Including Greenhouse Horticulture in the Circular Economy: Quantifying Material Flows

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Background

Lowering environmental impact is vital for sustainability, but it is not enough. Whilst Dutch greenhouse horticulture is increasingly efficient with various inputs (e.g. water and nutrients), many of these inputs come from finite linear sources: for example, natural gas for energy and CO_2 enrichment; phosphate rock (P) and potash (K), mined for fertiliser; basalt and peat for substrate; or crude oil for plastics.

The risks associated with this resource depletion can be reduced by including greenhouse horticulture in a circular agrifood system, where material flows can be exchanged with other sectors. However, quantitative knowledge on material flows within greenhouse horticulture itself is lacking.

Objective

Understanding where material flows come from and quantifying how they are transformed can help make better-informed decisions on how to include greenhouse horticulture in a circular agrifood system. Our research quantifies six material flows – biomass, water, nutrients, carbon dioxide, plastics and substrate – in Dutch high-tech tomato greenhouses.

Highlights

- Results from various literature sources and mass balance calculations show a consistent order of magnitude.
- At least half of the water, CO_2 and nutrients supplied does not end up in the tomato fruit, though 95% of nutrients ends up in plant biomass.
- Most Ca, Mg and S goes to non-yield biomass, showing potential for recovery.
- The mixing of mono-materials, such as plastics being mixed with biomass and spent substrate, presents a challenge for high-value material exchange with other sectors.

Follow-Up Research

- Quantification of cross-overs between greenhouse horticulture and pig farming, mushroom farming and aquaculture (complete).
- Experiment on using residual tomato/pepper biomass to feed black soldier fly larvae (complete).
- Project on circular and biobased plastics (ongoing).
- Exploration of circular sources of phosphorus and technologies to make fertiliser appropriate for soilless (e.g. hydroponic) systems (ongoing).
- Modelling of optimal mixtures for renewable substrate material, contributing to peat-free growing (ongoing).
- Quantification and modelling of CO_2/heat production from mushroom composting for greenhouse horticulture (ongoing).
- Exploration and experimentation with direct air capture (DAC) as a source of supplemental CO_2 (to start).

Results

In Figure 1, a material flow diagram is shown. Figures 2 and 3 show tree diagrams of the in- and outgoing flows respectively for scale. All numbers are in g per kg fresh yield.

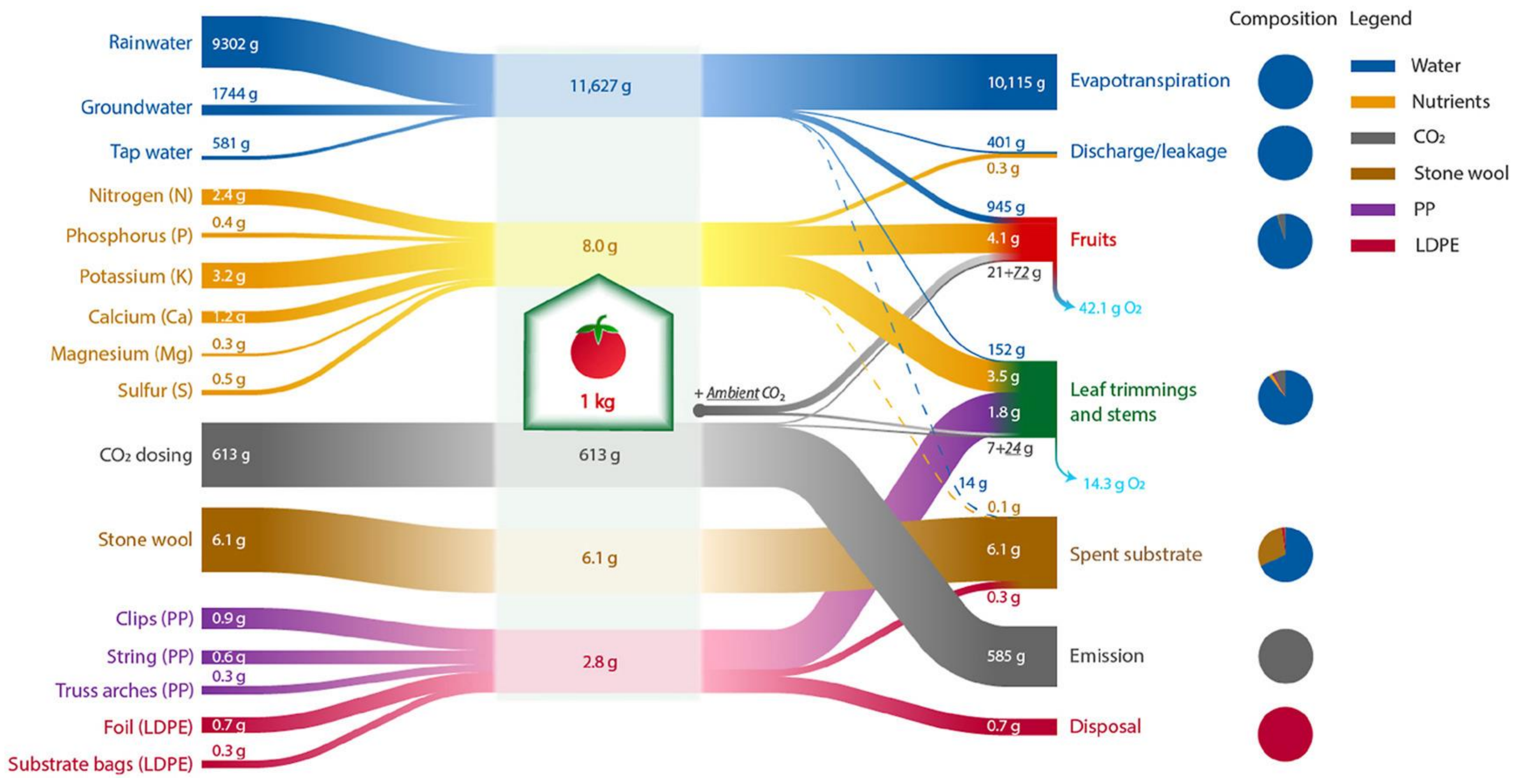

Figure 1. A material flow diagram for six materials in high-tech Dutch tomato greenhouse horticulture, to scale within each material. The different materials are not to scale between each other, since water would dominate and make the others imperceptibly small.

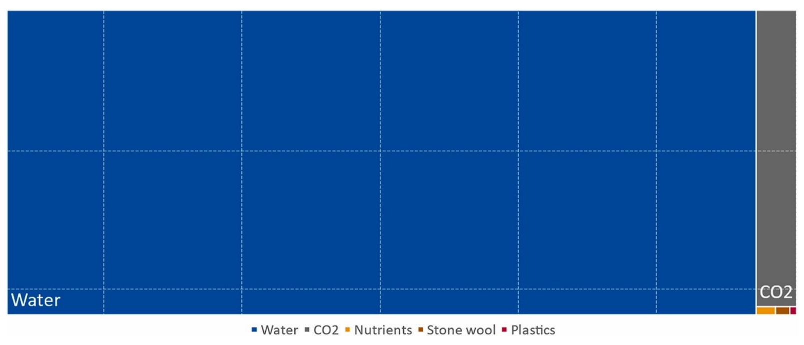

Figure 2. A tree diagram of incoming flows for high-tech Dutch tomato greenhouse horticulture. One square represents 1000 g per kg fresh yield and is on the same scale as Figure 3.

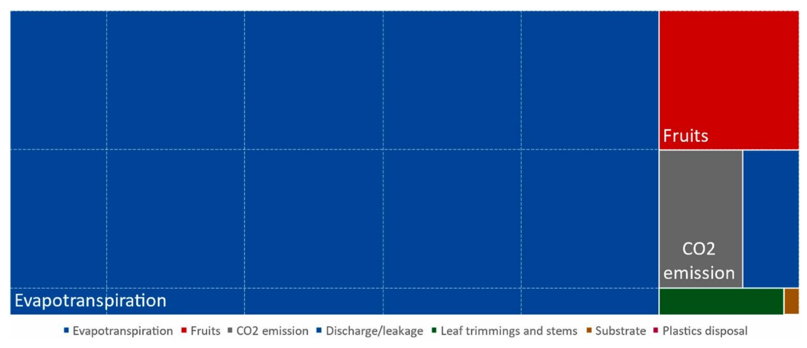

Figure 3. A tree diagram of outgoing flows for high-tech Dutch tomato greenhouse horticulture. One square represents 1000 g per kg fresh yield and is on the same scale as Figure 2.

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