Flow topology around a 6-rows vertical agrivoltaic power plant

A 2D CFD analysis of an ideal vertical agrivoltaics demonstrator

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1. Introduction

Vertical agrivoltaics is of interest for its potential to reduce wind loads on crops and make farming practices easier. In fact, it could reduce the costs associated with crop lodging and act as a windbreak. Some studies have shown that the mean wind speed decreases at the mid-height of the panel structure between two rows when the wind arrived perpendicular to the panel. To the authors' knowledge, no study has thoroughly analyzed the flow topology around inter-row and vertical agrivoltaic power plants in depth. In this work, we propose a computational fluid dynamics (CFD) approach to study the flow beneath the power plant close to the crops in a fairly precise manner. The approach used is applied to a 2D case in order to limit the numerical calculation, but could easily be transposed to more complex 3D cases.

2. Material and Methods

This study is based on an ideal six rows vertical agrivoltaic power plant above an crop of wheat at different growing stage. The numerical study was carried out using OpenFoam v2312 software to model the flow around the demonstrator using the RANS equations. Turbulence was treated using the two-equation closure model k-ω SST, selected among others for being well suited to the geometry studied. The mesh was chosen by carrying out a convergence study using the flow parameters under the panels as indicators. The effect of the crop on the flow was modelled by assuming it to be a porous blockage and adding a source of turbulent kinetic energy. The culture parameters were selected based on experimental data. The flow parameters studied, shown in Figure 1, enable us to understand the flow downstream of the first row of panels that reaches the crops: the contraction height H_c, maximum velocity U_{max}, location of the maximum contraction d and inlet height H_{in}. These variables were studied as a function of entry speed, clearance height, the form of the panel base and the presence of crops.

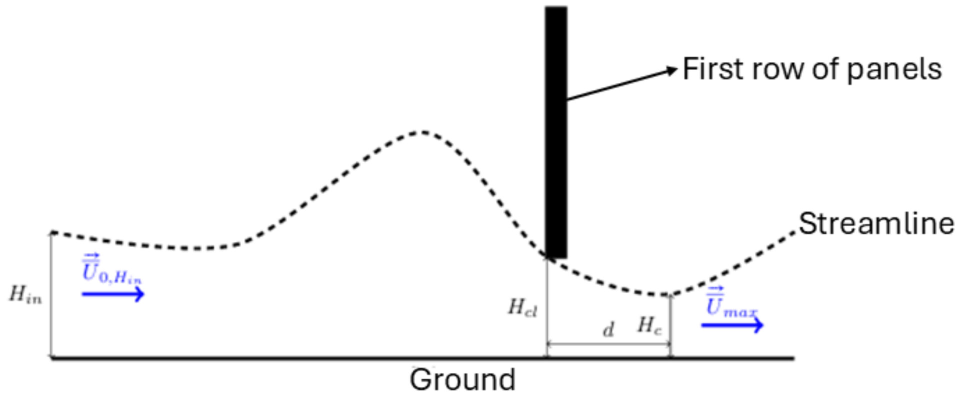

Figure 1. Diagram of the study parameters and the contraction effect under the panels.

3. Results and conclusions

3.1. Results

The plants act as a barrier to the flow and will strongly modify the flow downstream of the first panel in terms of speed and location of the maximum contraction, as shown in Figure 2. In fact, the plants absorb a portion of the fluid's momentum by generating a blockage. As a result, less mass will pass through (H_in decreases). At the same time, the portion of airflow that continues beneath the first panel rises above the plants (decrease in d/H_{cl}) and so reduce the contraction (Cr approaches 1). This will further reduce the speed of contraction. Another interesting observation is the order of magnitude of the part of the inlet flow that participates in the flow under the first panel (H_{in}). In fact, the height is much less than half the height of the panel plus the clearance height (0.93 m), whereas at first sight we might have thought that the lower half was participating, as in the case of a symmetrical flow. This effect is probably caused by the non-uniform velocity profile at the inlet and by the presence of the ground, which causes significant pressure at the bottom of the profile and causes the flow to rise. This observed effect makes it possible to reduce the mass flow under the flow and therefore ultimately the loads on the crops.

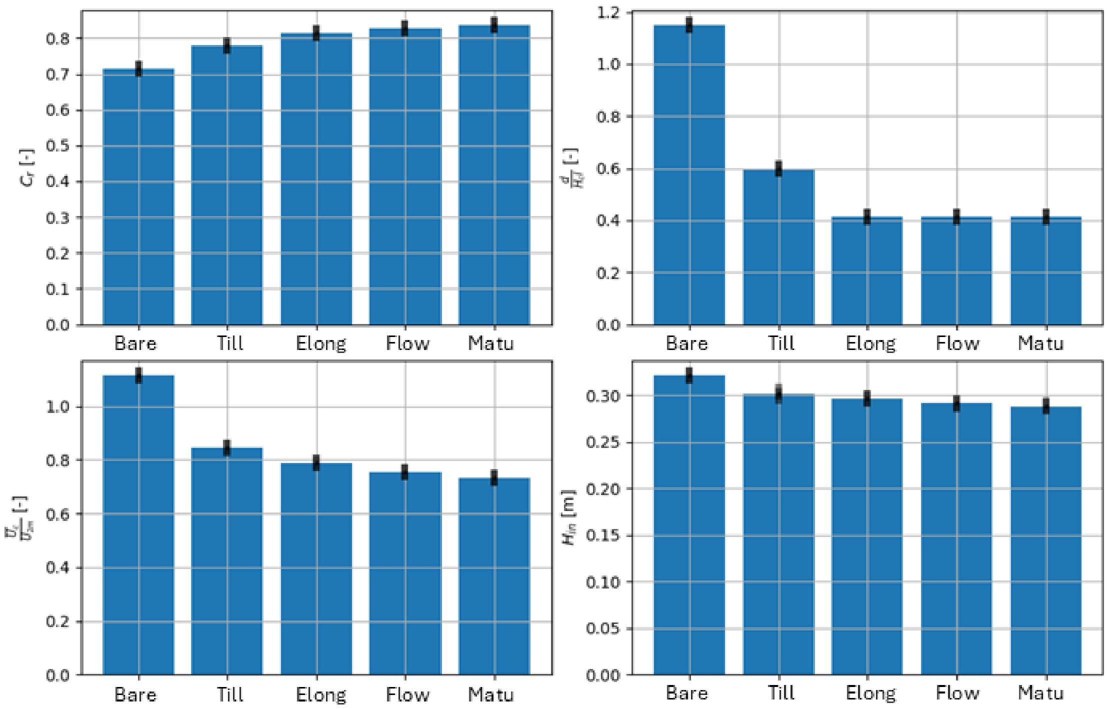

Figure 2. Effect of plant growth stage on the contraction observed under the first panel. Cr: contraction ratio, Uc maximum speed at contraction. Bare: bare soil, Till: tillering stage, Elong: elongation stage, Flow: flowering stage, Matu: maturity stage.

3.2. Conclusions

In conclusion, this study shows that the flow under the first panel is differentiated and fairly heterogeneous, with higher wind speeds, which could affect the results of agronomic tests on small-scale agrivoltaic demonstrators, especially after sowing or when the crops are still young and do not have a significant blocking effect. This effect could explain some of the stunted. Finally, this work highlights the critical role of plants on flows and therefore that it is difficult not to take them into account in CFD models.