation

LAI 2200 Plant Canopy Analyser

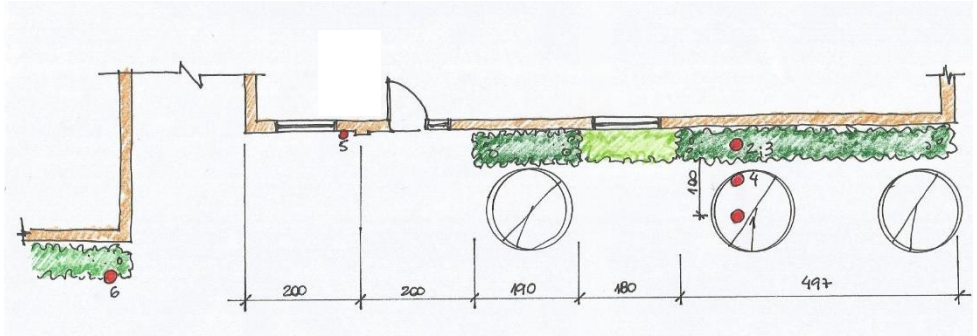




Green Façade



Orientação solar da fachada estudada



Localização dos pontos de medição.

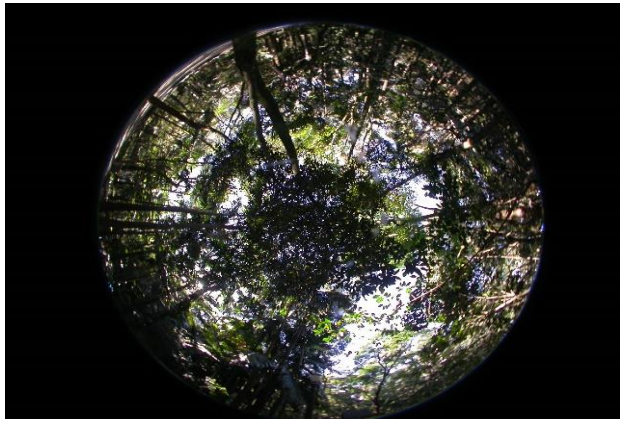
Vista da fachada estudada

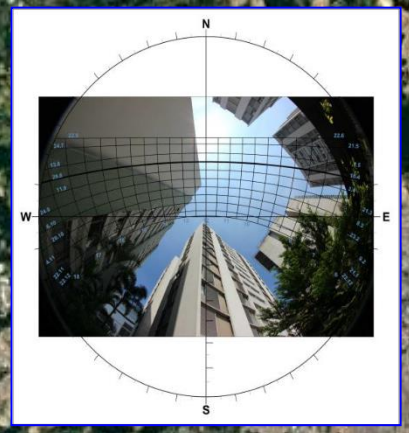
Green Façade

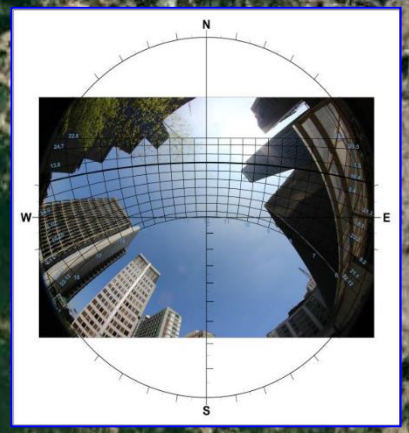
External surface temperature drops, but the effects of green façades in mean radiant temperature on the urban environment are very local, besides increments in LAD.

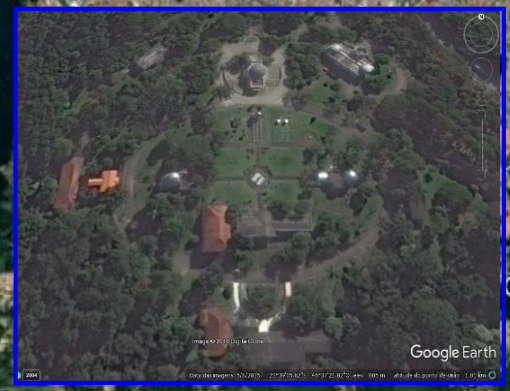
For now, no research, just tell me your feelings....

Microclimate measurements – Trianon Park, São Paulo









Estação do INMET (Mirante de Santana)

Estação (temporária) Bela Vista

Estação (temporária) Paulista

Estação Aeroporto de Congonhas (SBSP)

Estação IAG/USP

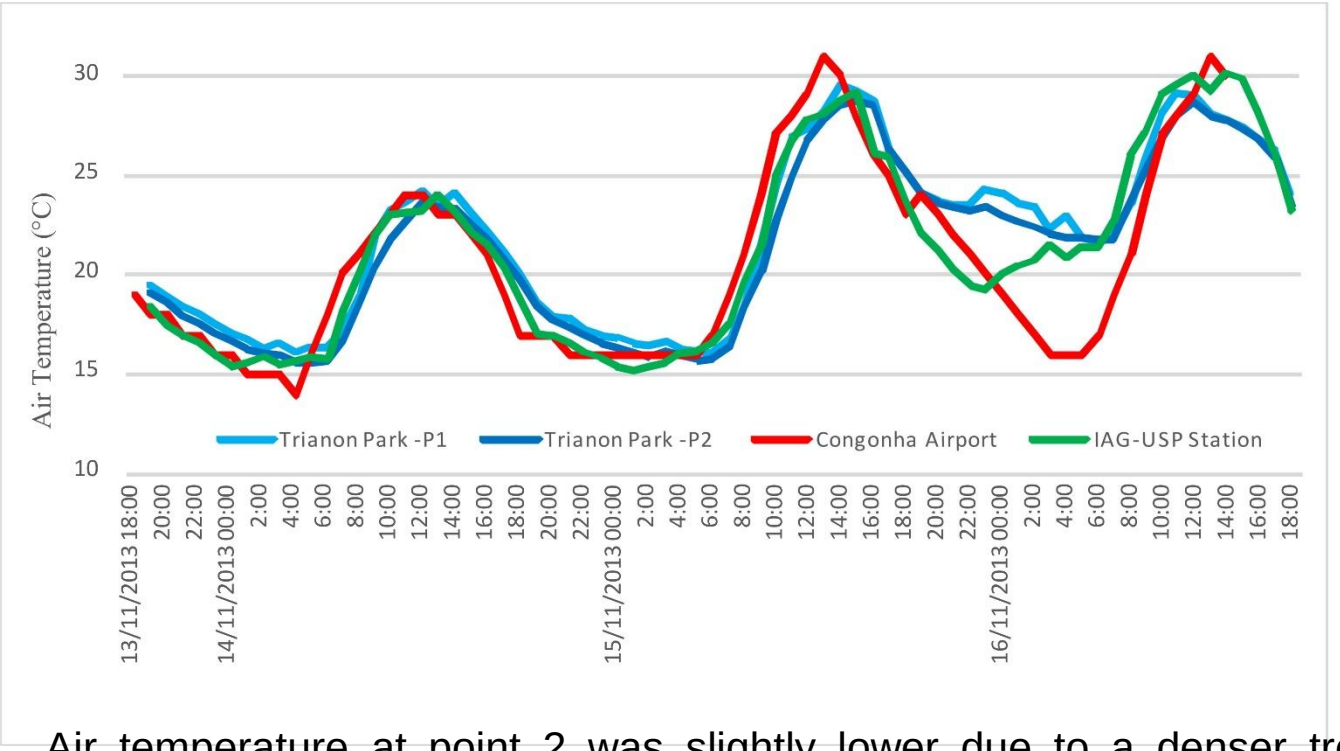
Copernicus

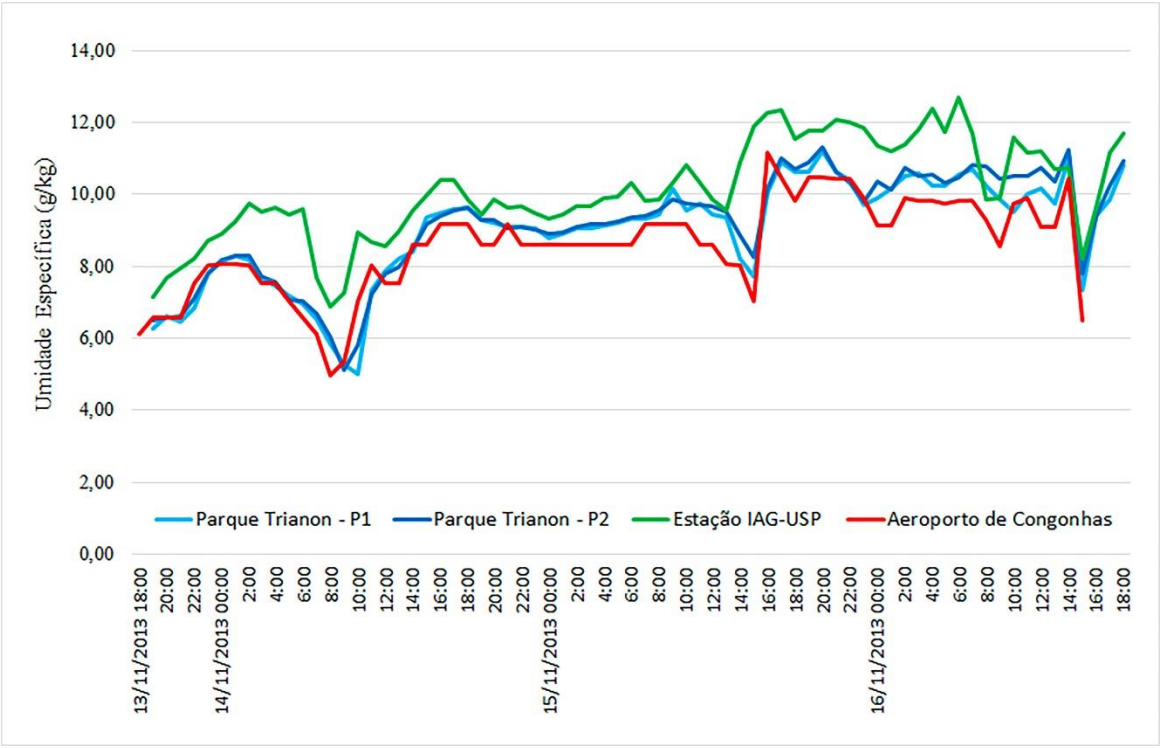
18.6 km

Google earth

23°35'14.59"S 46°32'59.41"O elev 778 m altitude do ponto de visão 80.78 km

Microclimate measurements – Trianon Park, São Paulo

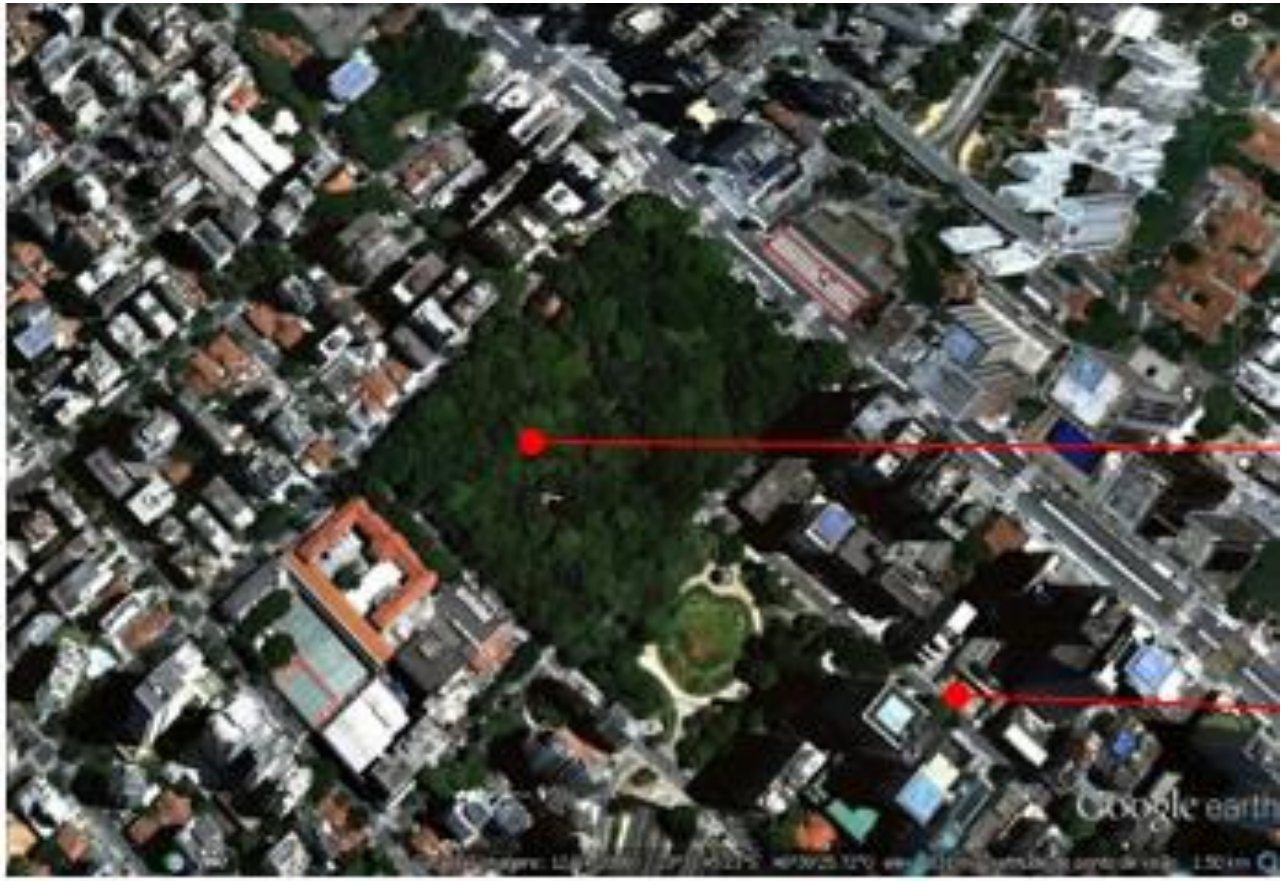




Air temperature at point 2 was slightly lower due to a denser tree canopy cover (LAI ~3 and natural soil conditions compared to LAI ~1,5 and next to a pervious paved pedestrian path at point 1). Congonhas Airport is in general warmer during the day and cooler at night due to the open sky site and impervious surroundings that allows a higher longwave radiation loss during nighttime. On the other hand, the park environments, especially Trianon, with the two meteorological stations placed under a dense tree cover is slightly warmer at night, as expected even for green a semi-confined space.

The specific humidity comparison shows the actual moisture content, contrasting the drier airport environment with the more humid park sites, mainly due to grass, natural soil and a dense tree canopy. In average, both points 1 and 2 inside Trianon Park were in-between IAG/USP Água Funda and Congonhas Airport humidity conditions

Microclimate measurements and simulation in an urban park and in a dense urban block



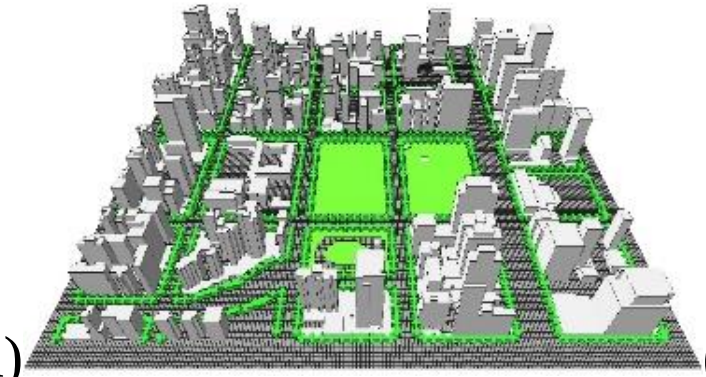
Location of two points for microclimate measurements –meteorological station at Trianon Park (Point 1) and another one at Paulista courtyard (Point 2).


Estação Paulista
Avenida Paulista
Estação Bela Vista
Image Landsat
Google Earth

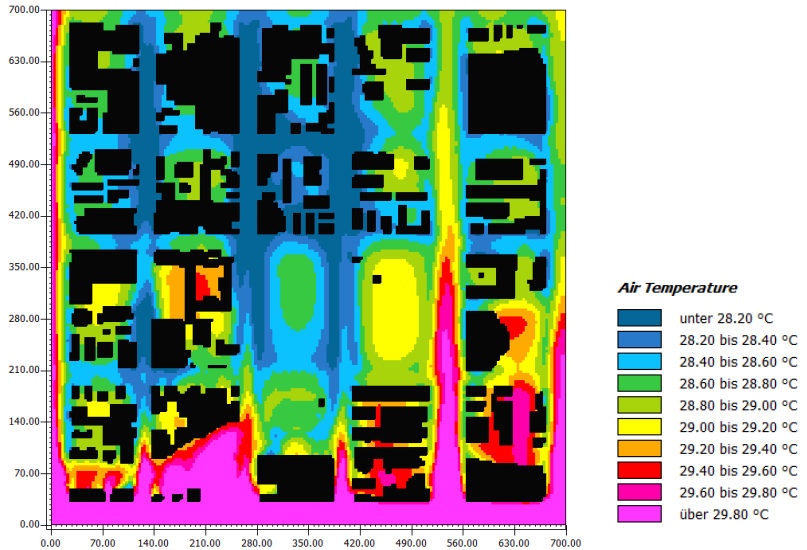
Microclimate measurements and simulation in an urban park and in a dense urban block

Microclimate measurements and simulation with ENVI-met Science for vegetation (Albero) and density studies.

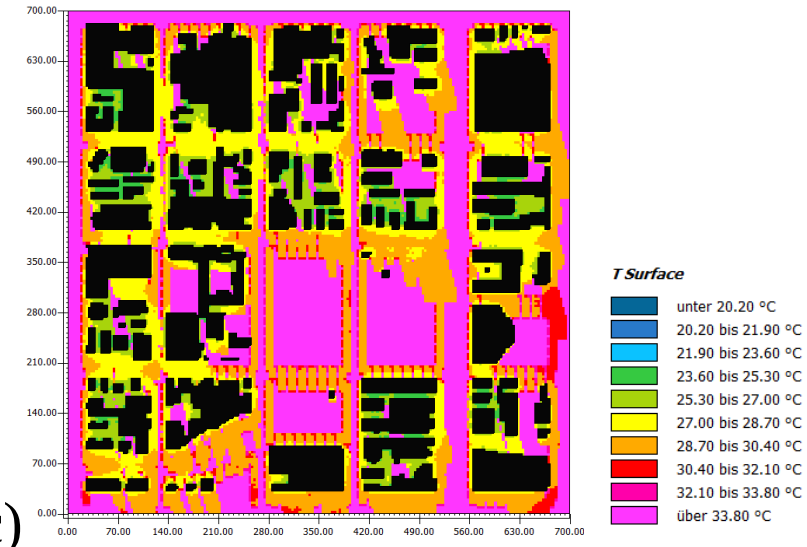
(a)



(b)



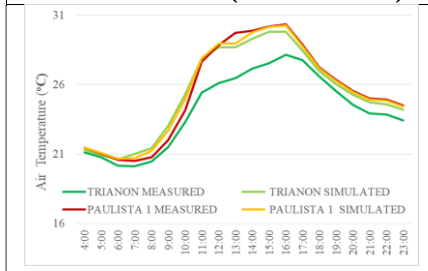
(c)



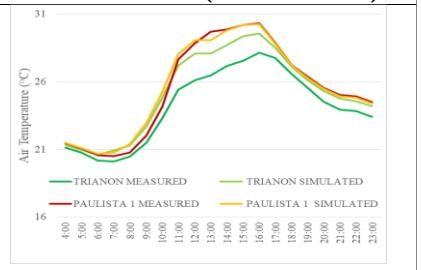
a) Dense street trees ; (b) air temperature at 14h; (c) surface temperature at 14h.

ENVI-met model – calibration process

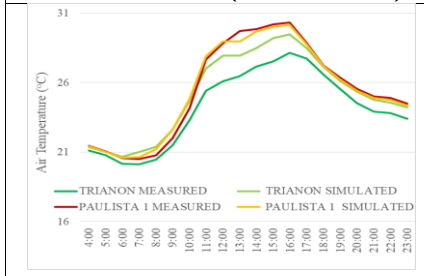
RESULTS FOR FF-1 (TREE TYPE B1)



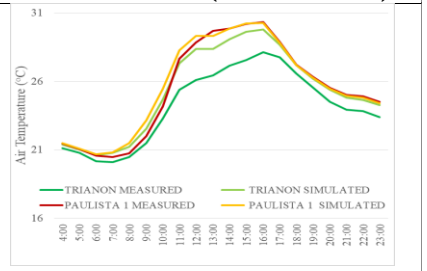
RESULTS FOR FF-2 (TREE TYPE B1)



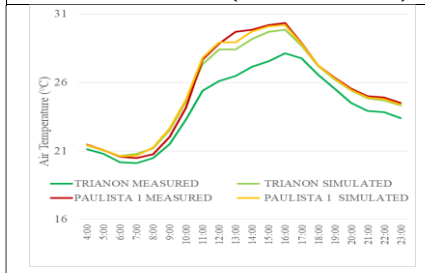
RESULTS FOR FF-3 (TREE TYPE B1)



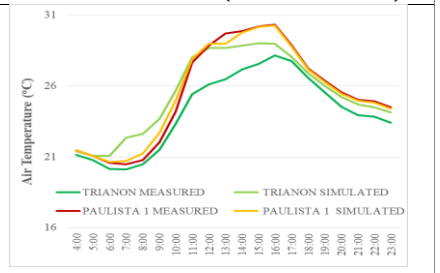
RESULTS FOR FF-4 (TREE TYPE BR)



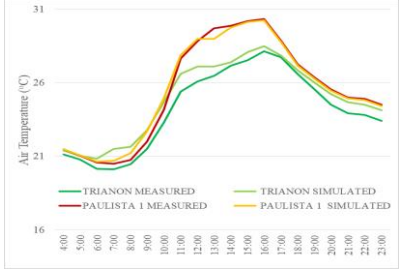
RESULTS FOR FF-5 (TREE TYPE BR)



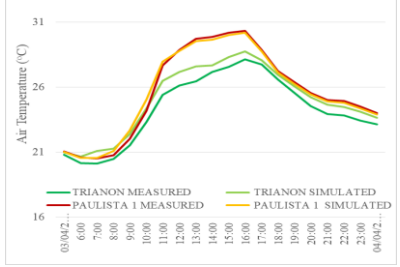
RESULTS FOR FF-6 (TREE TYPE BR)

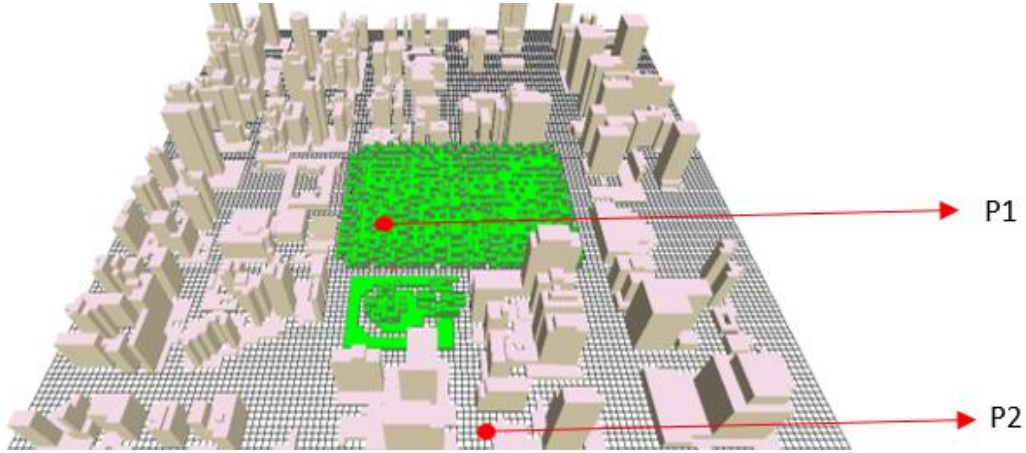


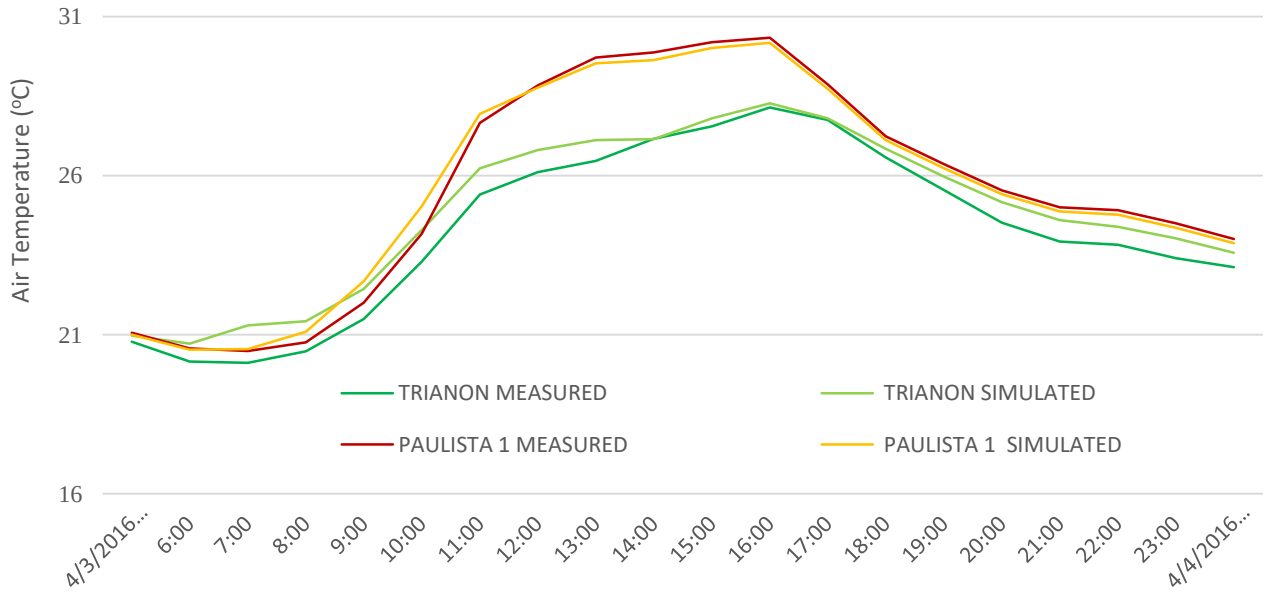
RESULTS FOR FF-7 (TREE TYPE BR)



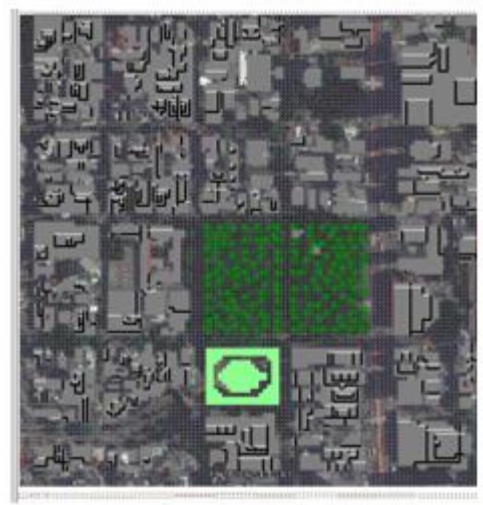
RESULTS FOR FF-11 (TREE TYPE B2)

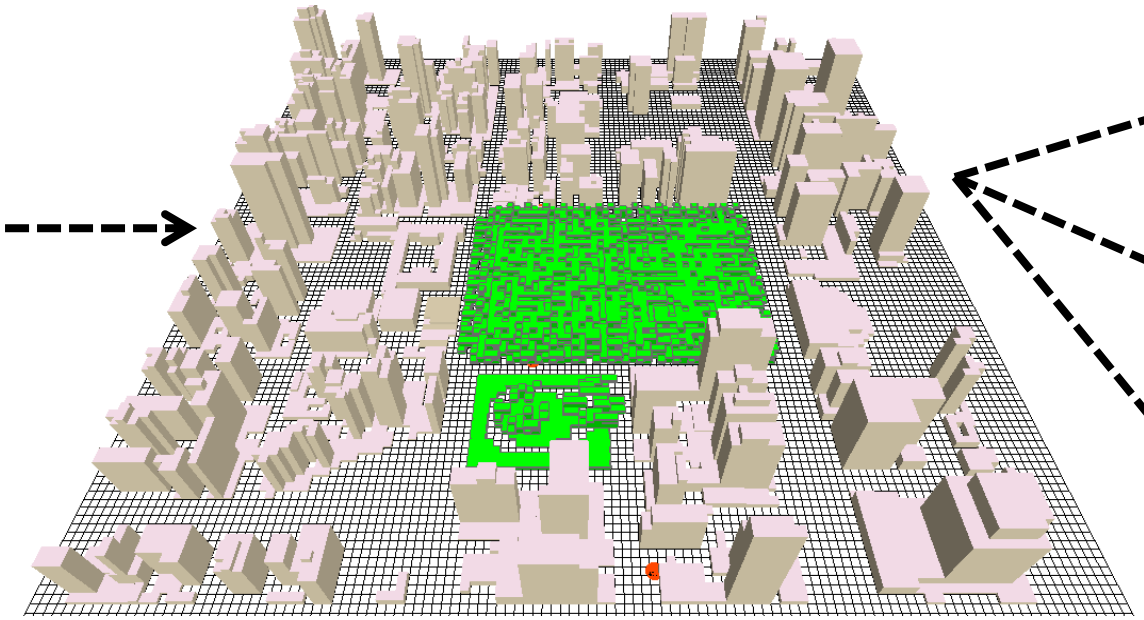


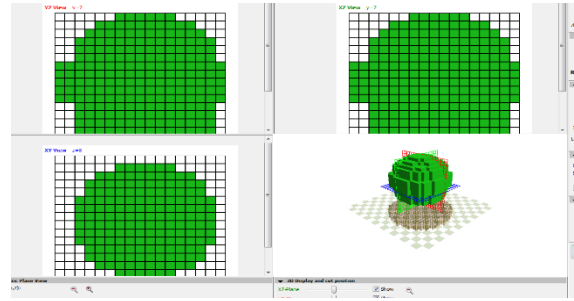


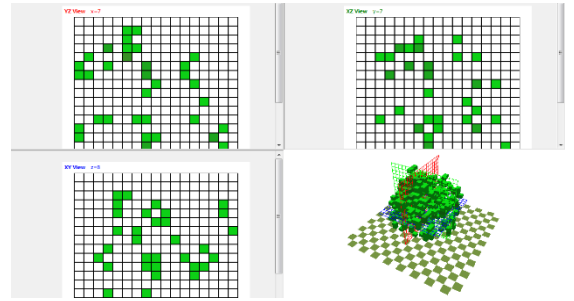


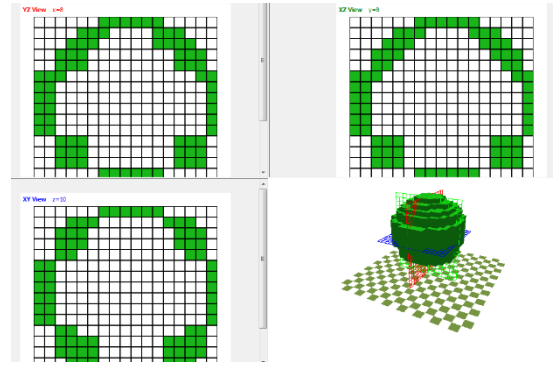
Simulation of the real scenario on ENVI-met



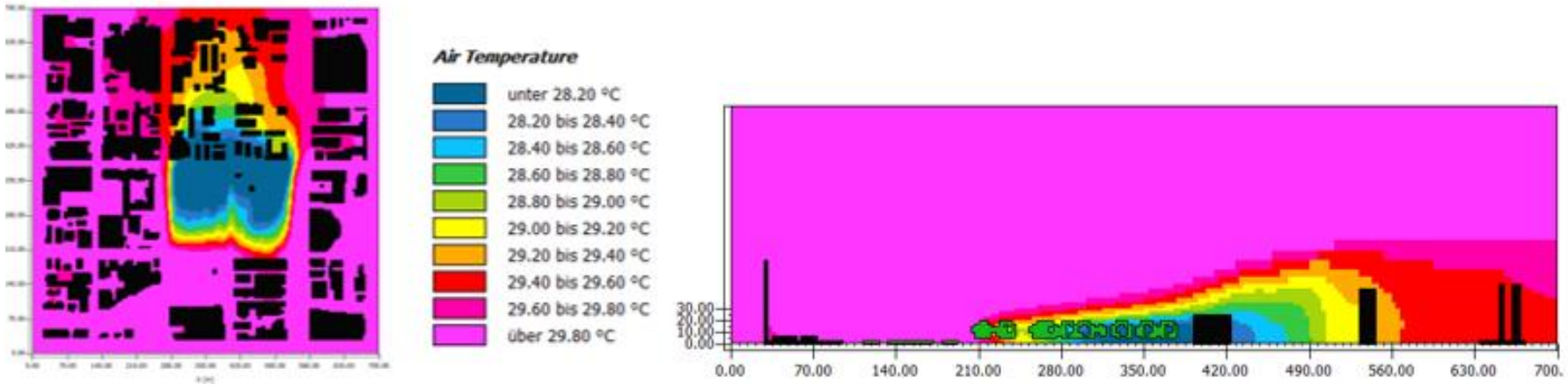




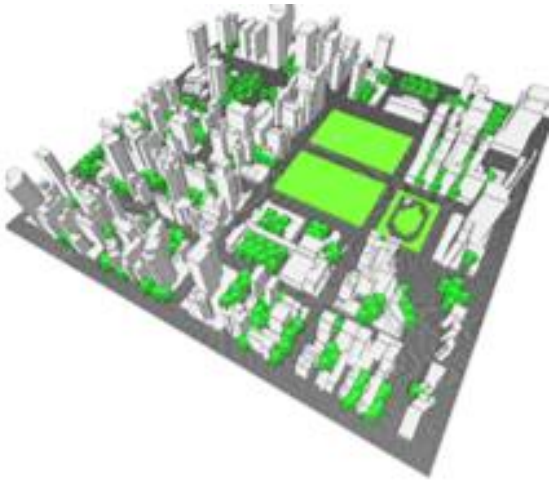


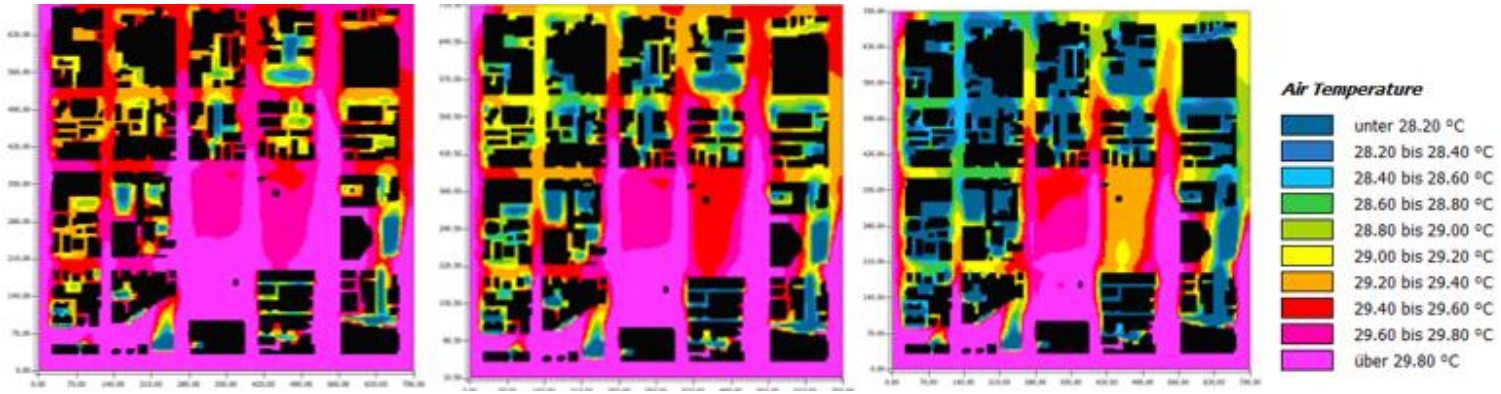


Microclimate effect of Trianon Park

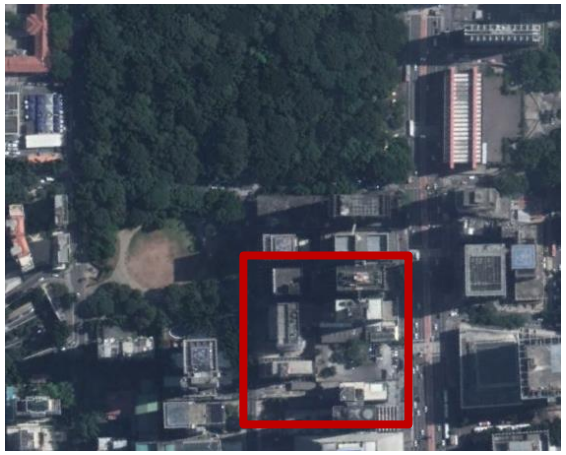


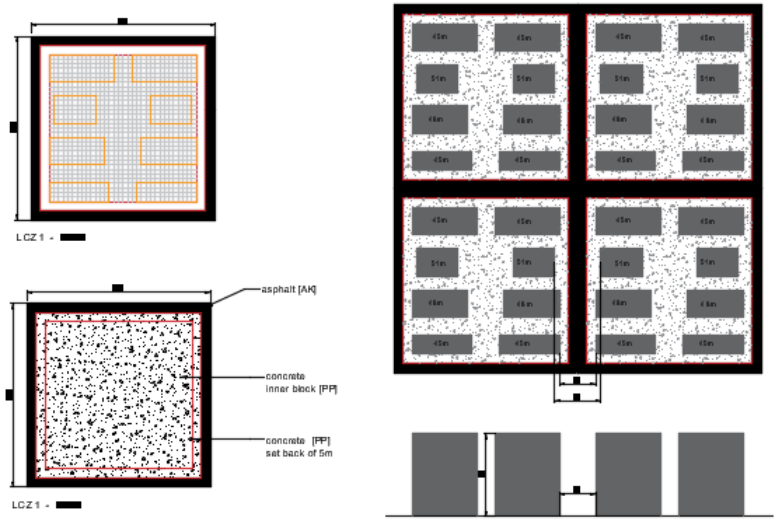
Proposals to increase vegetation inside the urban blocks



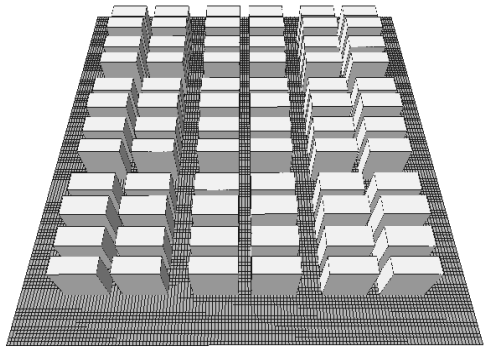


Simulation of parametric scenarios



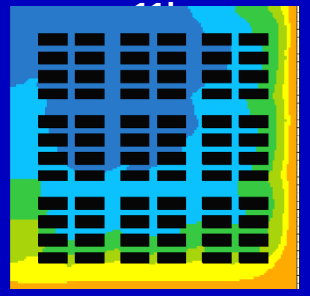


Grid 2.5m x 2.5m
Urban blocks: 100m x 100m
Street width: 5m
Frontal setback: 5m
Building heights: 45m (15 floors), 48m (16 floors), 51m (17 andares)

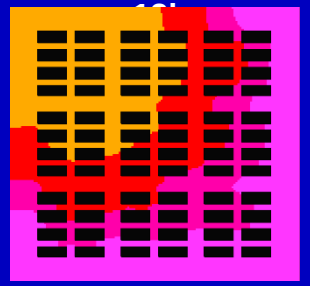


Results for air temperature

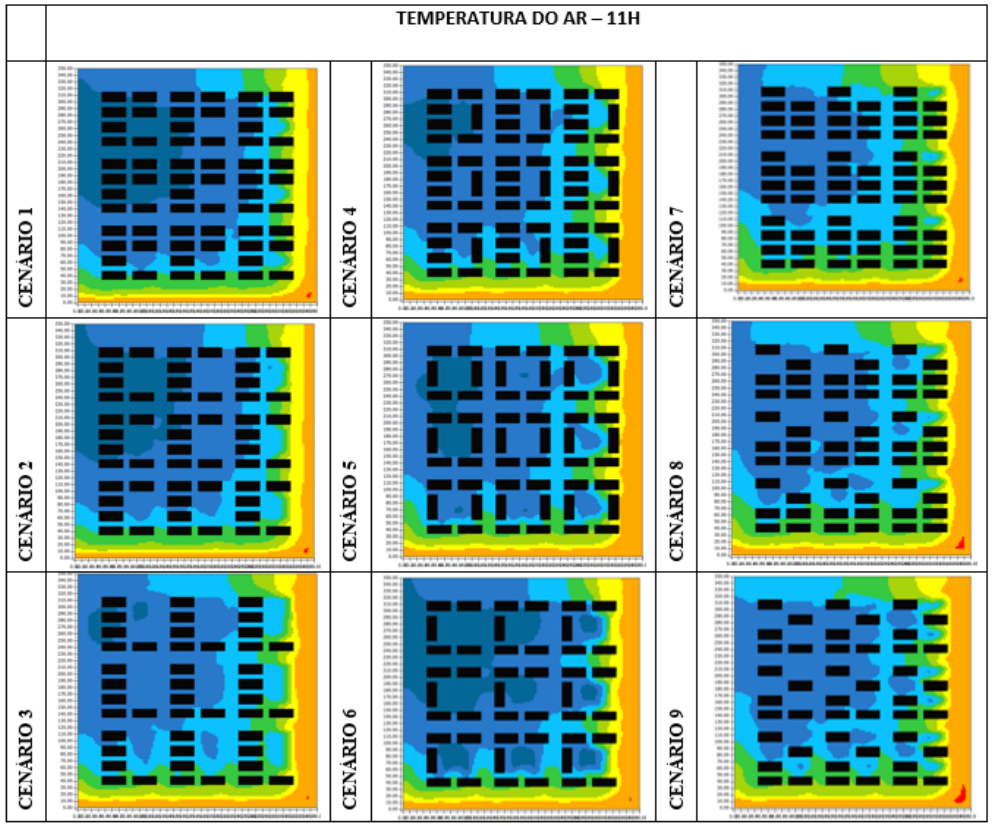
Caso Base –

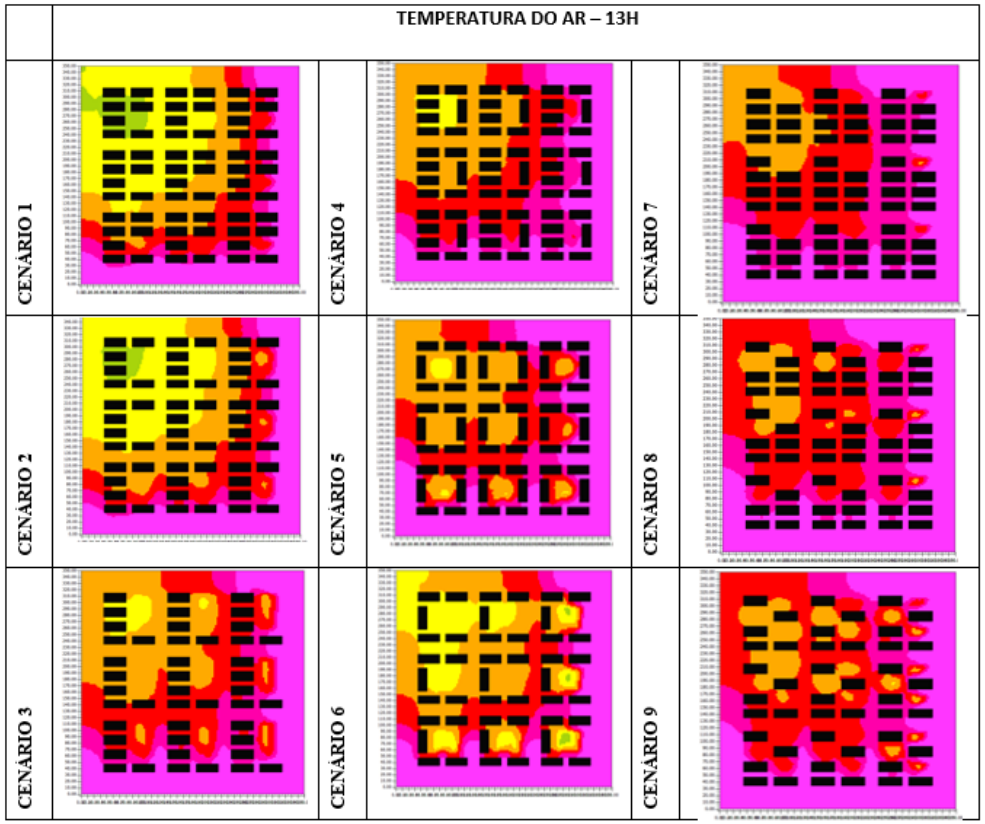


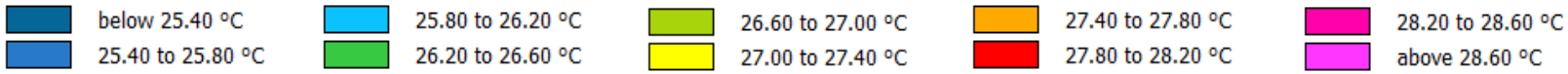
Caso Base –



Na quadra central :
Às11h - Temp ar aprox. de 25.8 ºC
Às 13h -Temp ar aprox. de 28ºC
Influência da ventilação e sombreamento pelos edifícios





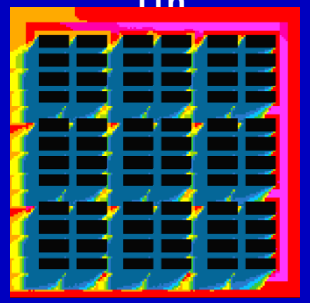


Na quadra central às 11h:
- Temp. ar abaixo das copas variou entre 25ºC a 25.5ºC
- Efeito da ventilação (direção a 135º) contribuiu no transporte
- Cenários 5 e 6 indicaram uma melhor distribuição do efeito da vegetação

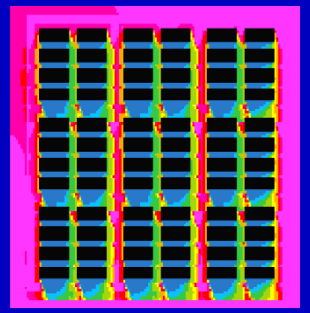
Na quadra central às 13h:
- Temp. ar abaixo das copas variou entre 27ºC a 27.8ºC
- Diferença de até 2ºC em relação as vias asfaltadas
- Cenário 6 apresentou o distribuição mais homogênea do efeito da vegetação

Results for surface temperature

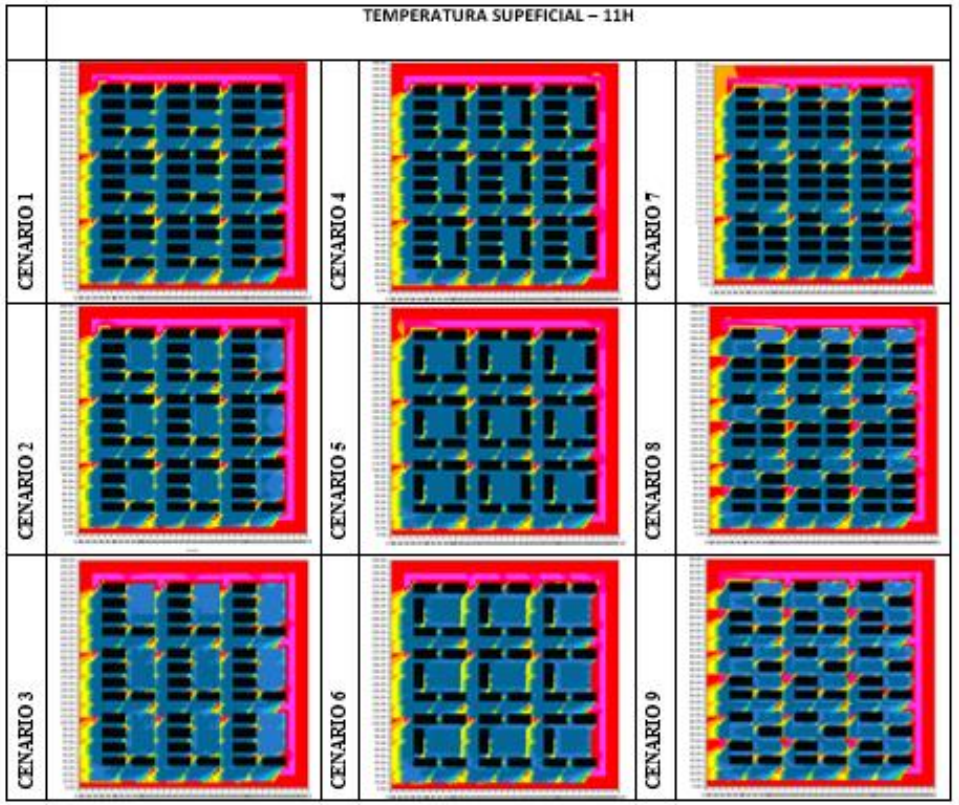
Caso Base – 11h

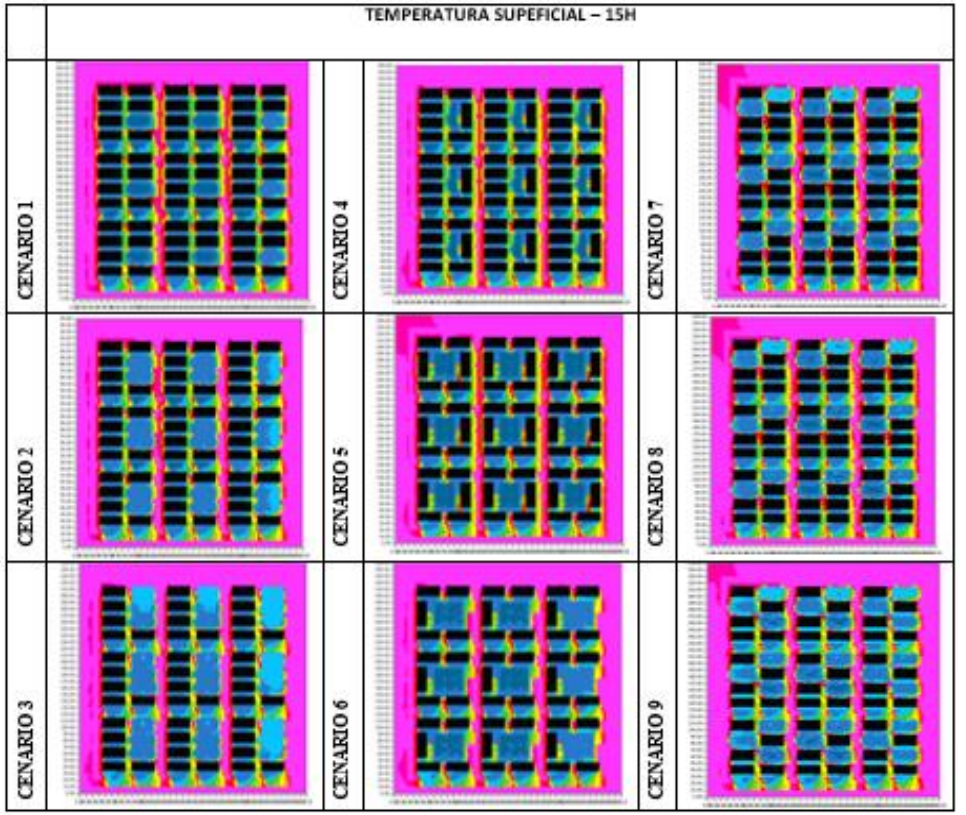


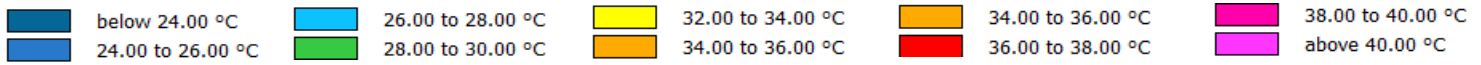
Caso Base –



Na quadra central :
Às11h - Temp ar aprox. de 25.8 ºC
Às 13h -Temp ar aprox. de 28ºC
Influência do sombreamento pelos edifícios





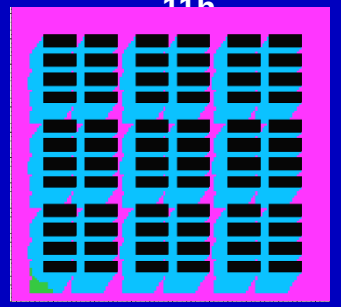


Na quadra central às 11h:
- Temp. ar abaixo das copas variou entre 22ºC a 24ºC
- Influência significativa da sombras dos edifícios.

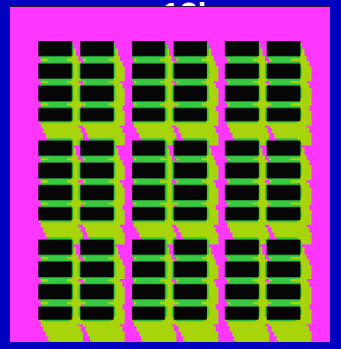
Na quadra central às 13h:
- Temp. ar abaixo das copas variou entre 24ºC a 28ºC
- Diferença de até 21ºC em relação as vias asfaltadas

Results for mean radiant temperature

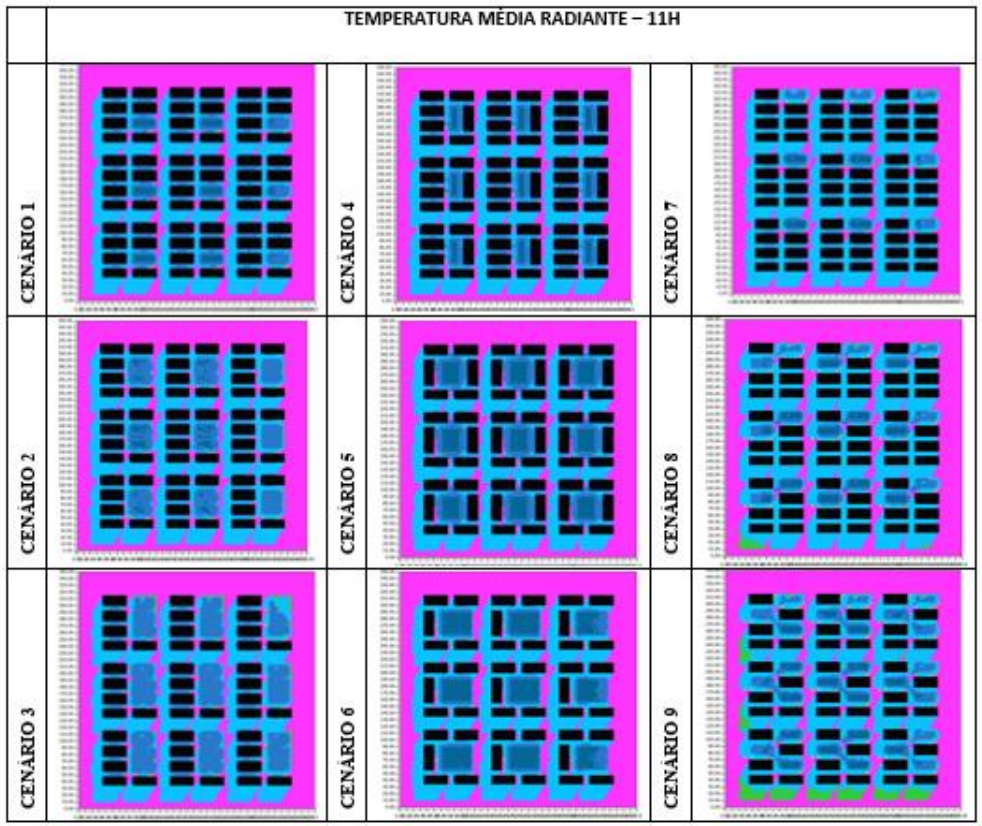
Caso Base – 11h

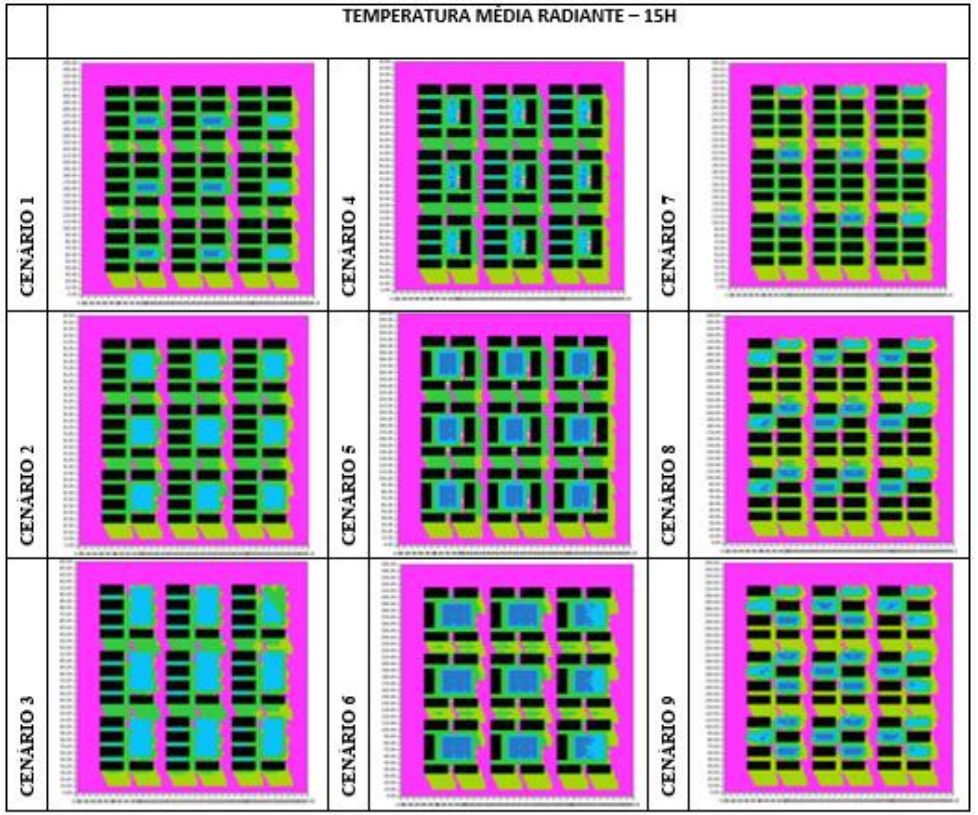


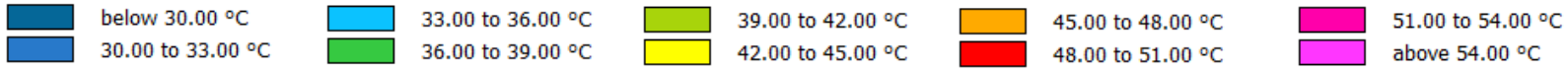
Caso Base –



Na quadra central :
Às11h - TRM aprox. de 25.8 ºC
Às 13h - TRM aprox. de 28ºC
Influência da ventilação e sombreamento pelos edifícios







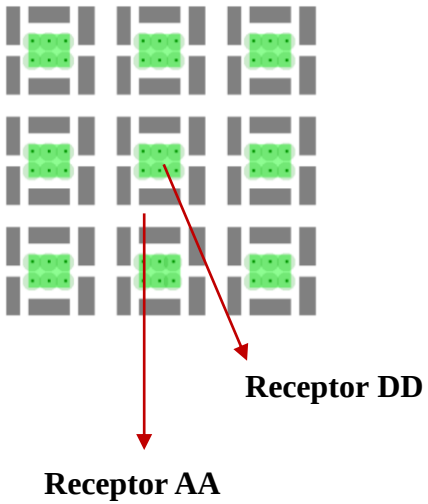
Na quadra central às 11h:
- TRM abaixo das copas variou entre 28ºC a 33ºC
- Efeito da vegetação apresentou temperaturas menores do que em áreas influenciadas pelo sombreamento

Na quadra central às 13h:
- TRM abaixo das copas variou entre 30ºC a 34ºC
- Diferença de até 28ºC na TRM em relação as vias asfaltadas

Temperature of Equivalent Perception - TEP

(Monteiro; Alucci, 2011)

$$TEP = -3{,}777 + 0{,}4828 \cdot Ta + 0{,}5172 \cdot Tmrt + 0{,}0802 \cdot Rh - 2{,}322 \times v \quad (^{o}C)$$



	TEP - vegetação*	TEP - via asfaltada**
cenário 1	30,2	32,8
cenário 2	30,6	32,5
cenário 3	30,9	31,3
cenário 4	30,5	32,4
cenário 5	29,7	32,4
cenário 6	29,8	32,1
cenário 7	30,1	33,2
cenário 8	30,1	32,7
cenário 9	30,2	32,8

*Receptor DD posicionado abaixo da copa, na parte central da área verde

** Receptor AA localizado na via lateral da área verde, sobre o asfalto

Faixas Interpretativas para o índice TEP

TEP	Sensação
> 42,4	muito calor
34,9 ~ 42,4	calor
27,3 ~ 34,8	pouco calor
19,6 ~ 27,2	neutralidade
12,0 ~ 19,5	pouco frio
4,4 ~ 11,9	frio
< 4,4	muito frio

Fonte: Monteiro, Alucci (2011)

Leituras recomendadas

- DUARTE, Denise. O impacto da vegetação no microclima em cidades adensadas e seu papel na adaptação aos fenômenos de aquecimento urbano. Contribuições a uma abordagem interdisciplinar. Tese (Livre-docência). FAUUSP, 2015 (https://www.researchgate.net/publication/305612950).
- DUARTE, Denise. Vegetation and climate-sensitive public places. In: Emmanuel, R. (Org.). Urban climate challenges in the Tropics: rethinking planning and design opportunities. London: Imperial College Press, 2016, p. 111-162. Chapter 5 (https://www.researchgate.net/publication/309747335).
- JONES, Hamlyn G. Plants and Microclimate. A quantitative approach to environmental plant physiology. 2 ed. Cambridge: Cambridge University Press, 1992. Reimpressão 1994.
- SHINZATO, P ; SIMON, H ; SILVA DUARTE, D; BRUSE, M. Calibration process and parametrization of tropical plants using ENVI-met V4 - Sao Paulo case study. Architectural Science Review, v. 2, p. 1-14, 2019 (https://www.researchgate.net/publication/330565759)
- WONG, Nyuk Hien, CHEN, Yu. Tropical Urban Heat Islands. Climate, buildings and greenery. Abingdon: Taylor and Francis, 2009.