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"Reconcile land system changes
with planetary health"

Concept analysis of zero water loss greenhouses

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Abstract

The escalating crisis of freshwater overextraction poses a serious threat to both ecological stability and human populations. Still, even in arid and semi-arid regions already facing severe water scarcity, agriculture remains the largest global consumer of water. While greenhouse cultivation can reduce some of this water consumption compared to open-field farming, conventional greenhouse cultivation still demands substantial amounts of water. This is because the majority of the water supplied is transpired by plants, with only a small fraction incorporated into their biomass. This transpired water is largely lost through ventilation, the process for regulating temperature and humidity, ultimately escaping into the atmosphere. Addressing this inefficiency demands a radical rethinking of traditional greenhouse architecture and operation.

Within the EXALT project – Coupling thermal desalination and extraction of dewatered salt with hydroponic greenhouse cultivation via heat pumps"– we conducted simulations to evaluate various strategies for minimising water consumption in tomato production, particularly in water-scarce regions like Jordan and Israel. Our evaluation considered both improved glass greenhouses and fully controlled growing environments (FCGE), representing completely closed systems with artificial lighting and regulated atmospheres. Employing a stepwise yet comprehensive approach to climatic and energetic optimisation, we were able to assess several key technical measures, including:

-Partial shading with building envelope integrated photovoltaics to reduce heat uptake of and produce electricity at the same time for air conditioning and lighting

-Adapted temperature profiles for improved energy efficiency

-High efficiency LED lights

The evaluation results was based on key performance indicators. We specifically considered:

-The harvested dry mass of fruits to quantify yield.

-The amount of water supplied from external sources to the greenhouse to assess water efficiency.

-The balance between locally produced energy (from PV) and the energy required for air conditioning and supplemental lighting to determine energy sustainability.

Our findings indicate that the energetically optimised greenhouse and the FCGE hold significant potential for arid regions where access to clean water is limited and saline water is the primary irrigation source. The remarkably low water consumption of these systems allows for water sustainable cultivation of crops like tomatoes even under these restrictive environmental conditions.

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