An Assessment of Control Methods in Closed-Loop Agriculture Systems

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March 26, 2023

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Introduction

- Producers are facing challenges, including climate change, water scarcity and population growth.[4]
- The global population is projected to reach 9.9 billion by 2050.[12]
- As urbanization continues to compromise farmland, alternative approaches must be explored.[2]
- There is a lack of optimization between systems.

Objectives

- Identify gaps in research concerning closed-loop agriculture systems.
- Identifying data availability to mobilize system optimization techniques.

Methodology

- Meta-research approach utilizing a text-mining approach.
- Keyword utilization for search on Web of Science, including; closed-loop, food, greenhouse, and agriculture.

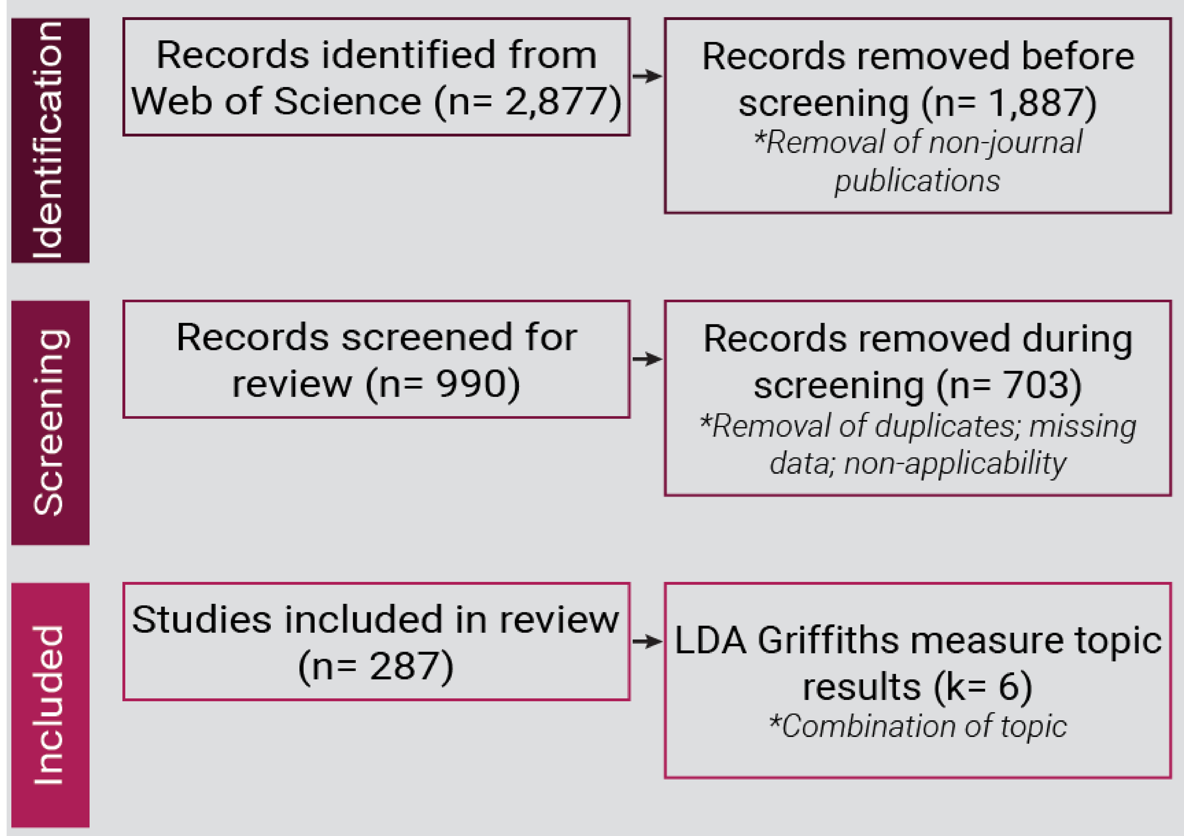

Figure 1. PRISMA[7], as applied in this systematic review paper, indicates the number of studies included in the review.

Learn More About This Work

The preprint of Closed-Loop Agriculture System Meta-Research Using Text Mining is available by scanning the QR code.

Results

- Greenhouses are influenced and impacted by biological and physiological subsystems.[5]
  - The plant being grown is part of the biological subsystems.
  - The infrastructure is part of the physiological subsystems.
- Growing conditions must be maintained and monitored for optimal plant and crop production while minimizing resource needs.[10]

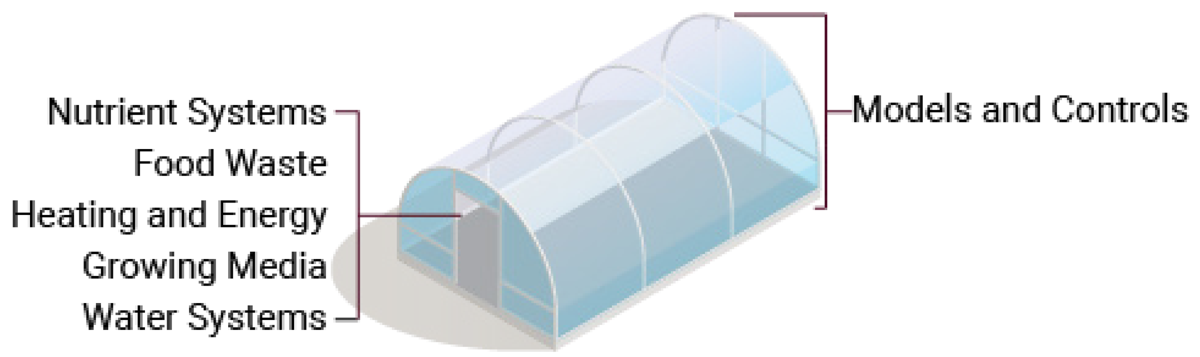

Figure 2. Topic modelling yielded six topics of value for further assessment. The topic 'Models and Controls' influences and impacts much of the remaining topics and encompasses aspects of the entire greenhouse system.

ENERGY UTILIZATION & HEATING

- Neural networks allow for performance testing and altering system parameters.[5]
  - Energy utilization and heating, which can be controlled with various algorithms, can be assessed in this manner.
- Energy can be conserved and reallocated to various subsystems in a greenhouse using fuzzy adaptive controls.[9]
  - Various control laws exist in a greenhouse system, including heating, fogging and CO_2 injection, which, when measured, can be used to determine energy utilization.
  - Input and output measurements are collected by controllers and actuators in order to make informed decisions on energy needs and demands.
- Energy conservation can be achieved by selectively supplementing lighting for precise areas within a greenhouse.[6]
  - Neural network-based modelling allows for the identification of plants that require wavelengths.

CLIMATE CONDITIONS

- Alternatives to user-controlled temperature and humidity control methods have been tested for effectiveness.[3]
  - Methods include Bayesian networks, fuzzy adaptive controls, and proportional-integral-derivative controls.
- The application of a Bayesian network provides effective information through probabilistic outcomes concerning climate conditions.[3]
  - This can effectively inform user controls if desired within the system.
- System modularity can be retained using parameter self-tuning proportional–integral–derivative (PID) controls if desired.[11]
  - Favorable approach allowing closed-loop system principles and practices to be retained while enabling flexibility to boost select aspects when needed.

GROWING CONDITIONS

- Irrigation system performance can be improved through the application of a closed-loop system.[8]
  - A comparative study indicated an event error of less than 2L/m^2 for the water introduced to the system using the closed-loop irrigation method over the open-loop irrigation method.
- Dynamic simulation model-driven approaches for irrigation systems indicate a high correlation efficiency between the model prediction level and observed experimentation values.[13]
  - Communication nodes carry out decisions made by the dynamic simulation, which is informed by a larger wireless sensor network and has been applied to drip irrigation pipes and ventilation equipment.
- The application of electrical conductivity sensors in closed-loop soil and soilless growing cultures allows for the predetermination of a plant's future nutrient needs.[1]
  - Nutrients are most commonly introduced and maintained through water within a greenhouse agriculture system.

Conclusion

- A closed-loop system is favourable to optimizing the interactions and relationships between various subsystems.
- The applications of models and controls allow for a closed-loop system approach.

Future Works

I. Connecting research and industry application
II. Energy dependency and other critical requirements
III. Criteria to select the appropriate soil or soilless growing environment
IV. The integration and resilience of a closed-loop system composed of many individual modules

Acknowledgement

This research was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grants.

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