Use of vegetation to increase building energy efficiency: application to a real case study

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Introduction

With the UN Sustainable Development Goal 7 in mind, a lot of effort need to be put to find ways to increase energy efficiency. Vegetation can help in reaching the goal, as plants have the capacity to modify the surroundings in different ways, among which the energy exchange.
Trees are treated as shadings, in order to understand if vegetation can really help in reducing energy consumption and Urban Heat Island Effect.

Methodology and case study

The building taken as case study is a residential tower composed of 21 floors, placed in Tirana, Albania. It has a rectangular shape and balconies, where vegetation is placed in permanent concrete planters. The building is currently under construction: the analyses conducted have been helpful during design stage.

Figure 1 Building render, source https://www.stefanoboeriarchitetti.net/

Modelling and simulation process

All the simulations have been carried out with Rhino and Grasshopper, a graphical algorithm editor integrated with Rhino's 3D modelling tools:

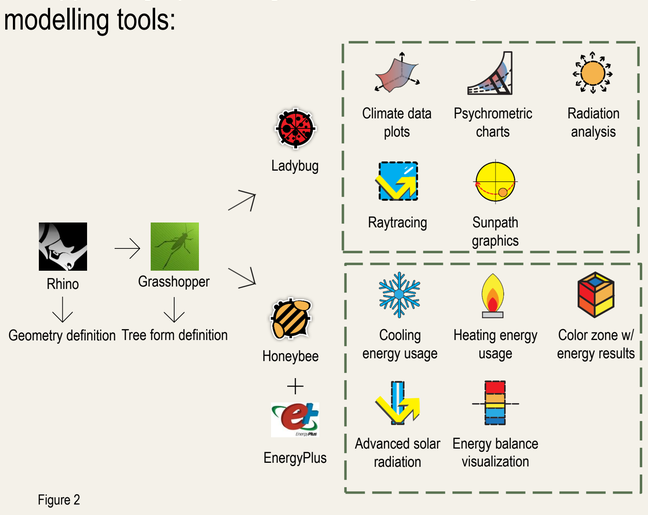


Figure 2

For each case study, eighteen simulations have been run, with these variables: two orientations (South and West); four tree types, plus the baseline (unshaded situation) to compare with; one or two trees placed simultaneously. Process is the following:

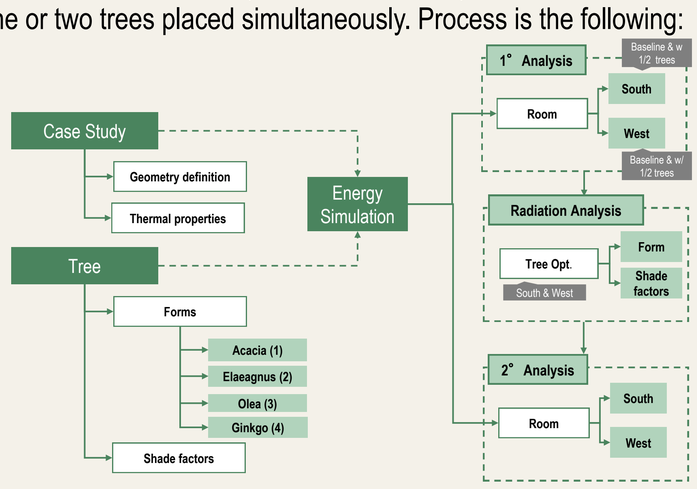


Figure 3 Process followed

Four trees species have been selected, all suitable in the project area and different for shape, dimension and shade factor:

Figure 4 Acacia melanoxylon

Figure 5 Elaeagnus angustifolia

Figure 6 Olea europaea

Figure 7 Gingko biloba horizontalis

Model description

The room is 6.7 x 3.1 m, with height of 3.3 m. All walls and floors are set as adiabatic except the one in contact with the outdoor, which has a window of 4.4 x 2.5 m. The HVAC system is set to provide cooling or heating air to a zone in sufficient quantity to meet specified thresholds.

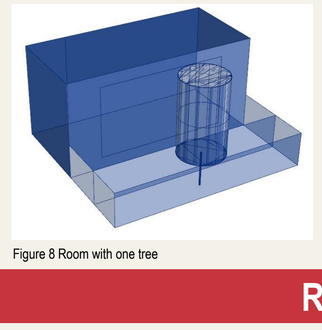


Figure 8 Room with one tree

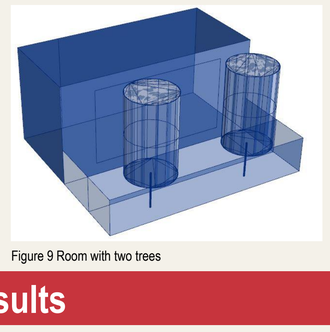
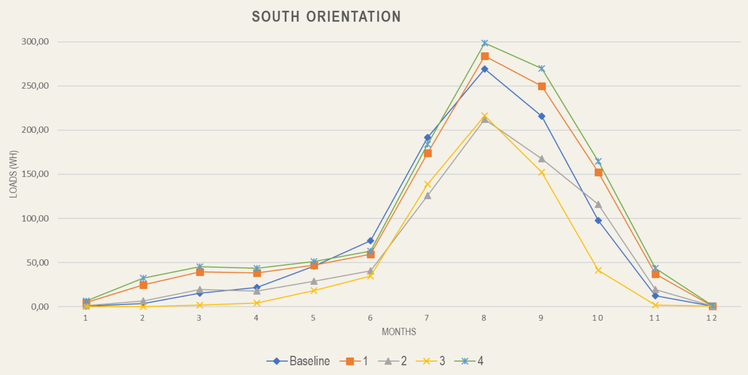


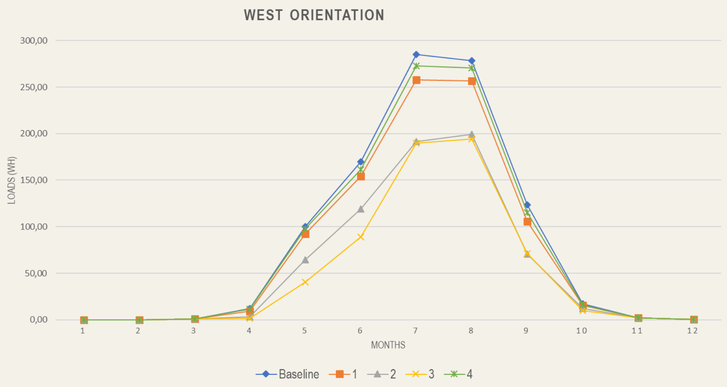
Figure 9 Room with two trees

Results

The results are expressed in cooling loads (Wh), monthly averaged.
In South orientation, in June the maximum reduction of cooling loads reached is about 53.1% respect to the baseline, with an annual saving of 35.6% for cooling.
Each tree has a different shading potential: differences lie on shapes and shading factors, but the relationship between loads and incident radiation is not linear.



Facing West, the percent decrease in cooling loads is of 47.5% in May, with an annual saving of 39.4%. All the trees are useful, but some of them can shade a wider area and get better results.



Comparing simulations with one and two trees, it is possible to say that the second option is preferable in South, as it gives significant improvements, and it could be useful in West.

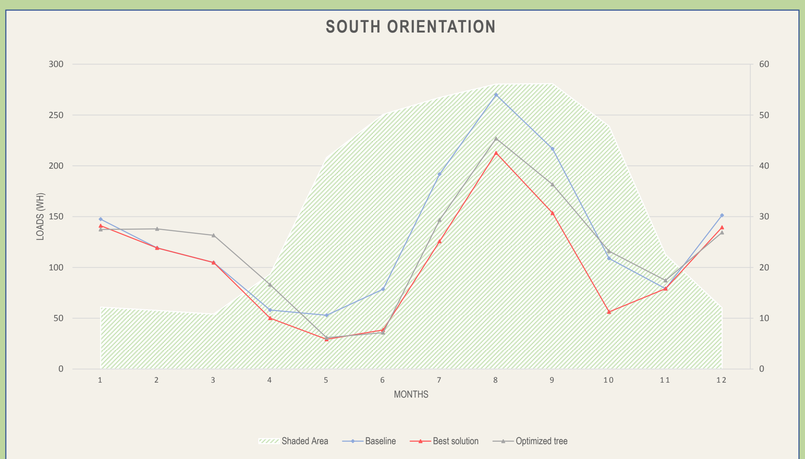
Percent decrease of annual cooling loads from one tree to two				
	1	2	3	4
South	3.6%	84.8%	51.2%	-3.5%
West	2.9%	25.9%	45.6%	17.2%

Optimization process

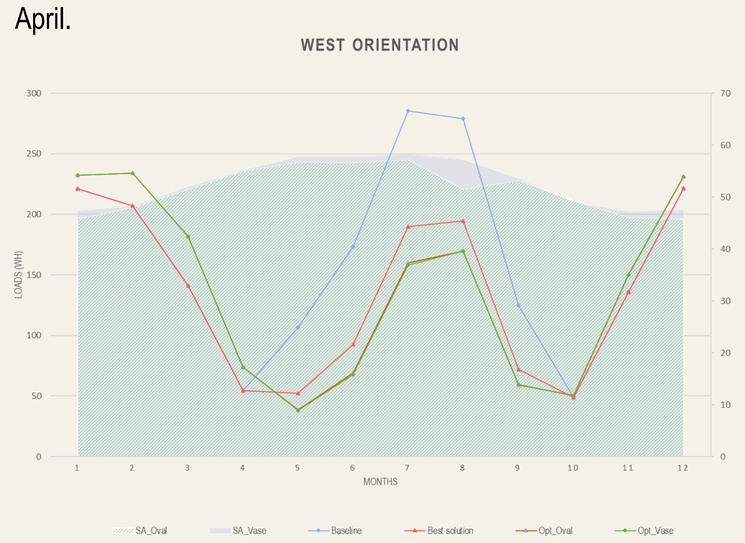
The further step was to find an optimized tree, in terms of shape and shading factor, which can achieve better savings.
It was later compared it with the best solution (found by taking the case with the lowest load for each month).
The solution has been performed by acting on tree geometry, by changing:

- bole height
- crown height
- crown diameter in both direction
- shading factor.

The graph plots heating + cooling loads (to consider the negative effect that the presence of trees can have of heating needs in winter) for the baseline, Best solution (found from previous analysis) and Optimized one, as well as the shaded area, for one tree.
In South, there is no possibility to improve the cooling loads without affecting the heating loads: the one proposed here is a good balance between winter and summer cases. The real power as shading devices is expressed in spring and summer period.



In West, the two Optimized solutions found are practically coincident, as they are better than the best solution from May to October, while they have higher heating loads from November to April.



The following table summarizes the results achieved.

Percentage of improvement of annual cooling and heating loads, respect to baseline		
	South	West
1 tree	8.2%	17.7%
2 trees	15.5%	20.8%

Discussion

In South orientation, the best is to choose trees with:

- circular base profile of crown
- bole arriving up to ¾ of the window
- broadly vase-shaped crown, higher than the window

In West orientation, the best option is to select trees:

- which can cover a great area of the window
- with crown covering more than half of the window area, with particular attention in covering the gap between tree trunk and façade.

The research was conducted on a hot-summer Mediterranean climate, and it can apply wherever there is need of shading devices.
Moreover, the methodology developed is applicable everywhere by changing climate inputs and choosing the appropriate tree species.

Guidelines on construction aspects

Vegetation is characterized by growth and changes, which must be controlled setting limits and ranges.
Aspects to be controlled are:
•mechanical stability of the building structure, as vegetation causes a high dead load, subjected by changes due to moisture content
•safety, as breakage of trunk could occur due to wind
•construction methods
•water supply and collection, to guarantee an adequate irrigation and water disposal
•maintenance, necessary to guarantee tree health.

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