FINDINGS AND ANALYSIS

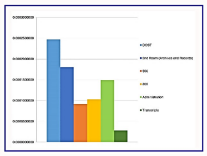
RESULTS OF THE THREE ATTEMPTS TO RELATE TREE SHADING AND THE AIR-CONDITIONING ENERGY CONSUMPTION:

ATTEMPT #1
- determined the cooling potential (capacity) of the shade trees and was able to express it to Tons of Cooling (TR)
- based on the formulas discussed by Villa Juan (2009) and Shi et al. (2019)

ATTEMPT #2
- determined the room that cools fastest
- demonstrated that the air-conditioned rooms with adjacent outdoor planting and/or shade tree(s) cool faster than rooms with exposed paved or bare outdoor areas
- based on scientific concepts and formulas such as the Newton's Law of Cooling

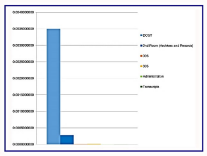
ATTEMPT #3
- the **successful attempt** to relate the tree shading and the building air-conditioning consumption
- made using Revit and Insight Energy Analysis

ATTEMPT 2: Results of the AC Rooms' Case Study



SOLUTION 1. Graph
2 dependent variables:
- Change in Temp.
- Room size

It considered only two dependent variables that are most critical as per the study's scope. Given the equation has less factors or less dependent variables, Solution 1 results to a better-looking graph.



SOLUTION 2. Graph
4 dependent variables:
- Change in Temp.
- Room size
- AC Cooling Capacity
- Present People

Although it has similar results with the other solution, Solution 2 has more variables considered, hence, the higher probability of outliers.

ATTEMPTS 1 & 3 | Summary of the Calculation Results:
The Shade Trees' Cooling Potential, the Shade Landscape Models' Energy Analysis, and Estimated Energy Savings

Site 1 (OUR)	Existing Shade Landscape	Proposed Shade Landscape	DIFFERENCE in Total Estimated Mean EUI (between Existing and Proposed)	DECREASE in Total Mean EUI	PERCENTAGE DECREASE (PD) in Total Mean EUI
TOTAL Estimated MEAN EUI or Energy Use Intensity (kWH/sqm. in a year)	983, 955.14	**953, 464.61**	30, 490.53	0.0309877	**3.10%**
Site 2 (Alumni Engg)	Existing Shade Landscape	Proposed Shade Landscape	DIFFERENCE in Total Estimated Mean EUI (between Existing and Proposed)	DECREASE in Total Mean EUI	PERCENTAGE DECREASE (PD) in Total Mean EUI
TOTAL Estimated MEAN EUI or Energy Use Intensity (kWH/sqm. in a year)	542, 346.77	**535, 120.31**	7, 226.46	0.0133244	**1.33%**
Site 3 (Math)	Existing Shade Landscape	Proposed Shade Landscape	DIFFERENCE in Total Estimated Mean EUI (between Existing and Proposed)	DECREASE in Total Mean EUI	PERCENTAGE DECREASE (PD) in Total Mean EUI
TOTAL Estimated MEAN EUI or Energy Use Intensity (kWH/sqm. in a year)	1, 220, 820.41	**1, 220, 007.31**	813.10	0.0005023	**0.05%**

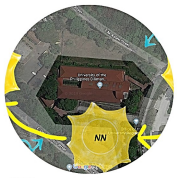
SYNTHESIS

THE STUDY SITES

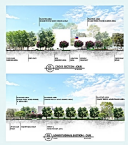
The Shade Landscape Inspiration: LEAF

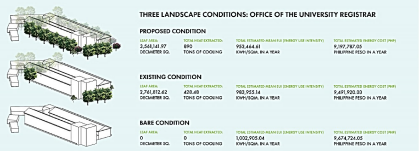
Proposed Shade Tree Landscape Site Developments

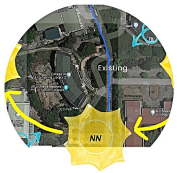
Visual Representations of the Key Results of Attempt 2 and Attempt 3:
Comparing the Three Landscape Conditions



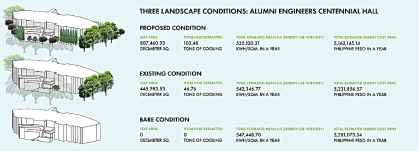
SITE 1
Office of the University Registrar
Administrative and Office Use



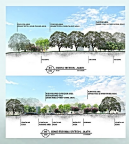




SITE 2
Alumni Engineers Centennial Hall
Library Use



SITE 3
Institute of Mathematics
Classroom Use



RECOMMENDATIONS: SHADE TREE LAYOUT GUIDELINES FOR COOLING

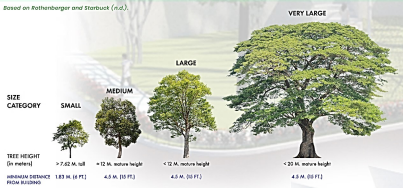
The thesis' proposed comprehensive guidelines for designing a shade landscape, mainly uses trees, for lessening the solar radiation received by the building, and for facilitating passive cooling for reducing the energy consumption of air-conditioning.

What primarily makes up a cooling shade tree landscape?

- ☑ Shade Trees
- ☑ Shade Massing
- ☑ Supplementary Elements
  - such as shrubs, grass, and light or off-white colored pavements

Recommended Minimum Distance from the Building Wall Based on the Tree Size

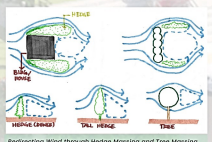
Based on Rothenberger and Starbuck (n.d.)



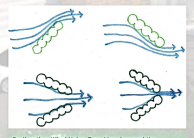
NOTE: For any sizes, the distance of a tree from another tree should be at least half the length of the mature width of its canopy.

Recommended Tree Layouts

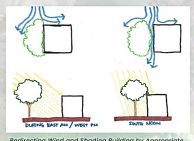
Plant Layouts Adapted from Spirn et al. (1981)



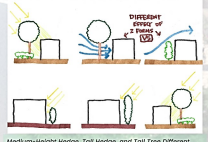
Redirecting Wind through Hedge Massing and Tree Massing



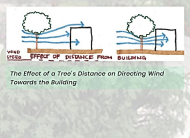
Redirecting Wind Using Tree Massing and the Orientation and Opening of Plant Massing



Redirecting Wind and Shading Building by Appropriate Distancing of the Tree Massing from the Building Wall



Medium-Height Hedge, Tall Hedge, and Tall Tree Different Effects on Shading and Cooling the Building



The Effect of a Tree's Distance on Directing Wind Towards the Building

SHADE LANDSCAPE FOR EFFICIENT BUILDING AIR-CONDITIONING:

TREE LAYOUT GUIDELINES FOR THE THREE U.P. DILIMAN BUILDING UNITS

UP COLLEGE OF ARCHITECTURE
LANDSCAPE ARCHITECTURE THESIS 2022

SANTOS, EUNICE D.
(RESEARCH TRACK)

GALINGAN, ZENAIDA
THESIS ADVISER

BACKGROUND OF THE STUDY

Thermal Comfort is a Demand and a Necessity for Quality Living

Air-Conditioning is a Relief to Urban Heat, a Temporary Mitigator, and a High Consumer of Energy

Vegetative Landscape is an Efficient Solution—a Mitigator that Maximizes Natural Resources

PROBLEM SETTING

RATIONALE

There can be **More Air-Conditioned Rooms** vis-à-vis the Development of School Facilities in UP Diliman

For a Sustainable Development, **Discourage Sacrificing Tree** Shade Coverage in Exchange for the Built Environment

Propose **Energy-Saving Measures** for Cooling a Building through Landscape Design"

PROBLEM STATEMENT

MAIN PROBLEM:

How can trees be designed as shading and cooling elements for the building in order to reduce indoor cooling workload and lessen energy consumption in air-conditioning the three studied sites in the U.P. Diliman Campus—Office of the University Registrar, Alumni Engineers Centennial Hall (Engineering Library 2) and the Institute of Mathematics?

SUB PROBLEMS:

1) What site-existing tree species, tree characteristics, tree massing and layouts can be used to facilitate shading, wind control and cooling for a favorable thermal condition for the studied buildings?

2) How can the tree shading and building air-conditioning be related in a way that can simulate the cooling energy consumption to determine whether a particular shade tree landscape condition does reduce the cooling energy consumption?

GOAL OF THE STUDY

This study aims **to propose a comprehensive guidelines for designing shade tree landscapes** that will facilitate passive cooling and improve ambient thermal condition leading to the reduction of cooling energy consumption in the three studied sites. This study also aims **to discover a way to relate the shade trees and air-conditioning**, and estimate the resulting energy consumption of cooling the three studied U.P. Diliman buildings—Office of the University Registrar, Alumni Engineers Centennial Hall, and Institute of Mathematics—with the three varying shade landscape condition models—Bare, Existing, and Proposed.

OBJECTIVES

1) To **analyze the different methods** for utilizing and assessing the benefits of trees in terms of shading and cooling.

2) To **estimate the cooling potential of trees** for the study sites.

3) To **propose recommendations** for a cooling shade tree layout.

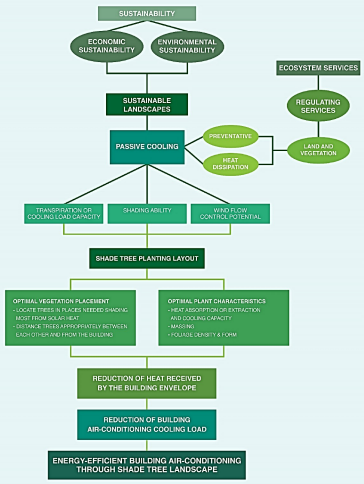
3) DETERMINING THE ESTIMATED OVERALL ENERGY SAVINGS OF THE THREE BUILDING UNITS

- **Calculating:** The *Percentage Decrease* (PD) between the Proposed and Existing Shade Landscape Energy Models
  Using the formula: Percentage Decrease (PD) = (decrease ÷ existing EUI) × 100

SHADE LANDSCAPE FOR EFFICIENT BUILDING AIR-CONDITIONING:

TREE LAYOUT GUIDELINES FOR THE THREE U.P. DILIMAN BUILDING UNITS

RESEARCH FRAMEWORK



Sustainability is said to be the capability to *continue a defined behavior indefinitely* (Thwink.org, 2014), and starting from this concept the thesis utilizes two of its main types or pillars—Economic Sustainability and Environmental Sustainability. The concept of **Economic Sustainability** aims to maintain the capital, preventing it from being exhausted. The concept of **Environmental Sustainability**, on the other hand, aims to secure the needs of the people without *compromising the needs of future generations* (RMIT University, 2017). Considering the financial and environmental aspects of achieving thermal comfort, this thesis pursues the ideas of **Sustainable Landscapes**. The sustainable landscape development aimed for this thesis incorporates the use of natural resources to practice the concept of **Passive Cooling**. As seen in the Research Framework diagram above, the Passive Cooling Concept is linked with the concept of **Regulating Services**. This concept is a type of Ecosystem Services and a concept that uses natural resources to regulate the ecosystem for the needs and benefits of the community. Land and vegetation, are natural assets that can be used to regulate the ecosystem and can exhibit the two techniques of Passive Cooling stated by the Build Abroad Organization (2017)—the Preventative Technique and the Modulation and Heat Dissipation Technique. There are three factors—Transpiration, Shading and Solar Heat Absorption, and Wind control—considered for naturally (passive) cooling the site. The thesis focuses on and maximizes the tree as the major plant type that shades the building against solar radiation (a primary heat source for heat gain). Using a Shade Tree Layout designed with the **Optimal Vegetation Placement** and **Optimal Plant Characteristics**, the shading and cooling landscape surrounding a particular building can aid in the ***Reduction of Heat Received by the Building Envelope*** (heat coming directly from outdoors to the exterior building walls). There is less heat received by the building so there is less building heat gain, resulting in the ***Reduction of Building Air-conditioning Cooling Load***. All these concepts, techniques, and pointers combined lead to the utilization of sustainable landscapes in the form of shade tree planting layout for the goal of efficient building air-conditioning, in other words, there is ***Energy-efficient Building Air-conditioning through Shade Tree Landscape***.

RESEARCH METHODOLOGY

1) DEFINING WHAT IS CONSIDERED A SHADE TREE

Shade Trees
- must be within the 7-meter Offset Parameter with few meters allowance for larger trees based on the recommendations of Rothenberger and Starbuck (n.d.)
- are included in the Cooling Capacity Estimates and Energy Analysis

2) THREE ATTEMPTS TO RELATE THE TREE SHADING AND AIR-CONDITIONER CONSUMPTION

ATTEMPT 1: ESTIMATING THE COOLING POTENTIAL OF A SHADE TREE

STEP 1: Estimate the Volume of Conical Tree Crown

$$Vcone = \frac{\pi d^2 h}{12}$$

(Conical or Pyramidal)
Where d is the base of the cone and h is the height.

Formula(s) based on the paper by Villa Juan, J. D. (2009).

STEP 2: Estimate the Number of Leaves in a Tree Crown

$$Q_{et} = \{(Q_l)\ (V_{tc})\} - C_{os}$$

Where:
Qet = the estimated total quantity of leaves in a given tree sample
Ql = the quantity of leaves in a cubic meter (d)
Vtc = the volume of the tree crown
Cos = the constant value (volume)of open space and other elements to substract from (Ql)(Vtc)

STEP 3: Estimate the Leaf Area and Total Leaf Area

$$A = \frac{\pi}{4} LW$$

Where (Shi et al., 2019):
L = refers to the radius of the length (semi-major axis)
W = the width (semi-minor axis) of the leaf

STEP 4: Estimate the Cooling Rate of the Leaves

$$T = (A_{total})(s)$$
$$T = (total\ leaf\ area)\left(\frac{0.5g}{dm^2}\right)$$

Where:
T = total grams of water transpired per hour of a tree
Atotal = total leaf area of a tree
s = stomatal transpiration (in grams) per dm2 of leaf surface per hour

ATTEMPT 2: CASE STUDY OF AIR-CONDITIONED ROOMS

- To determine if a room with shade(s) tree is air-conditioned faster than a room without shading

SOLUTION 1.
Let the independent variable
Outdoor Temperature be ..... **I**
Let the dependent variables
Change in temperature after a particular period of time be ..... **d*t**
Room Size (in sqm.) be ..... **r**
Where:
Change in temperature is d and time elapsed is t and
d = (initial indoor temperature)-(present indoor temperature)

Finding the Cooling Rate Ratio X then,
X= i/((d*5) (r))

SOLUTION 2.
Let the independent variable
Outdoor Temperature be ..... **I**
Let the dependent variable
Change in Temperature d for every 5 minutes t be ..... **d*t**
Room Size (in sqm.) be ..... **r**
Air conditioner's cooling capacity (in tons) ..... **c**
People present in the room (per head) ..... **p**
Shade Tree's cooling capacity ..... **s**

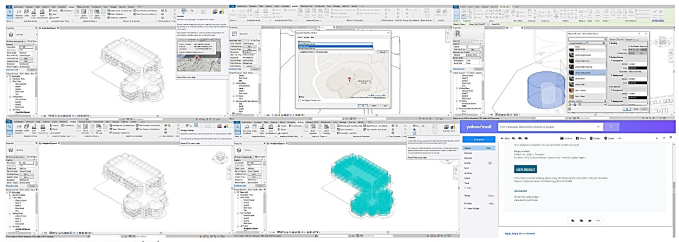
Finding the Cooling Rate Ratio X then,
X = i/((d*5) (r) (c) (p) (s))

ATTEMPT 3: REVIT AND INSIGHT ENERGY ANALYSIS

- To compare the energy consumptions of the three shade landscape conditions—the Bare, the Existing, and the Proposed
- To determine if more tree shading results to less energy consumption

HOW TO CREATE SITE MODEL FOR REVIT AND INSIGHT ENERGY ANALYSIS:

1. Import site topography map from CADMapper (*cadmapper.com*) and make it into contour map on Revit.
2. Create the site model based on the building plans and the shade trees' respective canopy width and height, and location.
3. For each shade tree representation, select the whole mass object, on the Properties tab, change the material to 'Default' Mass Shade'. Then, click 'Finish Mass'.
4. On Revit's Analyze tab and the Energy Optimization ribbon, specify the Geographic location for the site.
5. Specify parameters for the energy analysis.
6. Click 'Create Energy Model' to make the energy analytical model.
7. Begin energy analysis by selecting 'Generate' under the same Energy Optimization ribbon of the Analyze tab.
8. Wait for email confirmation that the model has been received, then another email informing that analysis is complete.
9. Access the analysis results by clicking 'View Insight' in the email and logging in to Autodesk Insight.



Screenshots from the Revit Energy Analysis (2021)

UP COLLEGE OF ARCHITECTURE
LANDSCAPE ARCHITECTURE THESIS 2022

SANTOS, EUNICE D.
(RESEARCH TRACK)

GALINGAN, ZENAIDA
THESIS ADVISER