Building Edible Ecosystem in Space:
Hypotheses on Contribution to Food, Health, Environment and Sustainability on Earth

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Abstract

Life support needed for space exploration becomes increasingly extensive as the missions extend over longer times and distances. Current space food cultivated on Earth is not sufficient to sustain the long-term health and well-being of astronauts, much less those of future residents of orbital and exoplanet settlements. We formalized a conceptual framework of life-supporting augmented ecosystems with a particular focus on the open and closed characteristics of the systems with respect to the material exchanges and biological interactions with the external environment. We then identified the prototypical mid-term challenges for ecosystem design in an isolated space environment, using experimented data from ground-based augmented ecosystems and the functional analysis of relevant ecological networks. We aim to identify essential requirements for the development of necessary technologies towards the realization of extraterrestrial ecosystems, which could also substantially contribute towards the adaptation to climate change and the prevention of environmental degradation on Earth.

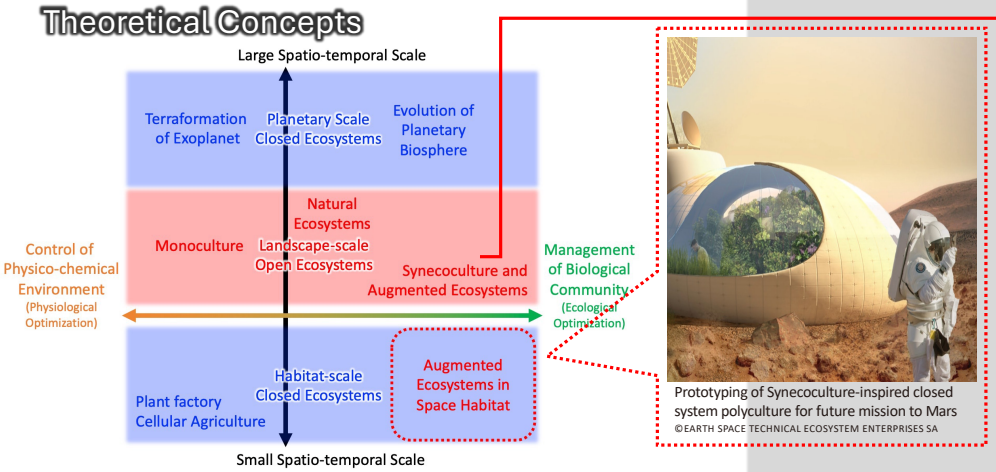


Figure 1. Nested open-closed structure of ecosystems and productivity optimization. Spatio-temporal scale vs. partial and total optimization modalities of natural and human-mediated ecosystems are shown. A particular focus is set on the possibility of augmented ecosystems in space habitats in this article (red dotted rectangle).

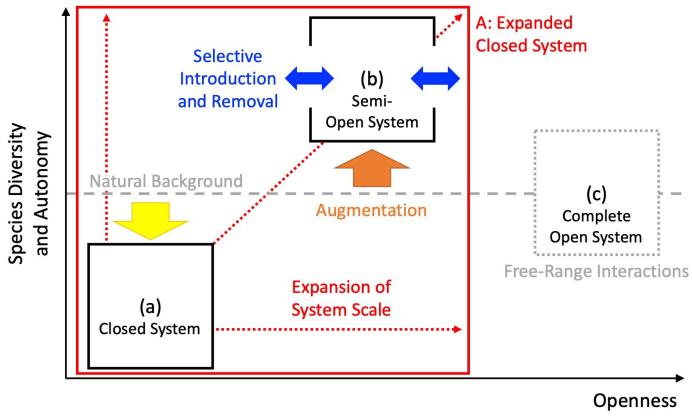
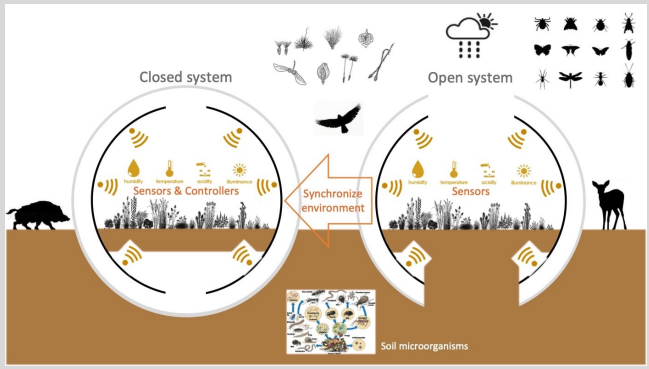


Figure 2. Nested open-closed structure of ecosystems and operational biodiversity. Relationship between the openness vs. coexistent species diversity in autonomous ecosystems and possible configurations of open-closed structure for the augmentation of internal biodiversity.



↑Conceptual diagram comparing a closed system (left) and an open system (right). In an open system, not only the atmosphere but also the effects from the surrounding soil are taken into account. By measuring environmental information such as temperature, humidity, and sunlight in an open system and feeding this back to a closed system to create the same condition, it is possible to evaluate the effects of interaction with the outside world in the open system.

Experiments on Earth

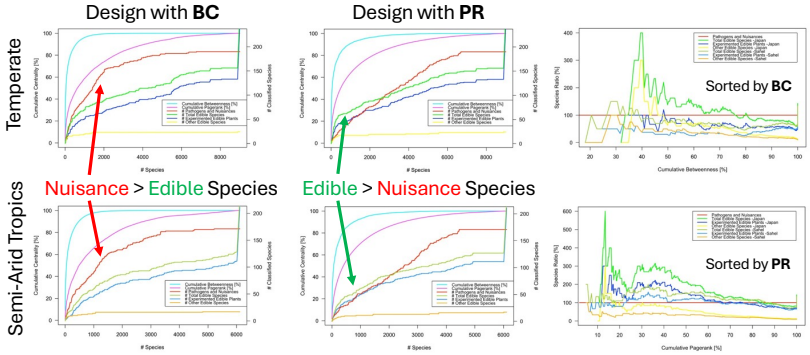


Figure 3. Ecological network analysis of the species related to synecological farming experiments in the temperate zone (J) and semi-arid tropics (S) towards the design of closed augmented ecosystems
Left Top: Experimental edible plant species and potentially interacting species sorted by the Betweenness Centrality (**BC**) score for experiments J.
Left Bottom: Experimental edible plant species and potentially interacting species sorted by the Betweenness Centrality score for the experiments S.
Middle Top: Experimental edible plant species and potentially interacting species sorted by the Pagerank (**PR**) score for experiments J.
Middle Bottom: Experimental edible plant species and potentially interacting species sorted by the Pagerank score for experiments S.
Right Top: Proportion of experimental and potentially interacting edible species with respect to potential pathogens and nuisance species, sorted by the Betweenness Centrality score for experiments J and S.
Right Bottom: Proportion of experimental and potentially interacting edible species with respect to potential pathogens and nuisance species, sorted by the Pagerank score for experiments J and S.

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