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# An examination of unwalled agricultural shading structures under calm wind conditions

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## 1. INTRODUCTION

Simple pitched roof unwalled shading structures are frequently used to control the environmental conditions animals [1], humans and agricultural crops [2] are exposed to. One such example is the vitivoltaics (combined viticulture and photovoltaic electricity generation) system proposed for the Charles Sturt University vineyard, as shown in Figure 1.

**Figure 1**. Concept for a photovoltaic shelter at Charles Sturt University's vineyard

Although these structures provide clear shading benefits, there is still a question as to how they influence the environment they are shading. This issue comes to the fore when the ambient wind conditions are calm and natural convection is the predominant transport mechanism. Specifically, does the shading structure create a microclimate by restricting the movement of air?

Developing our understanding of the airflow resulting from this style of structure will allow them to be designed to be more responsive to the crops, or the animals, they may shelter. In turn this may lead to productivity improvements [3].

## 2. METHOD

To understand the natural convection arising from a pitched roof unwalled shading structure, a 2D steady state model was formulated in a commercial finite volume CFD solver [4]. The computational domain was spatially discretised using a rectangular computational mesh of approximately 600,000 cells. The height of the shelter was varied to examine how the aspect ratio (AR) of the open sides (defined as the ratio of the height of the side to the height of the ridgeline) influenced the temperature under the roof. It was assumed that the roof had a pitch of 10 degrees, and its temperature was 10 – 40 degrees higher than the surroundings, resulting in Grashof numbers in the range of $10^7$ - $10^8$ where the ridge height defined the characteristic length.

In its treatment of turbulence, the solver employs transport equations for the turbulent kinetic energy and turbulence dissipation rate using the standard k-epsilon model. To describe the near wall flow the solver employs the Modified Wall Function approach, in the form of a Van Driest's profile [4]. In resolving the conservation equations, the solver uses a cell-centred approach where second-order upwind approximations for the fluxes utilise the QUICK scheme and the Total Variation

Diminishing (TVD) method. Finally, time-implicit approximations in the convection/diffusion and continuity equations are addressed using a SIMPLE-like approach and an operator-splitting technique. Despite its limitations [4] has shown that the solver is able to provide accurate prediction of natural convection in a square enclosure when compared with a benchmark numerical solution [5].

## 3. RESULTS

In examining the results of the simulation, it is apparent that, under calm wind conditions, a pocket of hot air can become trapped under the roof structure. Whilst this ‘pocket’ does not extend entirely to ground level, it is possible that this could influence the temperature of crops that are grown under the shelter. This is most significant when the roof is exposed to high levels of incident radiation (which result in a high temperature), as shown in Figure 2a. However, by increasing the aspect ratio of the side opening it is possible to alleviate this issue, as shown in Figure 2b.

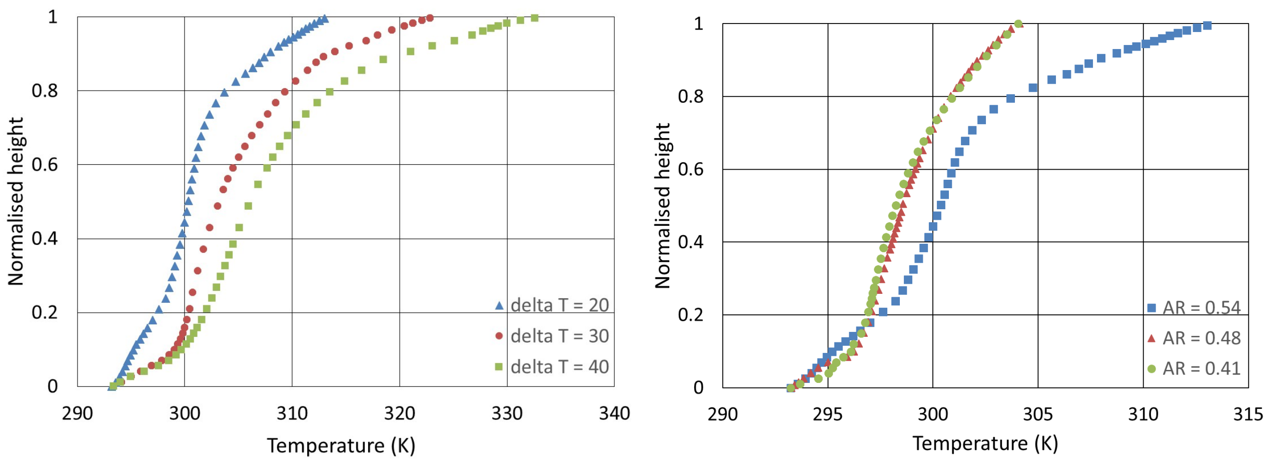


**Figure 3**. (a – left) Temperature v height, fixed AR, (b – right) Temperature v height, varying AR

In the context of low-lying crops, this temperature variation may not be significant. However, in the context of grapevines this may present both challenges and potentially opportunities.

## 4. CONCLUSIONS

This work has shown that although pitched roof unwalled shading structures can provide shade from direct solar exposure, they also have the potential to generate microclimates by restricting air movement. This may impact any crops or livestock using the shading structure for protection. However, these impacts can be somewhat mitigated through careful selection of the structure’s geometry.

## REFERENCES


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