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Closed-loop irrigation, struvite fertiliser & recycled infrastructure

Effective circular strategies for eco-friendly urban agriculture

RESULTS IN BRIEF

Urban agriculture comes with its own share of environmental impacts. Circular strategies like rainwater harvesting promise to reduce these impacts, but we find that not all strategies are resource efficient and environmentally effective.

The most eco-friendly and circular strategies for urban agriculture, based on our case of a Mediterranean tomato crop, include:

- **Using struvite** instead of non-renewable phosphate fertiliser to conserve freshwater
- **Employing recycled steel and materials** for urban agricultural infrastructure to reduce carbon emission, toxicity and freshwater pollution
- **Installing closed-loop irrigation** to minimise ocean and freshwater pollution. Yet, if new infrastructure is required, it could lead to an increase in carbon emission.

Action recommendations:

- **Promote these three strategies to urban farmers**
- **Upgrade wastewater treatment plants to enable struvite harvest**
- **Increase recycling of steel and other environmentally harmful materials**
- **Plan closed-loop irrigation systems from recycled materials**

Editors: Mira Kopp, Anran Luo

WHY USE CIRCULAR STRATEGIES?

Almost all food consumed in cities is produced elsewhere. Such global food flows create resource dependency, a considerable amount of transport and related environmental pollution. Urban agriculture aims to enhance sustainability and resilience by bringing food production back into the cities. Nevertheless, further guidance is needed to reduce **urban agriculture's contribution to waste creation and nutrient depletion.**

Circular approaches, in other words reusing waste as a resource, applied to urban food systems, offer **an economic solution to reduce these impacts** (Ferreira et al., 2018). Unfortunately, not all circular strategies result in environmental benefits. Therefore, we have evaluated which strategies are circular and most effective in protecting natural ecosystems and human health.

HOW TO DETERMINE THE MOST ECO-FRIENDLY AND CIRCULAR STRATEGIES – OUR APPROACH

To facilitate effective urban agriculture applications, we identified the best strategies and relevant subsystems with a **combined material circularity**[1] (hereinafter circularity) **and environmental assessment.**

Conventional approaches to assess the circular performance of production systems such as Circulytics by Ellen MacArthur Foundation (EMF) assume circularity to be equivalent to environmental benefits. But **for agricultural systems, circularity alone does not help** to determine the most eco-friendly alternative because the large amount of water needed obscures impacts from lighter inputs like fertiliser.

Our **Life Cycle Assessment Linear Flow Indicator** (LCA-LFI) tool clearly identifies the best strategies to increase environmental benefits and circularity. The indicator combines EMF's LFI with impact categories from a conventional LCA. Thus, a low value indicates the best alternative in terms of environment and circularity.

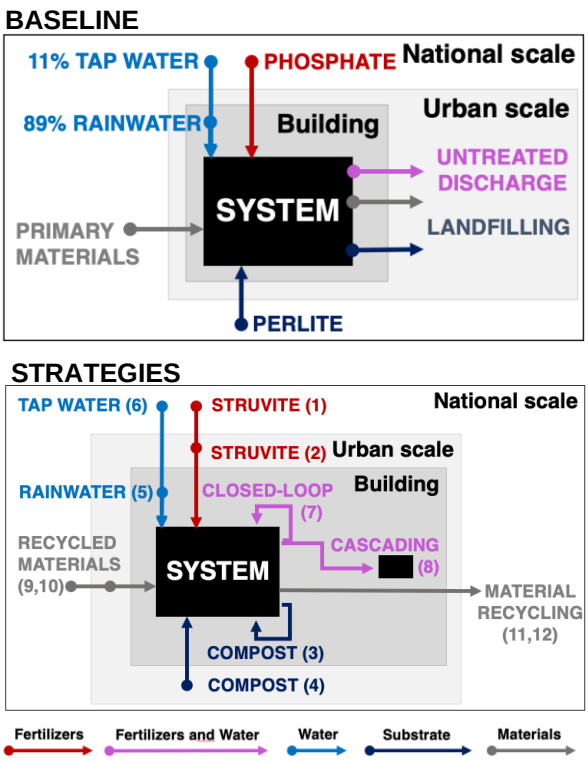

Figure 1: Baseline and evaluated strategies.

With LCA-LFI, we compared strategies for urban agriculture in four impact categories: **greenhouse gas emission, ocean pollution, freshwater pollution, and toxicity**.

Figure 1 shows the strategies that we have compared against the baseline of an actual rooftop tomato crop in the Mediterranean region.

[1] Material circularity describes a scale where 100% circular is a state without any material inputs or outputs and all wastes are reused as resources.

WHICH STRATEGIES ARE MOST EFFECTIVE?

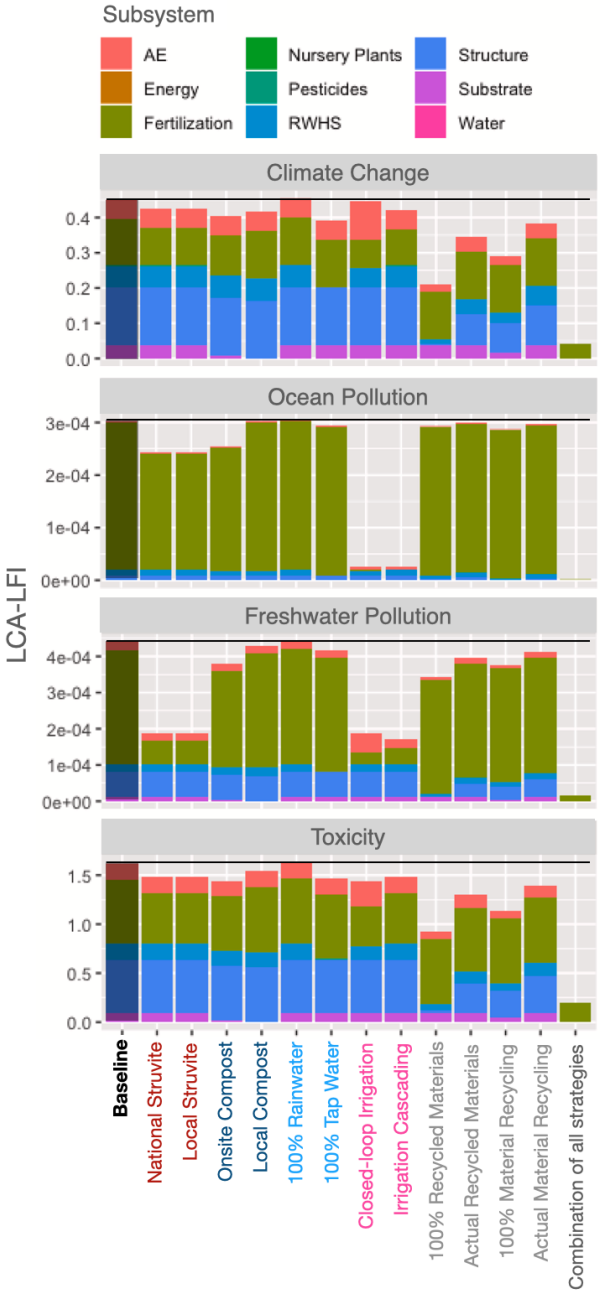

Figure 2: Urban agricultural strategies compared for circularity weighed by different LCA impact categories.

Our analysis reveals that only some strategies help to reduce linearity and environmental impacts of urban agriculture (Figure 2). Well-known circular practices like rainwater harvesting or composting do not score well although they show a high degree of circularity. **A combination of the following strategies is recommended:**

STRUVITE FERTILISER

Using struvite recovered from a nearby wastewater treatment plant as an alternative to rock-borne phosphorus fertilisers **halves the impact on freshwater pollution** without trade-offs with other environmental impacts**.** Also, it improves circularity, thereby **avoiding use of scarce phosphate resources.**

RECYCLED INFRASTRUCTURE

The use of recycled steel and materials in manufacturing the infrastructure for urban agriculture like hydroponic benches or greenhouses **reduces carbon emission, toxicity and freshwater pollution**.

CLOSED-LOOP IRRIGATION

Onsite nutrient reuse with a closed-loop irrigation system (or by cascading nutrient-rich wastewater to other less demanding crops) **more than halves the impact on water pollution** of freshwater and oceans. But it **raises energy-related carbon emissions** if new infrastructure needs to be installed.

LIMITATIONS

While our results have relevant implications for urban farming, the following limitations apply:

- All scenarios are based on the conditions of a Mediterranean tomato crop
- Potential impacts from the provision of new infrastructure for harvesting struvite and for cascading nutrient rich water to other crops are not included in the assessment
- Environmental effects other than carbon emissions, water pollution, energy demand and toxicity were not evaluated

WHAT CAN YOU DO? – OUR RECOMMENDATIONS

URBAN FARMERS

As urban farmers and related associations you can directly contribute to cleaner oceans and freshwater reserves, as well as to climate mitigation and the reduction of toxic substances, by implementing the following strategies in your rooftop farm:

- **Use struvite** as a phosphorus fertiliser
- Use available hoses, containers and pumps for **closed-loop irrigation** or cooperate with nearby urban farms to **cascade your nutrient-rich water**
- Install **recycled** hydroponic benches, closed-loop irrigation systems and green-house infrastructure
- Tell others about your experiences with these strategies!

In many cases, recycled materials and struvite fertiliser can even make your urban farm more affordable by avoiding rising prices and shortage of raw materials.

MUNICIPAL WATERWORKS

Struvite can be nasty if it blocks your pipes, but if it is harvested from the wastewater, it can become a valuable fertiliser for food production. Especially as global phosphate reserves diminish (Steffen et al., 2015), bolstering your local wastewater treatment plant with **enhanced biological phosphorous removal and a struvite recovery module** is an investment in the future.

SUPPLIERS & NATIONAL INDUSTRIAL POLICY

To mitigate climate change and protect human and ecosystem health from toxins, the recycling of environmentally harmful materials such as steel is indispensable. In order to raise the application of recycled materials in urban agricultural infrastructure:

- Suppliers of urban farming infrastructure should **prioritise equipment made from recycled materials**
- Architects should plan for **recycled rooftop farming infrastructure** especially with regards to closed-loop irrigation systems
- National industrial policy should **incentivise the recycling of steel** as the most impactful material on carbon emissions and toxicity

FURTHER INFORMATION & SOURCES

The full study **"Combining LCA and circularity assessment in complex production systems: the case of urban agriculture" (2021)** by M. Rufí-Salís, A. Petit-Boix, G. Villalba, X. Gabarrell & S. Leipold can be accessed here: https://doi.org/10.1016/j.resconrec.2020.105359

Potential of circular strategies in urban agriculture:
Ferreira et al. (2018). Urban agriculture, a tool towards more resilient urban communities?. https://doi.org/10.1016/J.COESH.2018.06.004.

Global phosphate decline:
Steffen et al. (2015). Planetary boundaries: Guiding human development on a changing planet. https://doi.org/10.1126/science.1259855

All images of the case study by Fertilecity.com

This brief can be cited as: Kopp, M. & Luo, A. (2021). Effective circular strategies for eco-friendly urban agriculture. Circular Economy Series, 5.

The **Circular Economy Series** presents research results of the research group "Circulus - Opportunities and challenges of transition to a sustainable circular bio-economy". The researchers are developing a comprehensive understanding of possible pathways to a circular economy in Germany and Europe. To this end, they combine perspectives from the social, environmental and engineering sciences to analyse the ecological and socio-economic consequences of the circular economy in various sectors.

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