Decision-Making Tool Enhance Waste to Wealth Understanding in Students

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Abstract – In mushroom farming, one-kilogram harvested results in about five kilograms of spent mushroom substrate (SMS), posing an environmental management challenge. As an in-tune work with the concepts of circular economy, cleaner production, and waste minimization, this study has developed a mathematical model than analyzes the valorization potential of SMS through polysaccharide production. The in-depth mathematical model is based on a system dynamics approach, which explains the interactive interplay amongst the production process, related costs, energy consumption, and caused emissions. The model has been developed in a generic way. Meaning that it can be re-adjusted flexibly for a different cleaner production process. A user-friendly interface has been developed. Users can easily maneuver around the variables within the model that offers instantaneous insight into the environmental and economic impacts of SMS valorization. This interface was later integrated into an educational context to serve as an interactive decision-making tool for cleaner production modelling. The main purpose of the developed tool was to favor understanding of causalities between production chains, energy consumption, labor, emissions, and expenses. This tool has been tested on master's degree students in a cleaner production course. Survey results show that 82% of students report the need to incorporate similar decision-making tools in their learning curriculum. In sum, the application of system dynamics to the valorization of SMS does not only present an attractive solution for this environmental problem but also shows great potential in setting educational backgrounds for an interactive and close-to-life learning process (Fig. 1). It is recommended to develop more interactive tools available for students.

Keywords* – *Bioeconomy; cleaner production; emissions; renewable energy; survey; system dynamics modeling

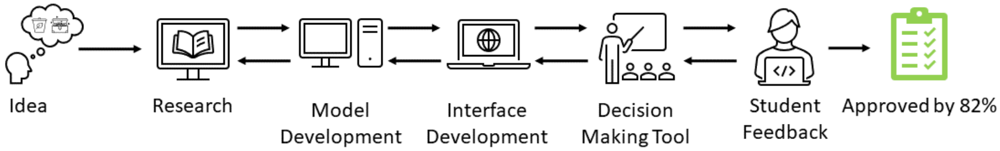

Fig. 1. Research study framework for decision making tool development and approval.

1. METHODOLOGY

Systems thinking is a holistic approach to understanding of behavior, patterns, and cycles rather than specific events in the system. The analysis of a system is performed by recognizing connections between system variables, identifying causality loops, and interpretation of dynamic behavior.

Causal loop diagrams are used to understand and communicate the behavior of complex systems. These are useful for locating leverage points that can lead to system behavior changes. However, they do not quantify relationships between the variables and the accuracy of these diagrams depends on the understanding of the identified variables and their relationships. Each arrow describes the relationship between two variables. The end of the arrow shows a "+" sign describing a positive interaction or a "-" sign describing a negative interaction. Positive interaction means that an increase in variable A results in an increase in variable B. Negative interaction means that an increase in variable A results in a decrease in variable B. Loops is a chain of arrows through variables where the last arrow returns to the initial variable from which the arrow comes from.

2. MODEL DESCRIPTION

The model involves numerous variable interactions that influence system behavior, as illustrated in a simplified causal loop diagram (Fig. 2). It self-corrects to align SMS input with system limits, such as labor, loan amount, storage, and perceived market share. Labor availability depends on the attractiveness of offered salaries, which affects workforce size and consequently the production capacity. Loan limits restrict investments in production capacity, impacting the production rate when old capacity is decommissioned. Full storage necessitates material depletion before new input. Variable interactions affect production expenses, which determine product pricing and perceived market share, influencing material inflow adjustments to align market coverage with perceived coverage. Balancing loops (B1-B5) and reinforcing loops (R1, R2) manage variable interactions, with waste recovery influencing material goals.

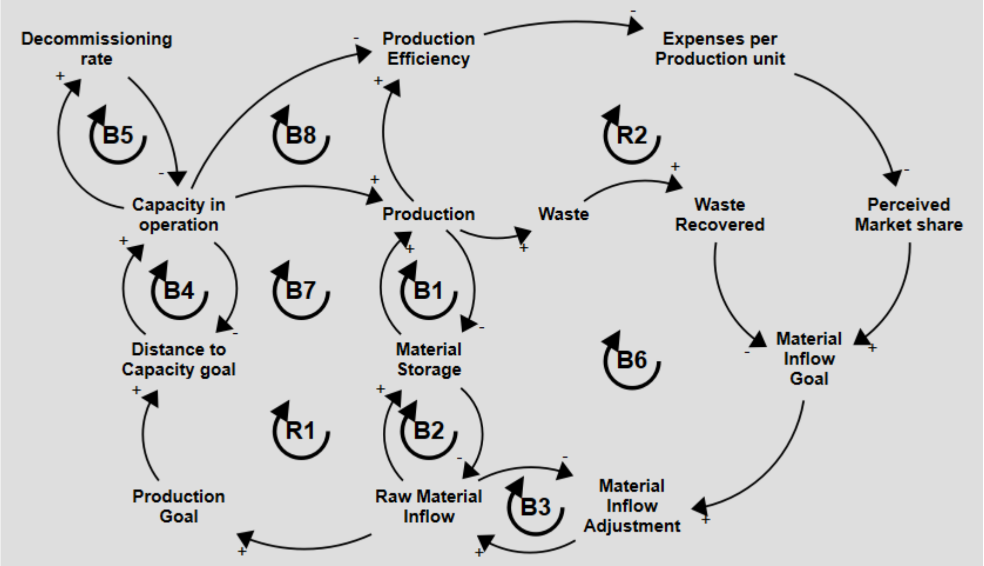

Fig. 2. Simplified causal loop diagram for the system dynamics model.

The model uses a stock and flow approach to quantify interactions, with six sectors: production, labor, capacity, energy consumption, finance, and substrate input, involving 455 variables. The structure can be adjusted with numerical limits, though users cannot alter the model's structure or policies.

3. USER INTERFACE

A decision-making tool with 8 pages, categorized into 5 sections, has been developed (Fig. 3). Pages 1-2 introduce SMS and its contents, while Pages 3-5 provide an overview of the laboratory setup for polysaccharide extraction, a causal loop diagram, and a stock and flow diagram with explanations for users unfamiliar with the methodologies. Page 6 displays environmental results with charts on energy consumption, emissions, and material use, including annual and cumulative data. Page 7 shows socio-economic results, featuring charts on profitability indicators, cash flows, and production efficiency. Page 8 includes a feedback survey for user suggestions. Pages 6-7 also have sliders and buttons for adjusting input data, allowing users to influence simulation outcomes by changing variables like water recovery, which can reduce costs and increase market share.

a) b) c) d)

Fig. 3. Pages of the developed decision-making tool.

4. RESULTS

Everyone who completed the evaluation questionnaire liked the tool and found it useful, though a broader audience evaluation is recommended for more comprehensive feedback on usability. During a tool testing lecture attended by over 20 students, all participated in discussions about interactive tools, but only 11 provided descriptive feedback (Fig. 4). Key findings include: sufficient information provided about the tool, high understandability ratings with only 9% finding it confusing, and detailed content. Most students (73%) find the simulation results reliable, and all rated the tool as valuable for decision-making, with 64% considering it very valuable. Over 80% expressed interest in more interactive interfaces in lectures. These results suggest that tool interactivity enhances comprehension of cleaner production materials, potentially improving student satisfaction and engagement.

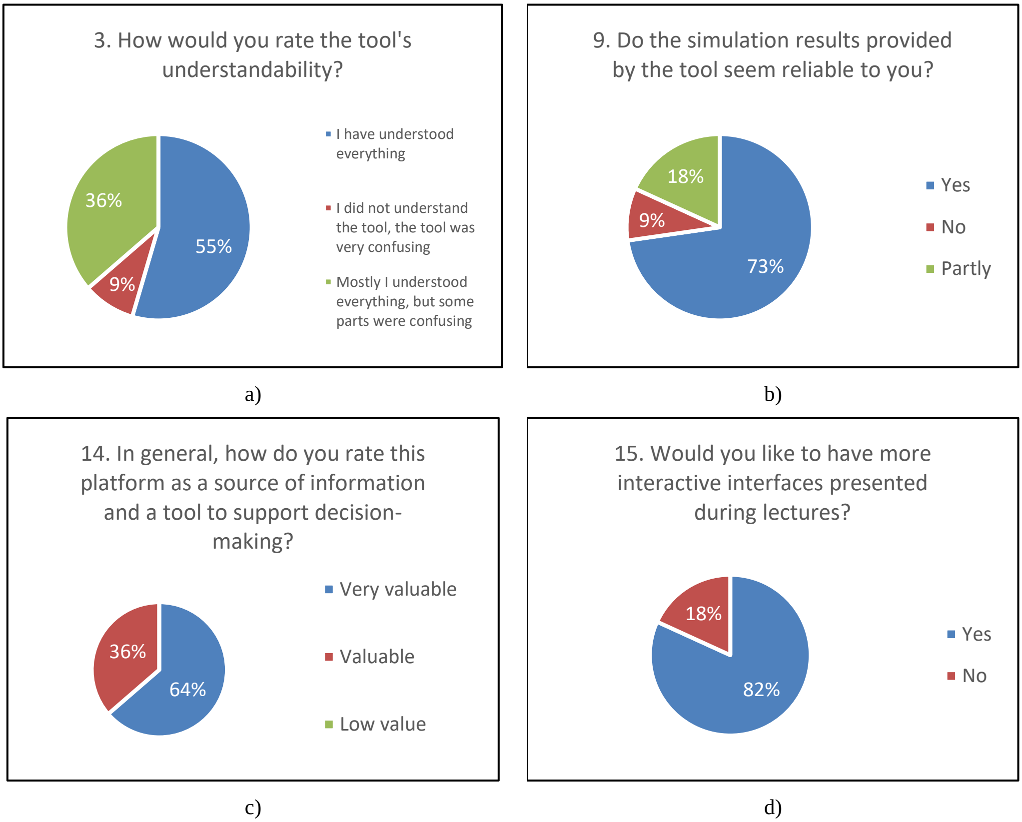

Fig. 4. Survey questionnaire answers.

5. CONCLUSION

Mushrooms are valued for culinary and medicinal uses, with 100 species cultivated commercially. Global demand is rising due to supply chain innovations and interest in veganism, but managing spent mushroom substrate (SMS) remains a challenge. A system dynamics model using Stella Architect explores SMS's socio-economic and environmental impacts, identifying leverage points in production through systems thinking. An interactive decision-making tool was tested with master's students in Environmental Technologies at Riga Technical University, who praised its clarity, detail, and educational value. Future research will focus on scaling, integrating energy and equipment costs, and broader testing to improve usability.

ACKNOWLEDGEMENT

This research has been funded by the European Union. Project ”Twinning in Environmental Data and Dynamical Systems Modelling for Latvia”. TED4LAT, No. 101079206. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.