Development of a Predictive Tool for Use in the Urban Farming Industry

Andrew Hadfield, Dr Leo Lue, Dr Mark Haw
Department of Chemical & Process Engineering - University Of Strathclyde, Glasgow
Dr Jens Thomas, Laurence Anderson - Farm Urban, Liverpool

Introduction

By 2050 global population is expected to reach 9.7 billion [1], necessitating a 40% increased yearly food production. Current industrial practices for the mass production of food hinder future production productivity [2][3][4]. Additionally, climate change will decrease the productiveness of key areas of global food production [5][6].

This project focuses on one current area of innovation in the agricultural industry – vertical farming. Vertical farms utilise Controlled Environmental Agriculture (CEA)' systems, where all parameters impacting plant growth are controlled to optimise year-round production [7]. This increases land productivity, whilst also reducing energy and water footprints for crop production.

Vertical farming can be a tough industry for start-up businesses. This is due to several factors, including the high capital cost of equipment and high running costs such as electricity and heating [8]. To assess a potential farm's economic viability, extensive research is required into farm location and operation. Unfortunately, there are currently few available tools which can help predict how such a hydroponic farm will operate. The aim of this project is to create one such tool.

Work at Farm Urban

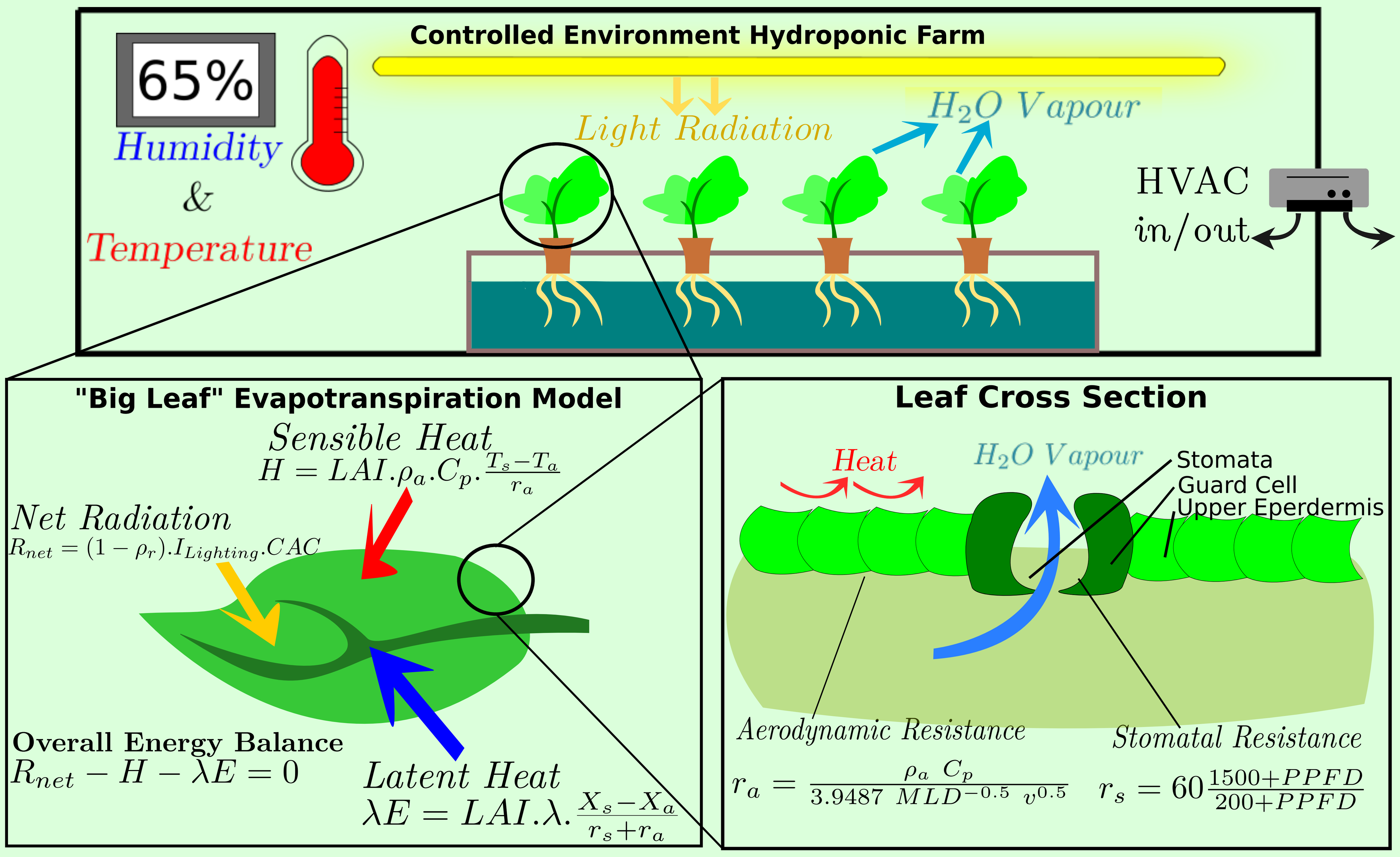
After joining Farm Urban as an intern, I spent the summer learning about the fundamentals of hydroponic systems.
Near the end of my time at the company, I joined a project that aimed to create a program that simulates how hydroponic farms perform. As an engineer, I would have a unique view of this project as the other employees at Farm Urban are all from a primarily scientific background.

Project Aims

- Develop a dynamic model to determine transpiration rates of plants in given environmental conditions
- Fit model parameters to optimise and then quantitatively analyse the simulation model by examining generated results against experimental data from Farm Urban
- Use the simulation to predict the evolution of environmental conditions in specific vertical farms

Modelling

Name	Symbol	Description
Cultivation Area Coverage	CAC	Describes the coverage of plant leaf per unit cultivation area
Leaf Area Index	LAI	Describes how much leaf area there is per unit area of leaf coverage
Mean Leaf Diameter	MLD	Mean leaf diameter of the plant
Aerodynamic Resistance	r_a	Controls both sensible and latent heat flux from the plant, and is based on the geometry of the plant leaf and properties of the air.
Stomatal Resistance	r_s	Influences the latent heat flux from the plant. Proportional to the opening of the stomata in the leaves of the plants.



Program Model

The program calculates the transpiration rate of plants in given environmental conditions. To do this;

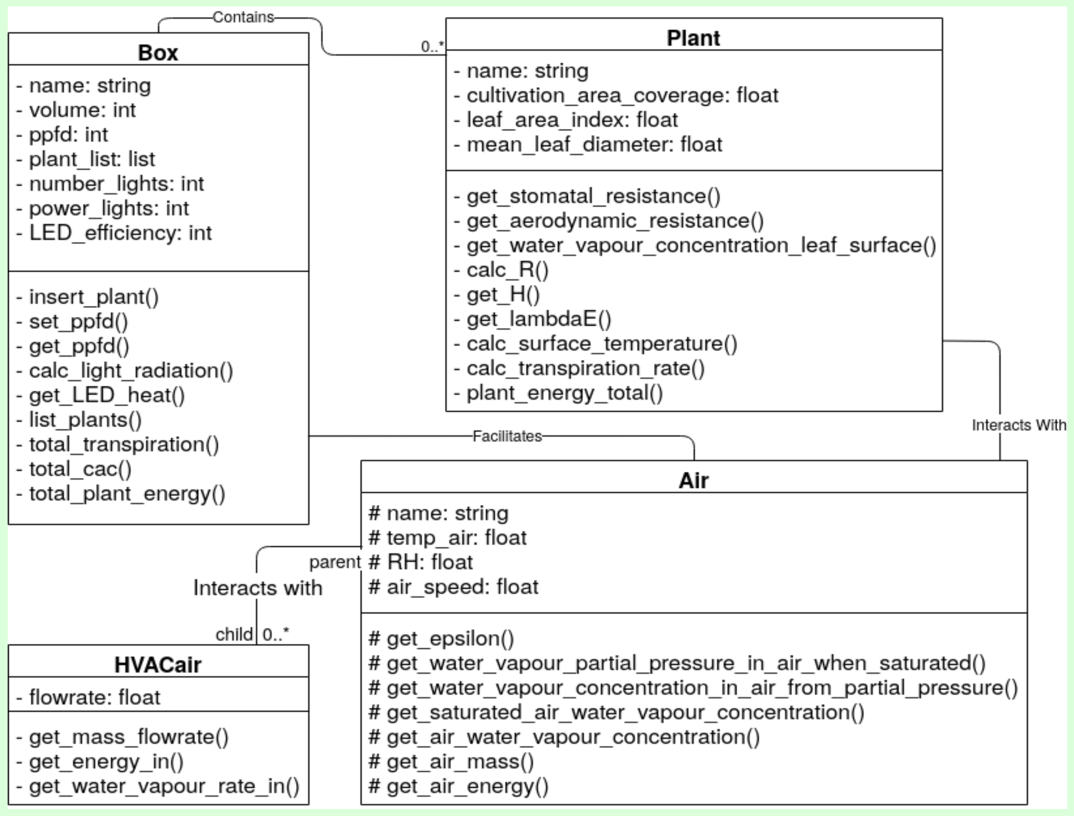
- 3D crop canopy is reduced to a 1D "Big Leaf", where net radiation is absorbed, heat is exchanged and water vapour escapes
- An energy balance is performed over the "Big Leaf" and the energy components are computed. Latent flux component directly gives the transpiration rate of the plants

To calculate the energy fluxes, the program must first calculate the resistances to these fluxes. The resistances are a function of the environmental conditions the plants are in;

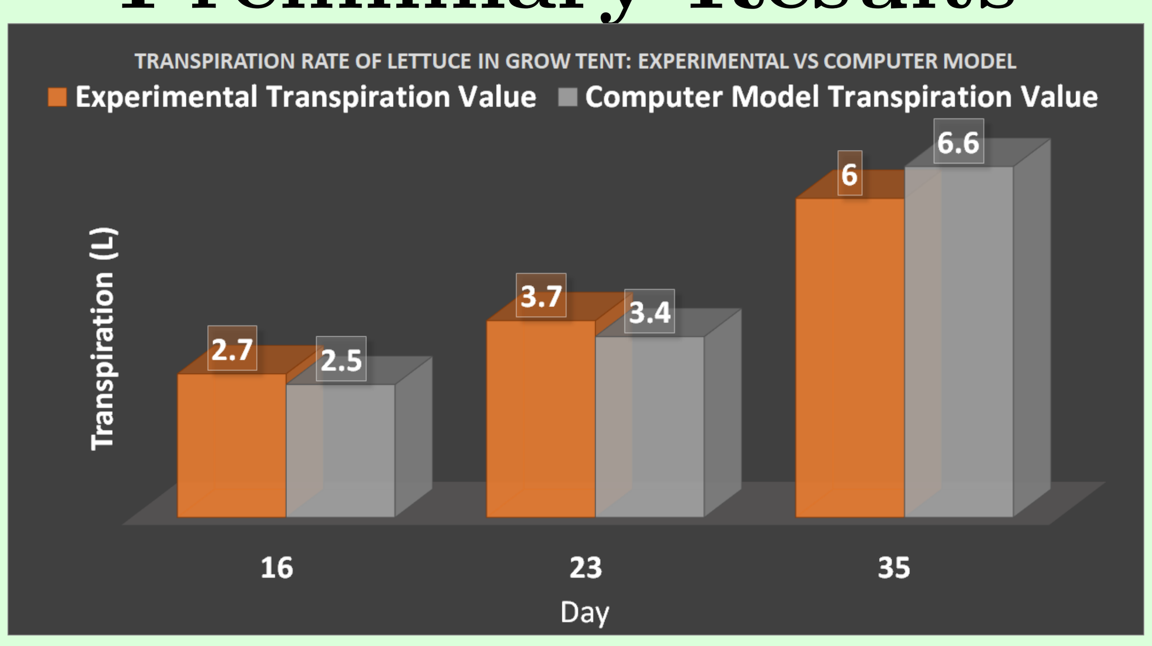
- Aerodynamic resistance impacts the rate at which heat can be exchanged from the leaf surface, and is a function of the leaf geometry and properties of the fluid exchanging the heat with the leaf, which is air
- Stomatal resistance represents how open the stomata of the leaf is, which regulates the rate at which water vapour can escape the leaf. The stomatal opening is assumed to be a function of the intensity of photosynthetically active light that reaches the leaf

Program Components

The transpiration model has been split into multiple components called classes to give greater flexibility to the code. The UML diagram below depicts how the individual classes of the transpiration model interact with each other to produce an output.

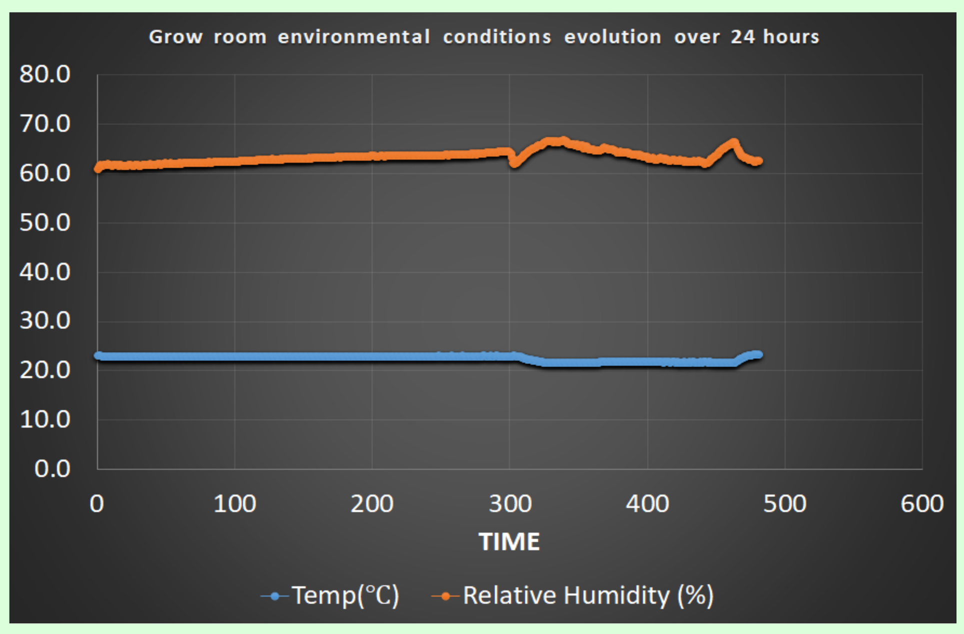


Preliminary Results



- Daily transpiration values of lettuce from experiment and the computer model is displayed
- The experimental and generated values vary between 7-10% for the compared days
- Further experiments should be carried out with different crop types to determine the overall applicability of the model

Future Work



- Environmental data from an experimental grow tent growing lettuce at Farm Urban over a period of 24 hours is displayed
- Next step is to fit the transpiration model into a functioning simulation that will detail the evolution of a grow space over time
- The parameters for the transpiration model and simulator will be adjusted until the simulation generates results similar to experimental data

References

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