DTP III Spatial Design World - Modelling Uncertainty

Group Member	**Student ID**	**Task I**	**Task II**	**Task III**
Choy Kar Leng Alicia	1008250	Who is the specific community of people you are hoping to serve with your garden?	Field approach & Cell approach	Analysis I (Dataset & Methodology and Introduction)
Yeo Hui Ying	1008241	What are existing practices in the community you identified to address food security & mental health issue?	Cell approach & Implementation	Analysis I (Analysis & Modelling and Conclusion)
Gan Xiao Tong	1007959	What kind of human relationship are you hoping to foster with your garden in the community you identified?	Field approach & Cell approach	Analysis II (Dataset & Methodology and Conclusion)
Guinness Hartanto	1008053	How could your garden cause possible harm to the community you identified and what are your plans to mitigate that harm?	Cell approach & Implementation	Analysis II (Analysis & Modelling and Appendix)

Introduction

Vertical gardens present a sustainable approach to addressing urban challenges like food security. With urbanization, maximizing the use of vertical spaces for food production has become increasingly vital. Using our product, Celestine Canopy (shown in appendix), this report investigates how the angle of connections between the individual modules and the depth of the spoons (plant pot) of our structure affects the average food production of each plant. Since the average food production of each plant is proportional to the amount of sunlight (incident radiation) exposed to the plants, we decided to make incident radiation our dependent variable. This study employs statistical modeling to determine ideal design parameters that boost the efficiency of attaining food security while catering to the needs of our target community (young families).

In Singapore, majority of the Asian family's diet consist of carbohydrates such as rice, noodles and bread. Hence, our project aims to grow plants like wheat, rice and soybean in our vertical garden. The optimal Photosynthetically Active Radiation (PAR) level for these plants is around 15–20 mol/m²/day which is approximately 279 kWh/m² of incident radiation[1]. Hence, our aim is to find the parameters which produce the incident radiation that is at/nearest the optimal level.

Assumptions for both analysis:

Category	Assumption
Sun path location	Singapore, Yishun Street 43, sun path used is constant between simulations
Light condition	Constant sunlight. No seasonal or weather variation
Shading	Fixed shading dynamics without interference from external structure
Plant Conditions	Constant soil, water nutrients provided, no limiting food production factor
Simulation accuracy	Grasshopper model is accurate in representing real-world light distribution and shading effects
Structure of design	All other features of our dome structure are constant aside from the independent variables.

Analysis I: Optimizing average food production of each plant by varying angle.

Dataset & Methodology

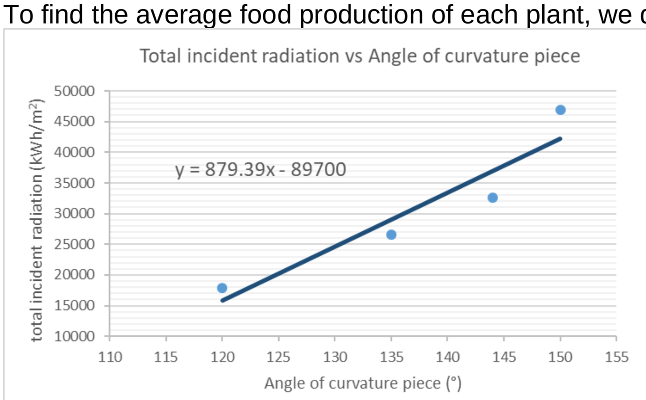
Category	Variable type	Details
Angle of connection between cells (°)	Independent	Angle of curvature piece ranging from 120° to 150°
Number of modules	Independent	Number of modules ranging from 64 to 159
Incident radiation (kWh/m²)	Dependent	Solar energy received by tile surface

Analysis & Modelling

First, we modelled the curvature piece of our structure with different angles and recorded the total sunlight exposed on the plants to determine the best angle for the result we hope to obtain. While increasing the angle, we are required to also increase the number of modules to maintain the shape of our product since the angle of curvature piece is proportional to the number of modules (shown in appendix). Hence, the number of modules for the corresponding angles is set as shown in Figure 2.

Model	Equation	R^2 value	Key insights
Total incident radiation vs angle of curvature piece	Total incident radiation (kWh/m²) = 879.39 x angle of curvature piece (°) - 89700	0.8861	Total incident radiation increases by approximately 879 per degree

To find the average food production of each plant, we divide the total sunlight by the number of modules. Hence,



Angle of curvature piece	Number of modules	Average sunlight per plant (to 5 sf)
120	64	279.93
135	95	279.62
144	111	293.92
150	159	294.85

Figure 1 Figure 2

Figure 1 confirmed the linearity assumption of the regression model, supporting the reliability of the findings. Scatter plots show a positive correlation between incident radiation and angle of curvature piece.

Based on the linear regression, the total incident radiation (kWh/m^2) = 879.39 x angle of curvature piece (°) - 89700. Since the required incident radiation is approximately 279 kWh/m^2 per plant, we must multiply this value by the number of modules to find the total sunlight. However, the number of modules varies for different angles. Hence, we set the angle of the curvature piece to be 135° for our product as its corresponding sunlight exposure is the nearest possible to the optimal level.

<u>Analysis II: Optimizing average food production of each plant by varying depth of spoon.</u>

Dataset & Methodology

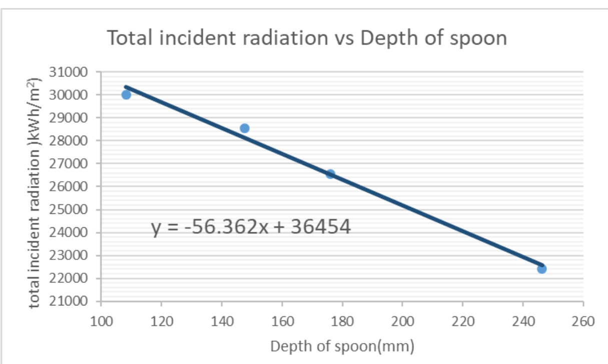
Category	Variable type	Details
Depth of spoon (mm)	Independent	Depth of spoon ranging from
Number of modules	Independent	Number of modules ranging from 74 to 137
Incident radiation (kWh/m^2)	Dependent	Solar energy received by tile surface

Analysis & Modelling

Next, we modelled the depth of our spoon of our structure with different values and recorded the total sunlight exposed on the plants to determine the best depth for highest incident radiation obtained. While decreasing the depth, we are required to also increase the number of modules to maintain the shape of our product. Hence, the depth of spoon is inversely proportional to the number of modules (shown in appendix). The number of modules for the corresponding depths is set as shown in Figure 3.

Model	Equation	R^2 value	Key insights
Total incident radiation vs depth of spoon	Total incident radiation (kWh/m^2) = -56.362 x depth of spoon (mm) + 36454	0.9903	Total incident radiation decreases by approximately 56.4 per mm

To find the average food production of each plant, we divide the total sunlight by the number of modules. Hence,



Depth of spoon	Number of modules	Average sunlight per plant (5sf)
246.4	74	303.10
176.0	95	279.61
147.7	116	246.25
108.2	137	219.19

Figure 3 Figure 4

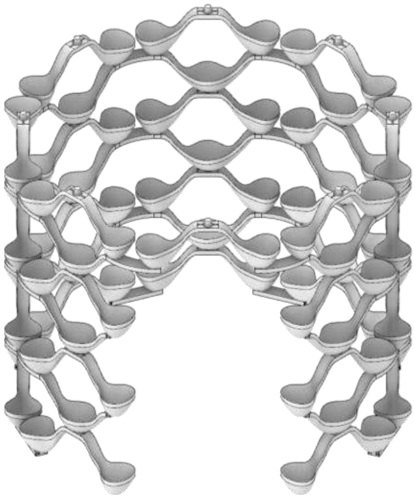
Figure 3 also confirmed the linearity assumption of the regression model, supporting the reliability of the findings. Scatter plots show a strong negative correlation between incident radiation and depth of spoon. Like the reason above, since the depth of spoon at 176m provides us with approximately 279 kWh/m^2 of incident radiation which is the nearest possible to the optimal level, we set this value as our depth of spoon for our structure.

Conclusion

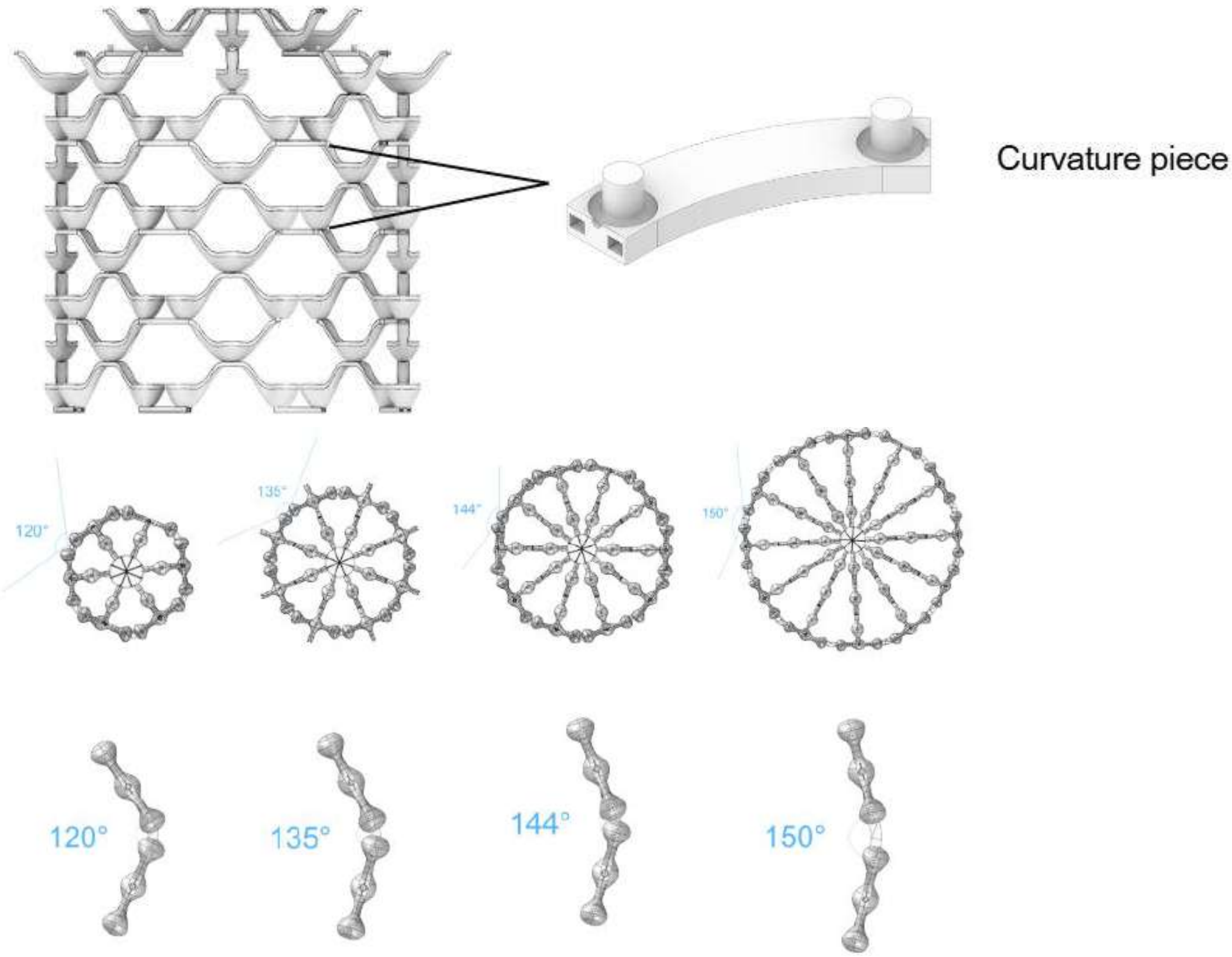
By optimizing these parameters, the Celestine Canopy ensures efficient use of vertical space to produce food sustainably, catering to the dietary needs of young families in urban environments like Singapore. This approach not only maximizes food production per plant but also minimizes the need for extensive trial-and-error simulations by using predictive modeling to achieve desired outcomes. Through thoughtful design, our vertical gardening system provides a promising solution to the challenges of urban food security and sustainability.

Appendix:

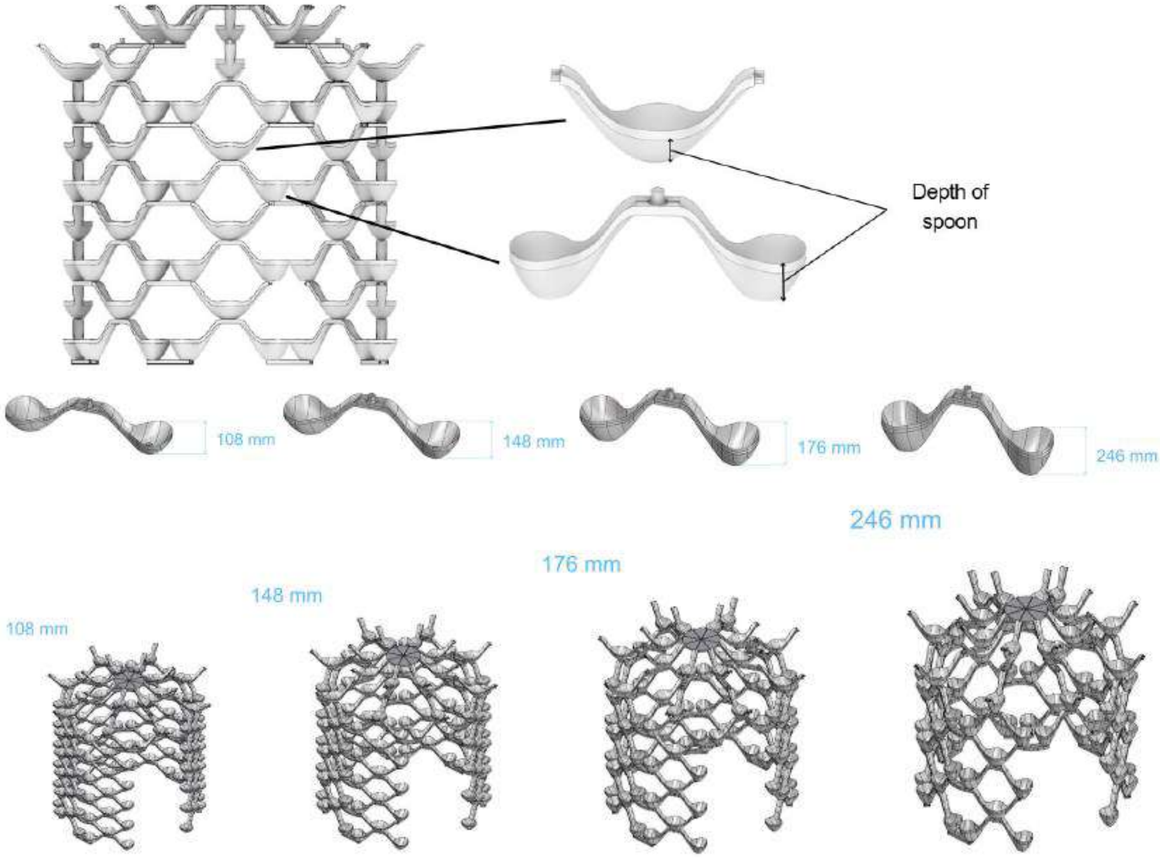
Structure of Celestine Canopy:



Angle of curvature piece:



Depth of spoon:



Reference for [1]

- https://www.canr.msu.edu/floriculture/uploads/files/dli%20requirements.pdf
- https://extension.psu.edu/forage-and-food-crops/agronomic-crops/production-and-harvesting
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2005JD006730