Transitioning extensive green roofs to crop production for enhanced urban agriculture

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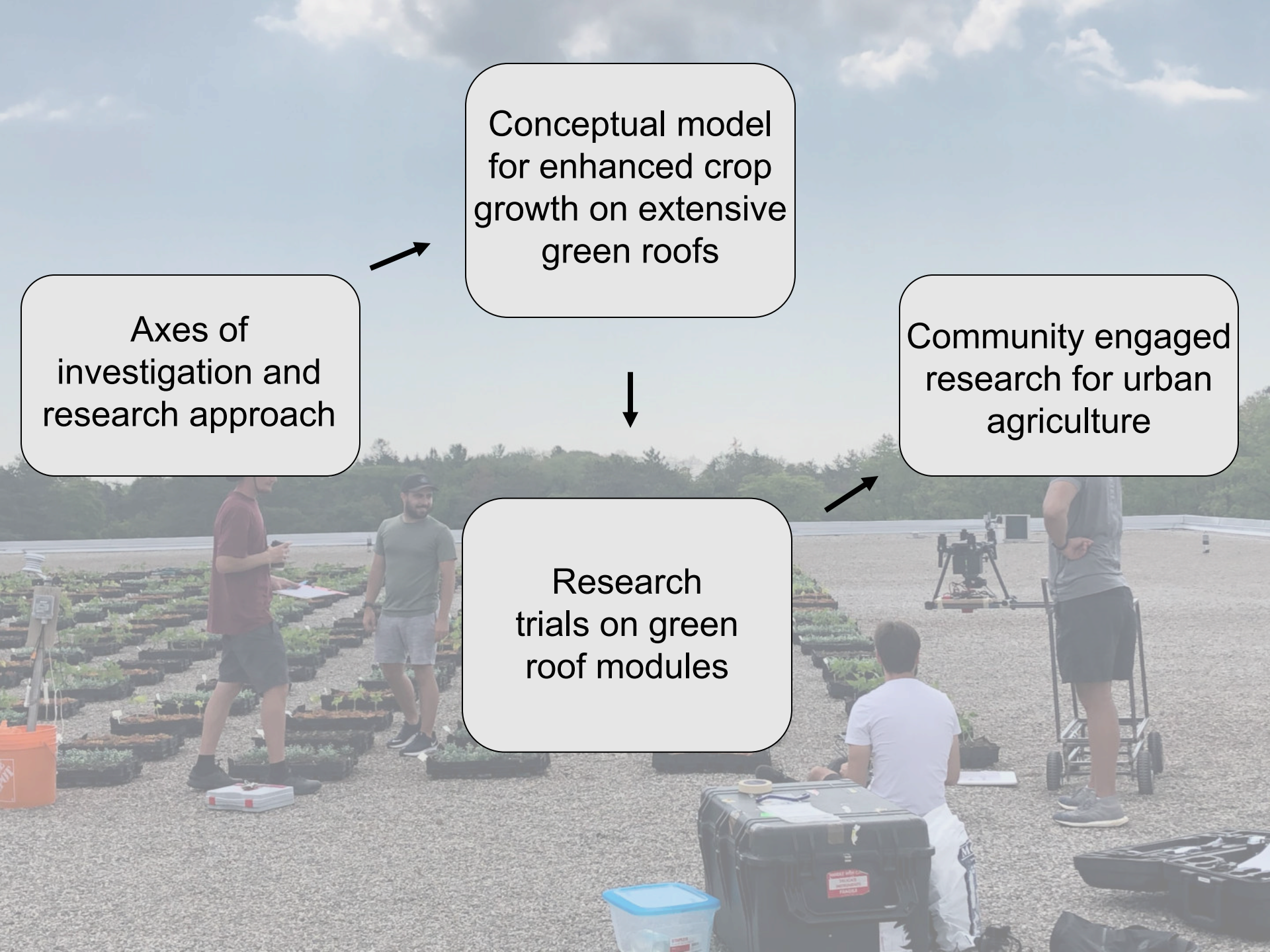

Conceptual model for enhanced crop growth on extensive green roofs
Axes of investigation and research approach
Community engaged research for urban agriculture
Research trials on green roof modules

UNIVERSITY OF TORONTO

We study plant-soil interactions, nutrient cycles and ecosystem function in diversified agroecosystems, and the social processes that lead to system transitions

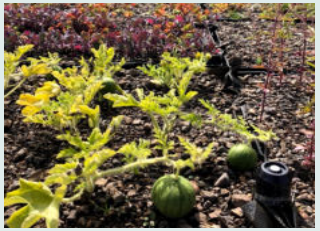
Integrative Agroecology Lab

Agroforestry

Intercropping

Organic agriculture

Green roofs



Functional, taxonomic and genetic diversity

SSHRC CRSH

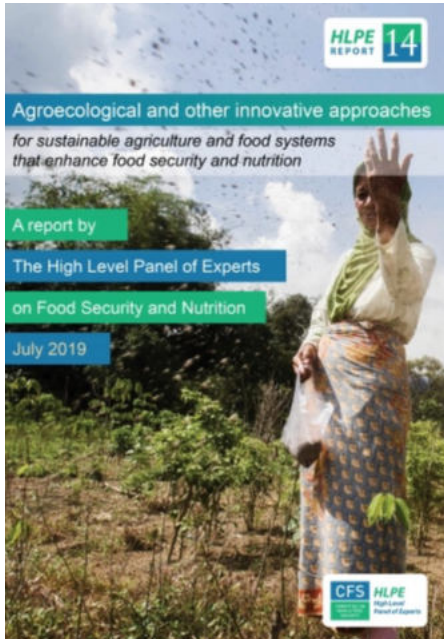
NSERC CRSNG

Agriculture and Agri-Food Canada

IDRC | CRDI
International Development Research Centre
Centre de recherches pour le développement international

Canada Research Chairs
Chaires de recherche du Canada

Canada



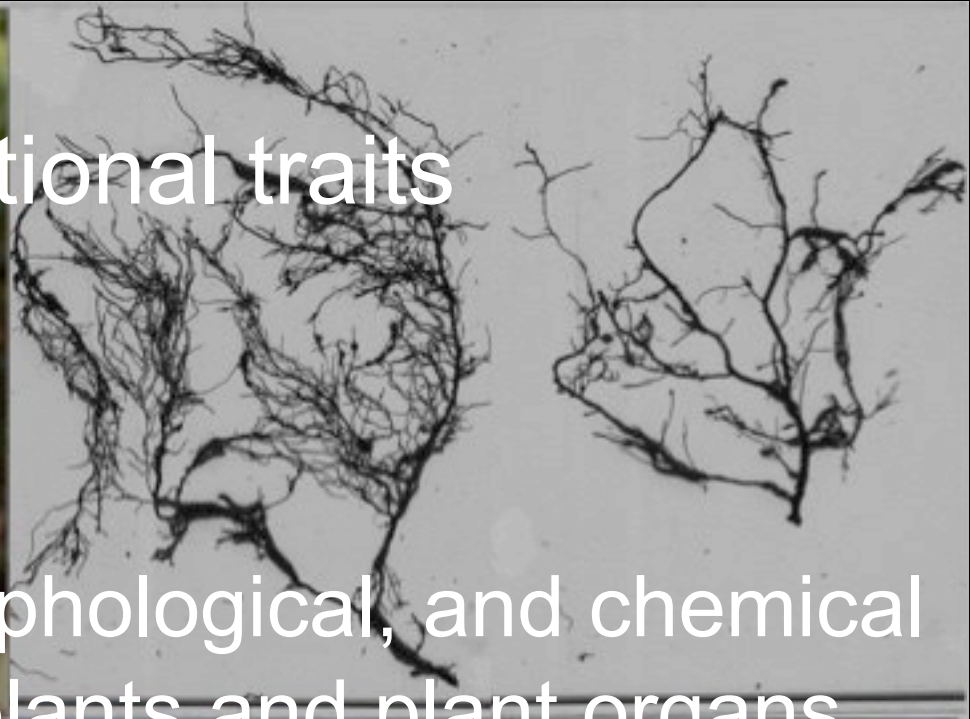
Review

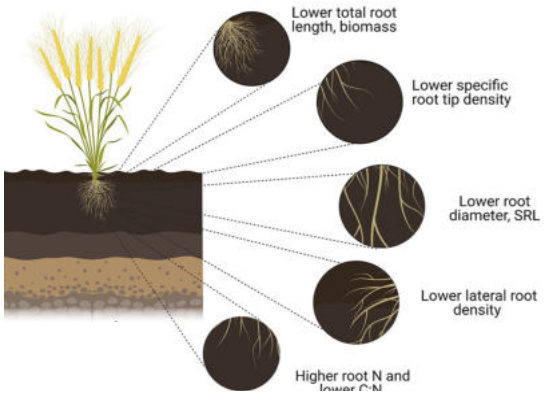
Agroecology in Canada: Towards an Integration of Agroecological Practice, Movement, and Science

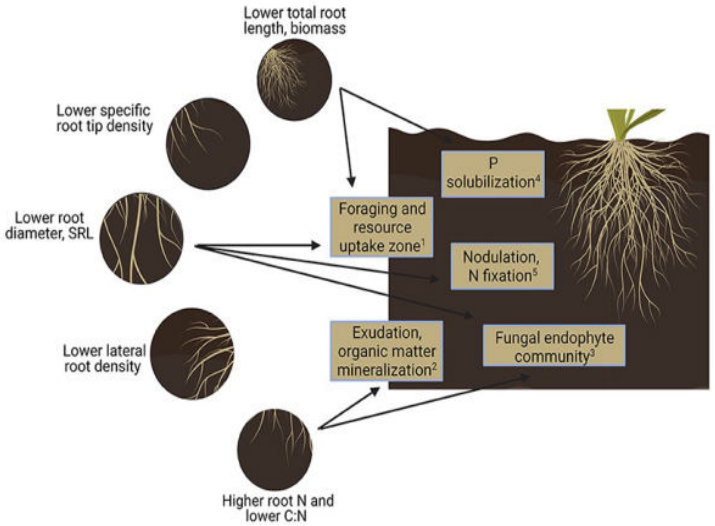
Marney E. Isaac [1,2,3,*], S. Ryan Isakson [2,3], Bryan Dale [3], Charles Z. Levkoe [4], Sarah K. Hargreaves [5], V. Ernesto Méndez [6], Hannah Wittman [7], Colleen Hammelman [8], Jennifer C. Langill [3], Adam R. Martin [1,2], Erin Nelson [9], Michael Ekers [3], Kira A. Borden [3], Stephanie Gagliardi [1], Serra Buchanan [1], Sarah Archibald [3] and Astrid Gálvez Ciani [2]

Plant functional traits

The physiological, morphological, and chemical characteristics of plants and plant organs







Journal of Applied Ecology

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REVIEW

Plant functional traits in agroecosystems: a blueprint for research

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EDITORIAL

Journal of Applied Ecology BRITISH ECOLOGICAL SOCIETY

Functional traits in agroecology: Advancing description and prediction in agroecosystems

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[2]Department of Geography, University of Toronto, Toronto, Ontario, Canada

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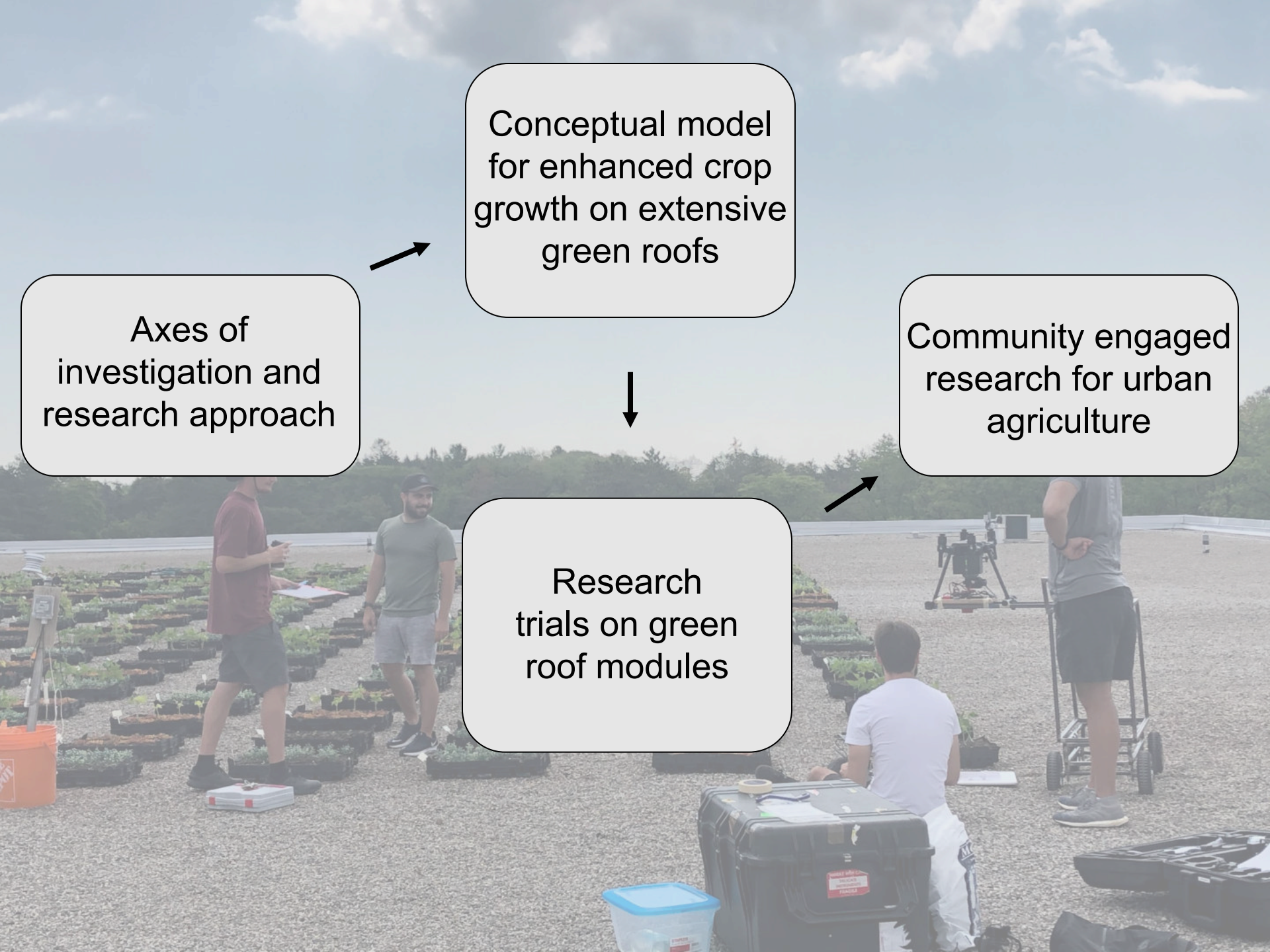
1 | THE IMPACTS AND PARADOXES OF MODERN AGRICULTURE

2012). But while agroecology is well positioned to address many of these pressing global issues, the science of agroecology lacks a theo-

Isaac et al. (2021) Frontiers in Sustainable Food Systems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In 2009, the City of Toronto enacted the Green Roof bylaw. Between 2010 and 2017, approximately 420 green roof permits were issued in Toronto.

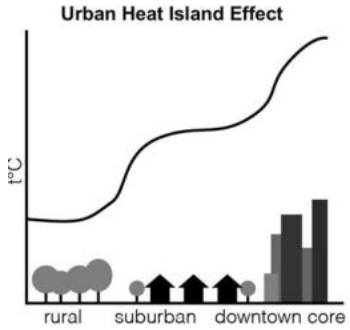
Photo source: blogTO

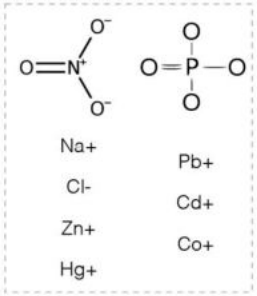
The Design of Living Infrastructure for Ecosystem Services (DesignLIFES)

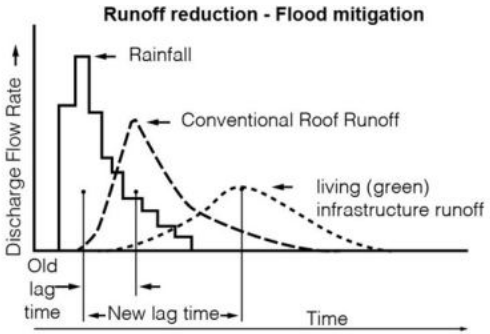
About DesignLIFES

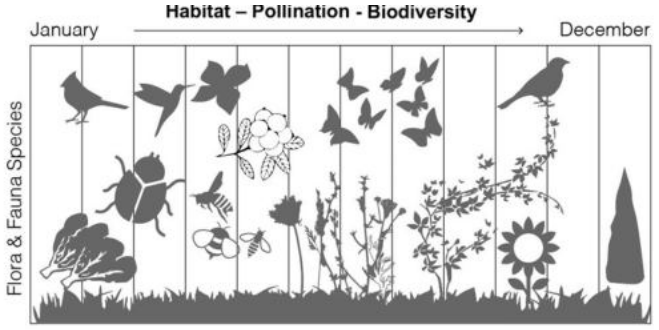
NSERC CRSNG

The Design of Living Infrastructure for Ecosystem Services (DesignLIFES) Network is a CREATE program that will train the next generation of engineers, landscape architects and scientists in the interdisciplinary professional and technical skills they will need to design, create and manage living and green infrastructure for Canadian cities. DesignLIFES is funded by NSERC CREATE Program.





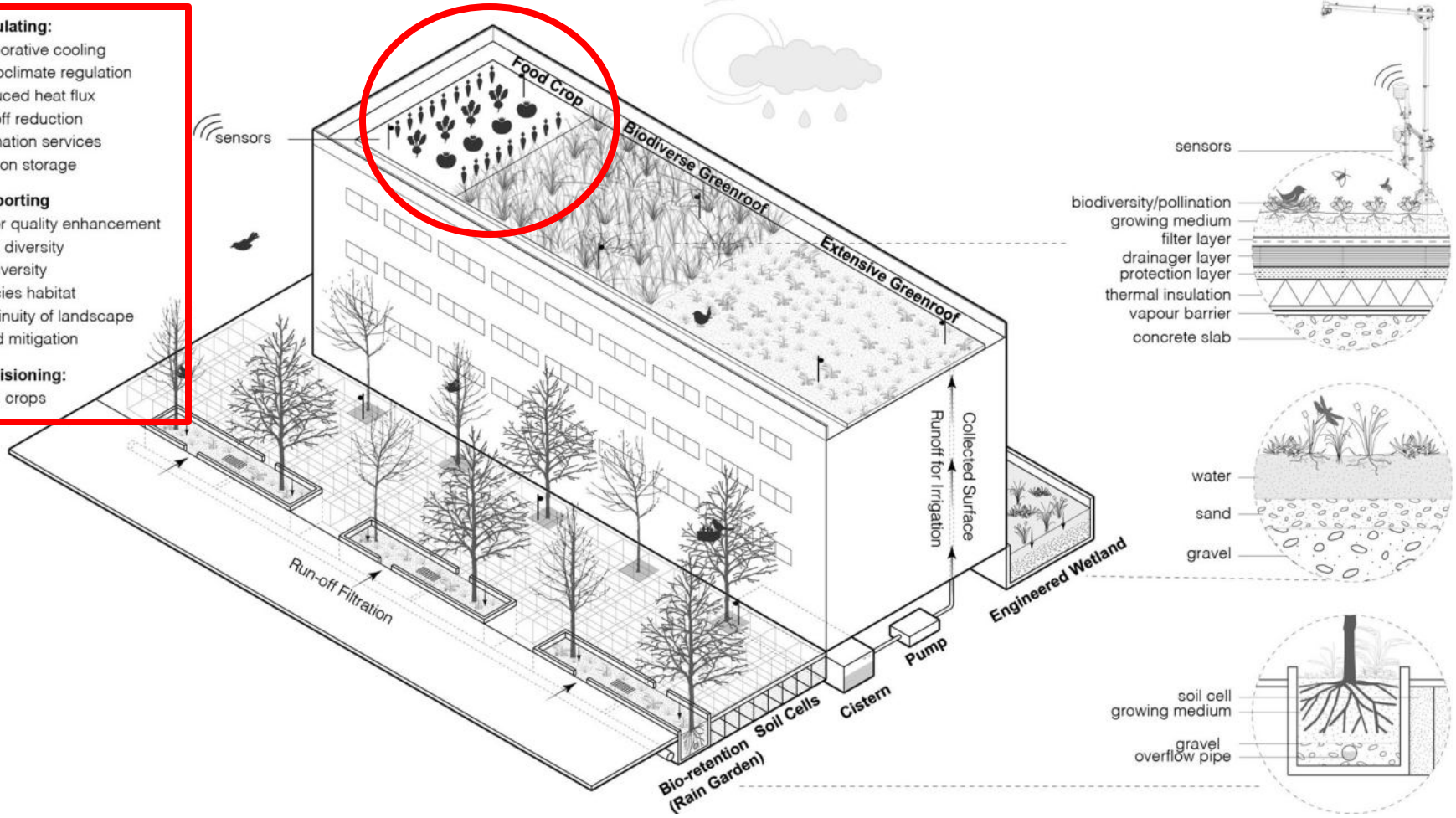




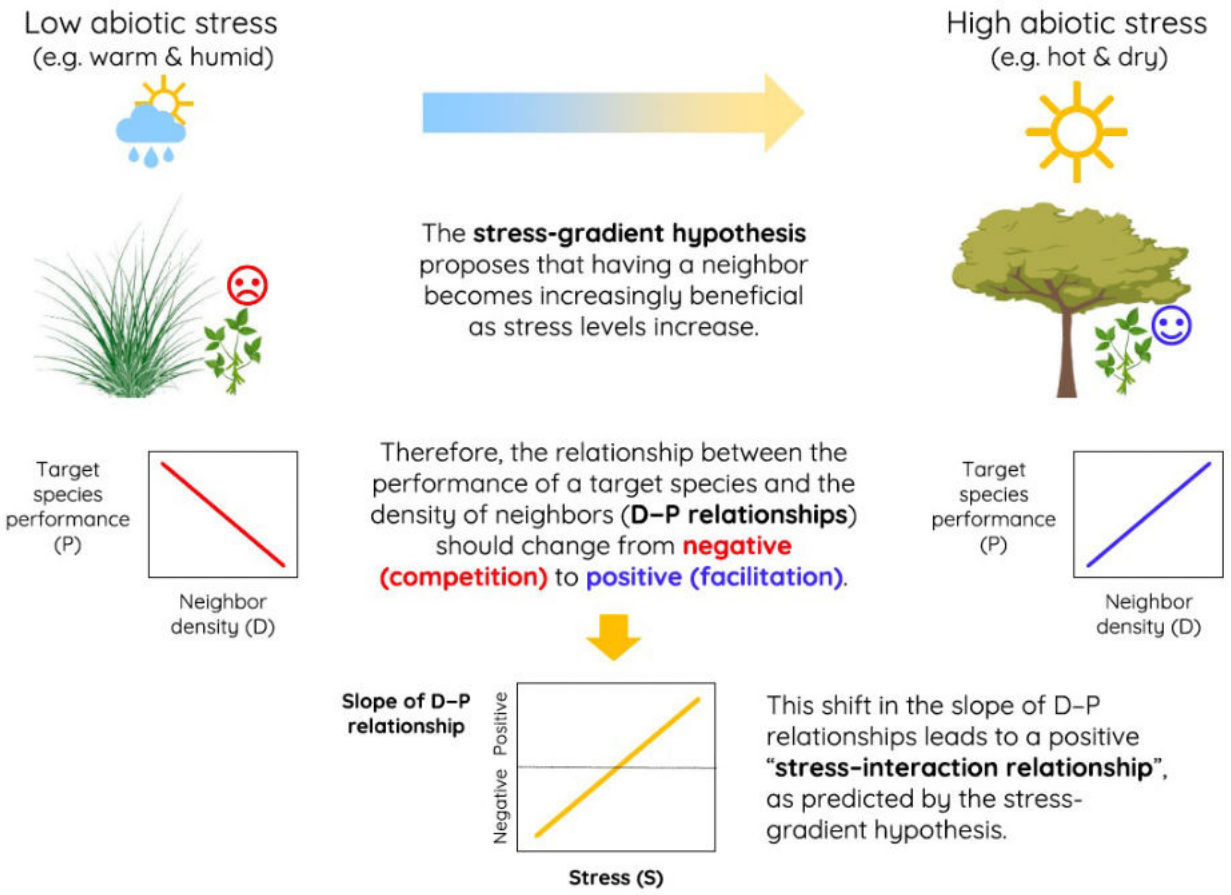
Regulating:
Evaporative cooling
Microclimate regulation
Reduced heat flux
Runoff reduction
Pollination services
Carbon storage

Supporting
Water quality enhancement
Plant diversity
Biodiversity
Species habitat
Continuity of landscape
Flood mitigation

Provisioning:
Food crops



A model for green roof research that integrates (i) modern trait–environment theory and (ii) facilitation ecology in a refined stress-gradient hypothesis originally developed in other stressful environments

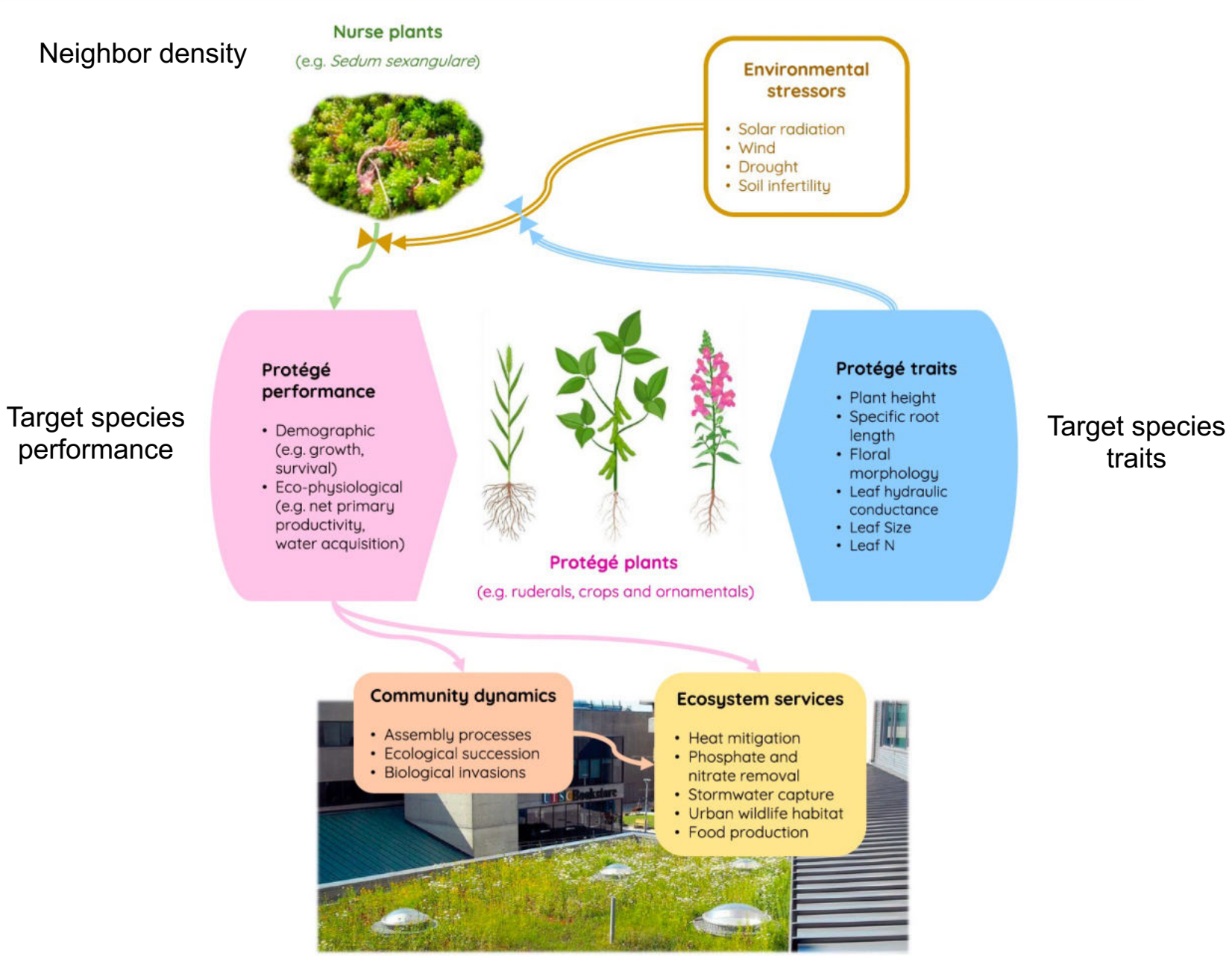


Rolhauser et al. (2023) Ecological Solutions and Evidence

Neighbor density

Target species performance

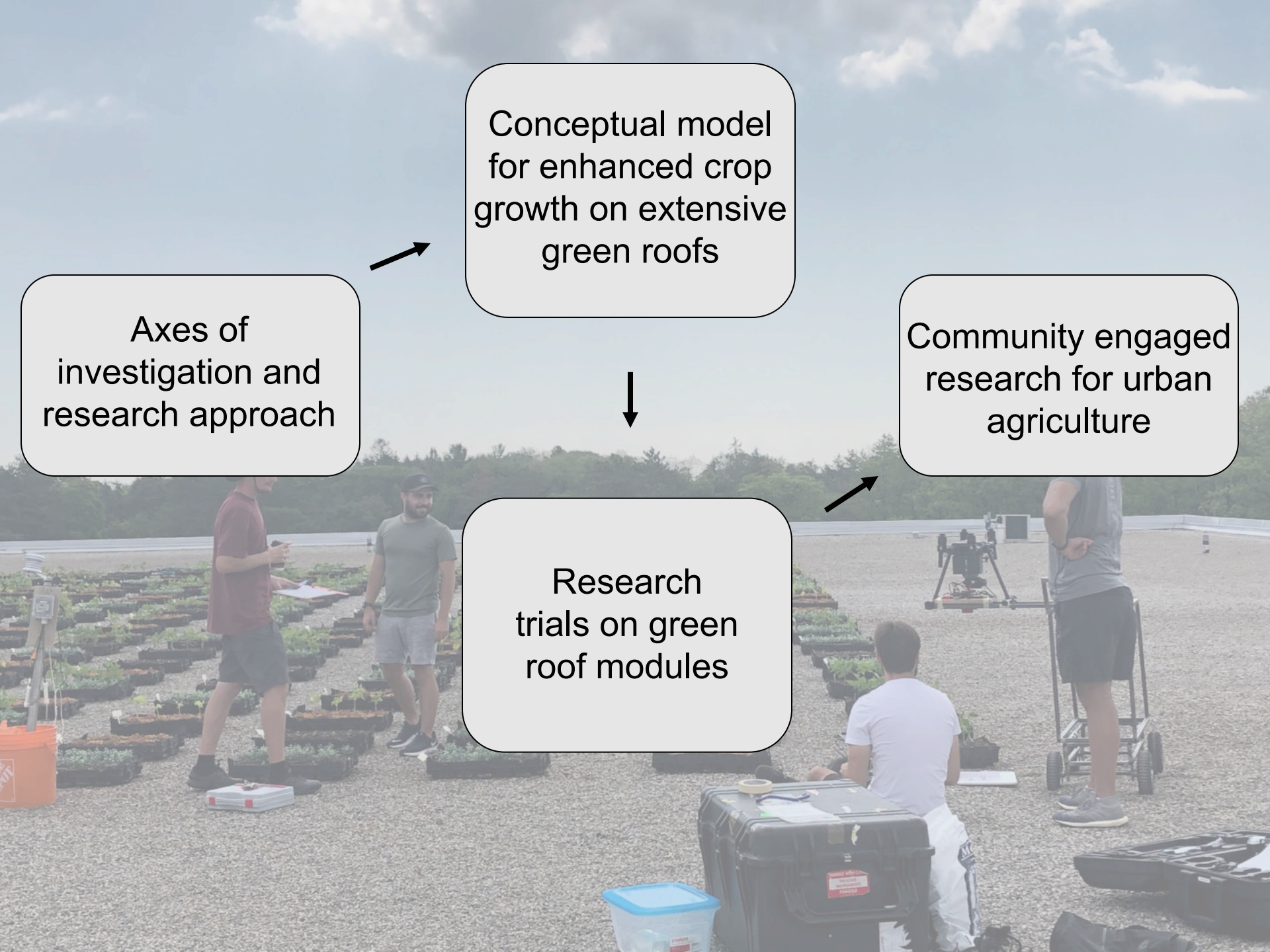
Target species traits



Rolhauser et al. (2023) Ecological Solutions and Evidence

Nurse-Protégé relationships

- To **assess** which portion of the stress gradient will favour positive nurse–protégé interactions on green roofs.
  - Nurses may increase protégé beneficial traits under high stress, but this performance may be significantly lower compared to a situation with both low stress and low competition.
- To **predict** under which environmental conditions facilitation enhances ecosystem services.
  - The yield of protégé under relatively high stress with a nurse plant compared to the yield of isolated plants without nurses in more benign conditions.
- To **determine** whether crop production in a stress-plus-nurse environment is feasible or whether resources need to be added.
  - Associated environmental and economic costs need be evaluated.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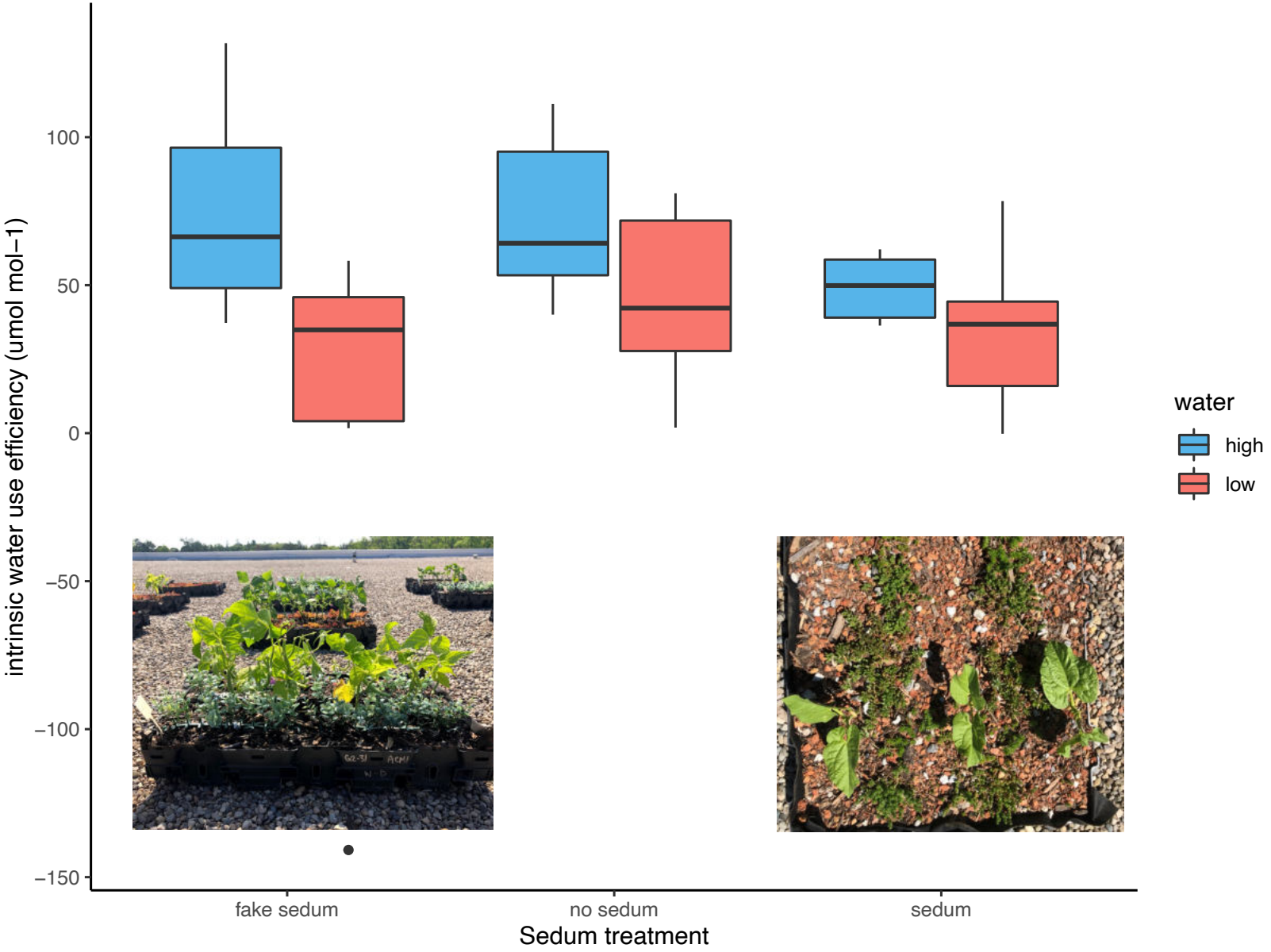
G2-31 ACM
W-D

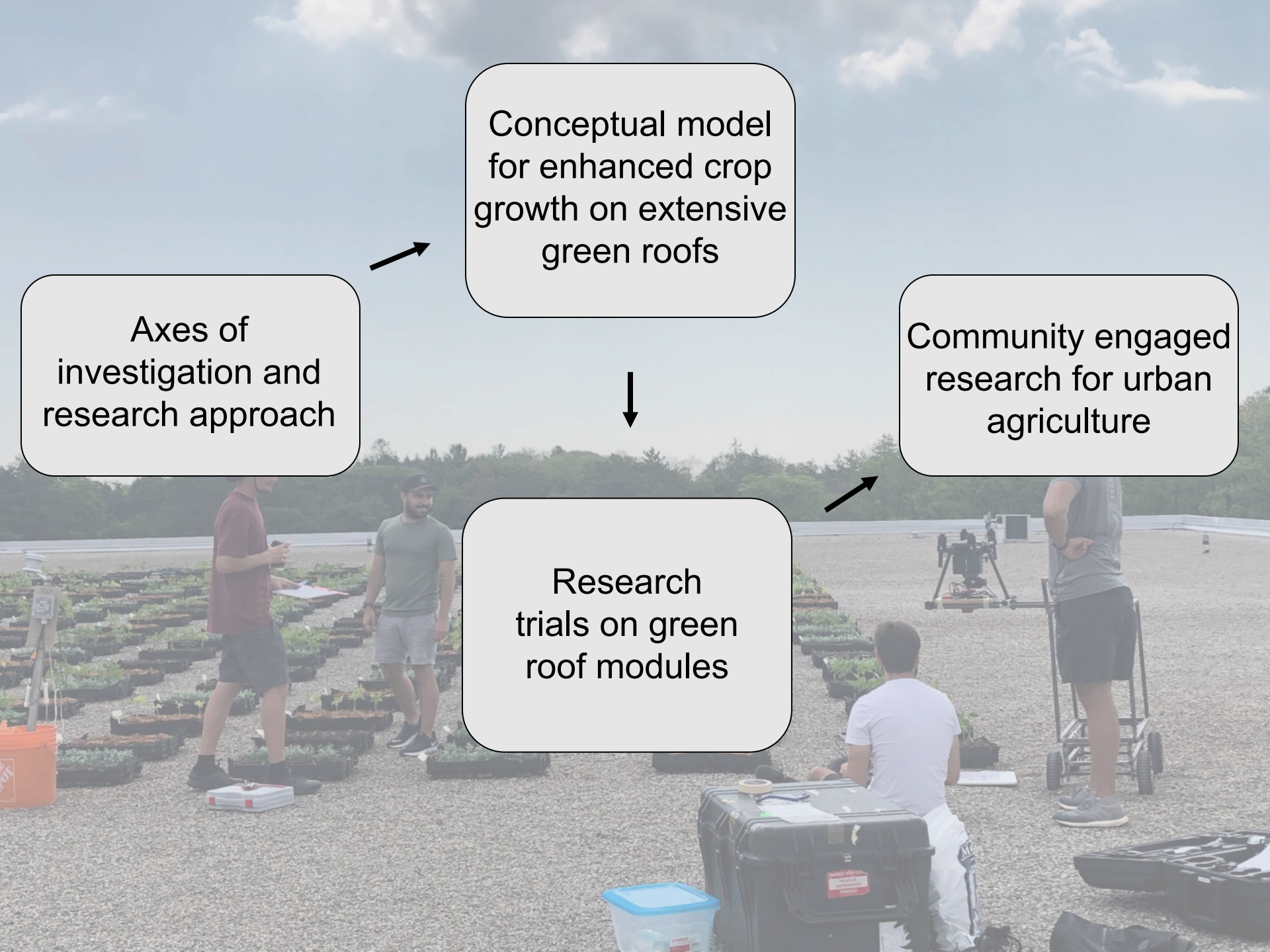
Green roof testing facilities

- Extensive green roof modules with bean (*Phaseolus vulgaris*) monocropped or intercropped with *Sedum* in an additive design, plus a high crop diversity treatment.
- 2 watering levels (reduced: 12-35% substrate moisture; high: > 35% substrate moisture).
- 9 functional traits:
  - leaf economic traits (photosynthesis (A_{sat}), µmol CO_2 m^{-2} s^{-1}; Specific Leaf Area (SLA), mm^2 mg^{-1})
  - leaf hydraulic traits (water use efficiency (WUE), mmol CO_2 mol^{-1} H_2O); chlorophyll fluorescence (F_v / F_m))
  - crop performance traits (biomass, g; height, cm)
  - root traits (root diameter, mm; Specific Root Length, SRL, m g^{-1})


intrinsic water use efficiency (umol mol−1)
100
50
0
−50
−100
−150
fake sedum
no sedum
sedum
Sedum treatment
water
high
low

0.40
0.35
0.30
0.25
root diameter (mm)
no sedum
sedum
Sedum treatment
water
high
low


Bush Beans
Radish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What is the future of urban farming? UTSC researchers test which crops fare best on city roofs

Toronto has one of the most progressive green roof policies in North America – and was the first city on the continent to make them mandatory for new construction. Green roofs help cool buildings, leading to lower energy costs.

There are currently more than 700 dotting the city but most use shallow substrates (a mix of organic material, crushed bricks and some minerals such as sand and shale) instead of soil – and little to no irrigation. They require minimal maintenance and have not been designed with farming in mind.

"Growing food in these conditions is not easy," says Marney Isaac, a professor in the department of physical and environmental sciences at U of T Scarborough who is co-leading a project with Scott MacIvor, an assistant professor in UTSC's department of biological sciences, to test whether these roofs can become food-growing gardens.

Isaac, who is an expert on plant-soil interactions and sustainable agriculture, says a major challenge is making sure the crops get enough nutrients. Since the typical green-roof substrate is not as nutrient-rich as soil – and dumping loads of fertilizer on the tops of buildings isn't possible – the team is testing a type of organic fertilizer.

Heat (too much) and moisture (not enough) are also concerns. Most Toronto green roofs are planted with sedum, a durable and drought-tolerant type of succulent that is efficient at storing water and cooling the soil. The researchers are looking at how different species of sedum might help more sensitive plants, such as crops, grow in harsh conditions.

The researchers are currently growing a variety of crops in 400 individual modules – boxes measuring 60 centimetres by 40 centimetres – on the roof of Highland Hall at U of T Scarborough. The goal is to see how certain plants interact with each other – a tried-and-true farming process known as intercropping. For example, planting legumes contributes nitrogen to the soil, which supports the growth of other crops.

It's possible that one day your local grocery store will be able to grow food on its roof. Or people living in condos and apartments will be able to ascend a few floors to harvest their own fruits, vegetables and herbs, including ones not commonly stocked in stores. "It could give people living in cities an opportunity to grow the types of culturally important foods they can't easily get," says Isaac. **—Don Campbell**

1. Researchers planted dozens of boxes atop UTSC's Highland Hall with a mix of crops and sedum. The team provides varying levels of water and nutrients to simulate stress on the plants

PHOTOGRAPHS BY DON CAMPBELL

2. The research team measures leaves and vegetables to track plant growth. Here, a researcher cuts a vine with scissors to harvest a bean

3. This machine detects how well the plant is breathing

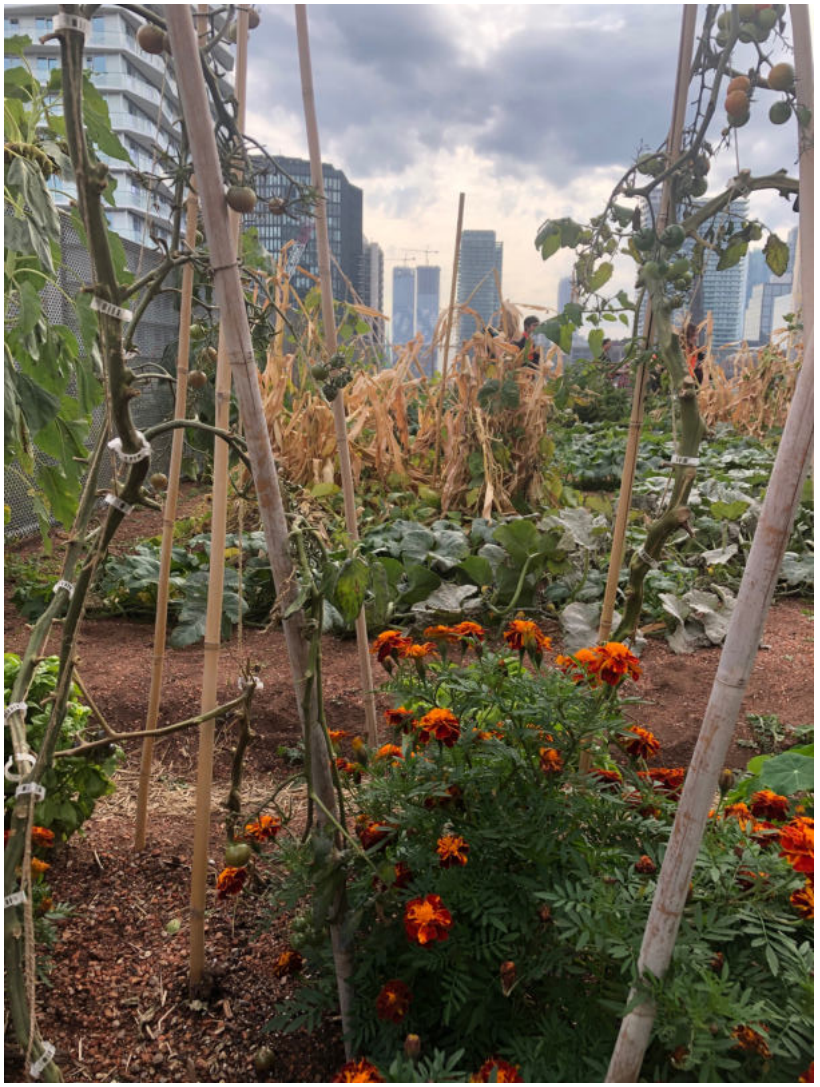
4. Another device helps determine how well the plants perform photosynthesis. When taking measurements, the researchers use remote sensing to avoid harming the plants

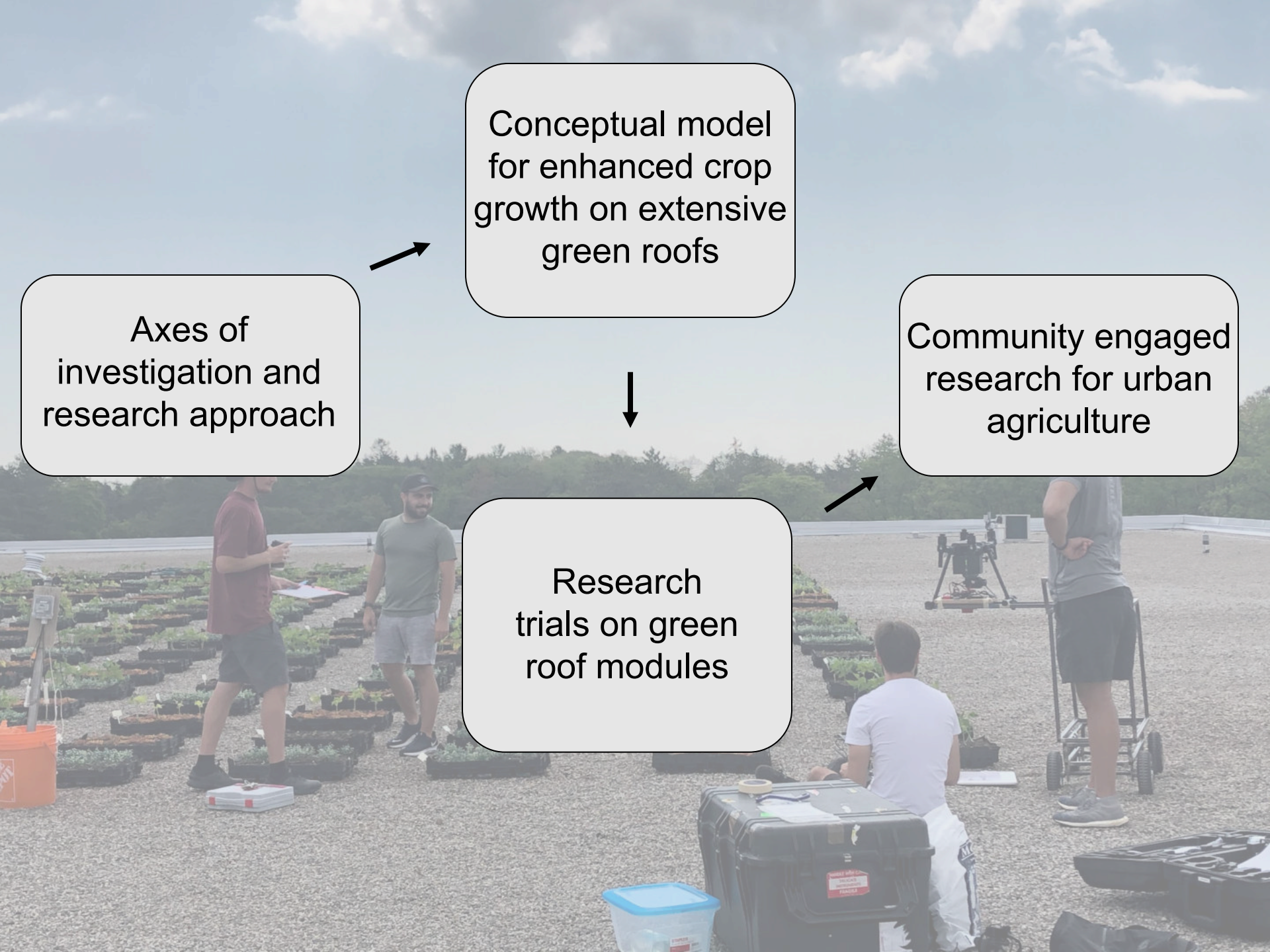
5. At the end of the season, crops are picked, dried and weighed

Towards Sustainable Agriculture in Canadian Cities

Interconnected themes:

- **1)** restore environmental conditions for annual and perennial crop production in urban and peri-urban environments and green roofs;
- **2)** measure and model GHG emissions and C sequestration in these systems;
- **3)** develop crop breeding programs and biofertilizers that are specific to urban and green roof production; and
- **4) i**mprove public-private arrangements to advance the adoption and implementation of low-GHG urban and peri-urban agriculture and green roofs, particularly on underutilized sites and within low-income communities.

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