

A/OP/15

A Systems Thinking Approach for Sustainable Vertical Tea Farming in Sri Lanka: Insights from Causal Loop Diagrams and Dynamic Modeling

Samarakoon SMABK^{1,4}, Ariyawansa T², Rupasinghe CP³

¹*Faculty of Graduate Studies, University of Ruhuna*

²*Department of Agriculture Technology, Faculty of Technology, University of Colombo*

³*Department of Agricultural Engineering and Environmental Technology, Faculty of Agriculture, University of Ruhuna*

⁴*Department of Agricultural Engineering and Soil Science, Faculty of Agriculture, Rajarata University of Sri Lanka*

Background: Tea (*Camellia sinensis*) cultivation is constrained by challenges associated with traditional cultivation methods, limited land and labour availability, inefficient utilization of resources, and vulnerability to climate change. Vertical farming that stacked layers within controlled environments to grow crops is a sustainable alternative to maximize the efficient use of resources, while facilitating, year-round production. This approach for tea requires robust systems-thinking frameworks to address complex interdependencies between biological, environmental, economic and operational (technology and social) factors.

Objective: This study integrates Causal Loop Diagrams (CLDs) and System Dynamics (SD) modelling based on secondary data to explore feedback mechanisms in vertical tea farming and identify leverage points for improving yield and reducing labour dependency through a systems-thinking approach.

Methods: The system dynamics model was developed using AnyLogic software, with input data sourced from published literature. The system dynamics model was simulated over a one-year time by using input data obtained from published literature to capture temporal trends in vertical tea farming systems. Model validation was performed by comparing simulation results with historical yield data.

Results: The CLD revealed that vertical tea farming systems, with integrated technology adoption and renewable energy, create reinforcing feedback loops that enhance yield, product quality, and export income while reducing waste and operational costs. Traditional cultivation showed up to 30% yield loss with labor costs near 60%, while vertical systems improved yield by 20–25% and cut water use by 70–90%, though energy needs exceeded 40% of costs. CLDs showed that vertical tea farming with technology and renewable energy integration creates reinforcing feedback loops that enhance yield, quality, and export income while reducing costs.

Conclusion: Using a systems-thinking framework with CLDs and SD modelling, this study highlights how vertical systems can improve agronomic precision and resilience, positioning them as sustainable, scalable alternatives aligned with circular economy principles.

Keywords: Sri Lanka, System Thinking Approach, Vertical Tea Cultivation