Urban Food System Innovations: Multiscale Modeling and Action Analysis

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Sustainable Healthy Cities

A National Science Foundation-supported Sustainability Research Network (SRN)

PRINCETON UNIVERSITY

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Today's Talk: Innovations in Urban Food Systems

A. Background & Interdisciplinary Framework

B. The New "Urban" Lever & Baseline

C. Innovations in Modeling & Sustainability Analytics

- **Transboundary modeling of urban food systems**
- **Measuring sustainability outcomes, and their trade-offs (Example of Environmental Outcomes)**

D. Innovations in food actions

- **Science + Policy Engagement in Minneapolis, MN**
- **Designing interventions: focus on multi-objective spatial planning of urban farms**

Acknowledgement:
Colleagues, NSF Grants, City-Policy Partners

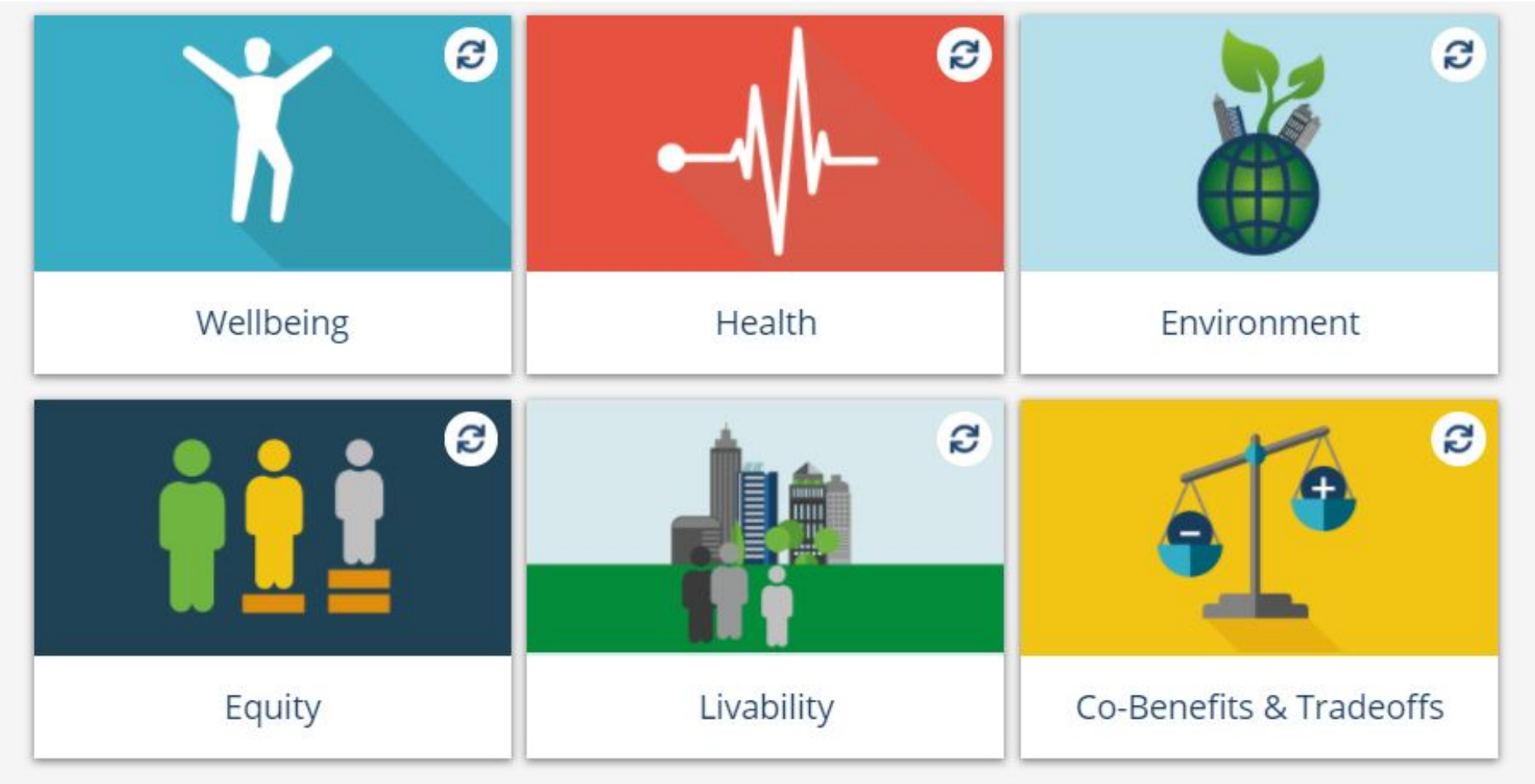
Integrative Graduate Education, Research and Traineeship (IGERT)- Sustainable Urban Infrastructure, Lead PI

Partnerships in International Research and Education (PIRE): Developing Low-Carbon Cities in the US, China, and India. Lead PI

Sustainability Research Network (SRN) - Sustainable Healthy Cities Network, Lead PI

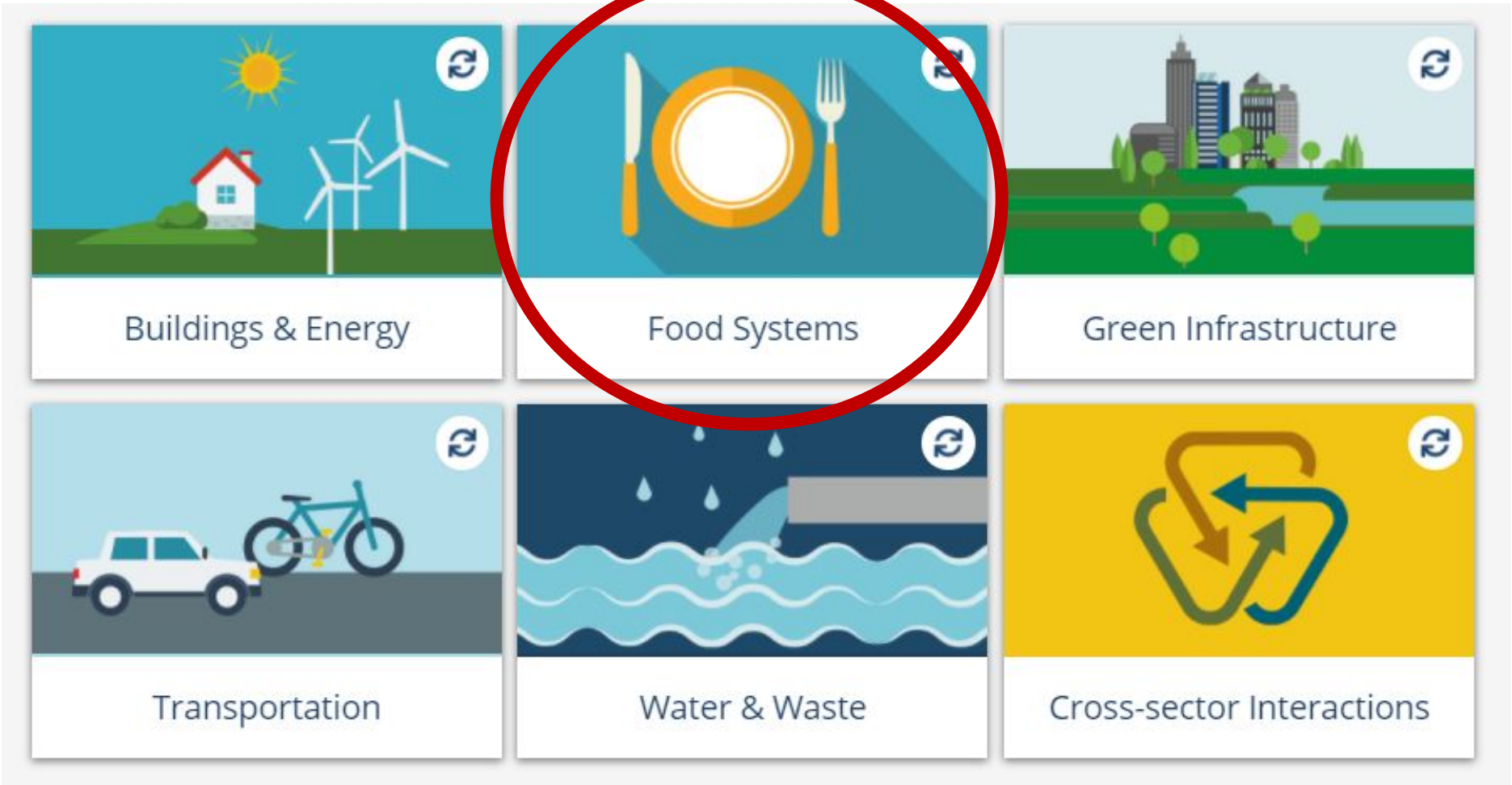
Smart & Sustainable Communities: Smart Spatial Infrastructure Planning to Improve Access (Co-Lead w Shashi Shekhar)

Key Outcomes



www.sustainablehealthycities.org

Key Sectors



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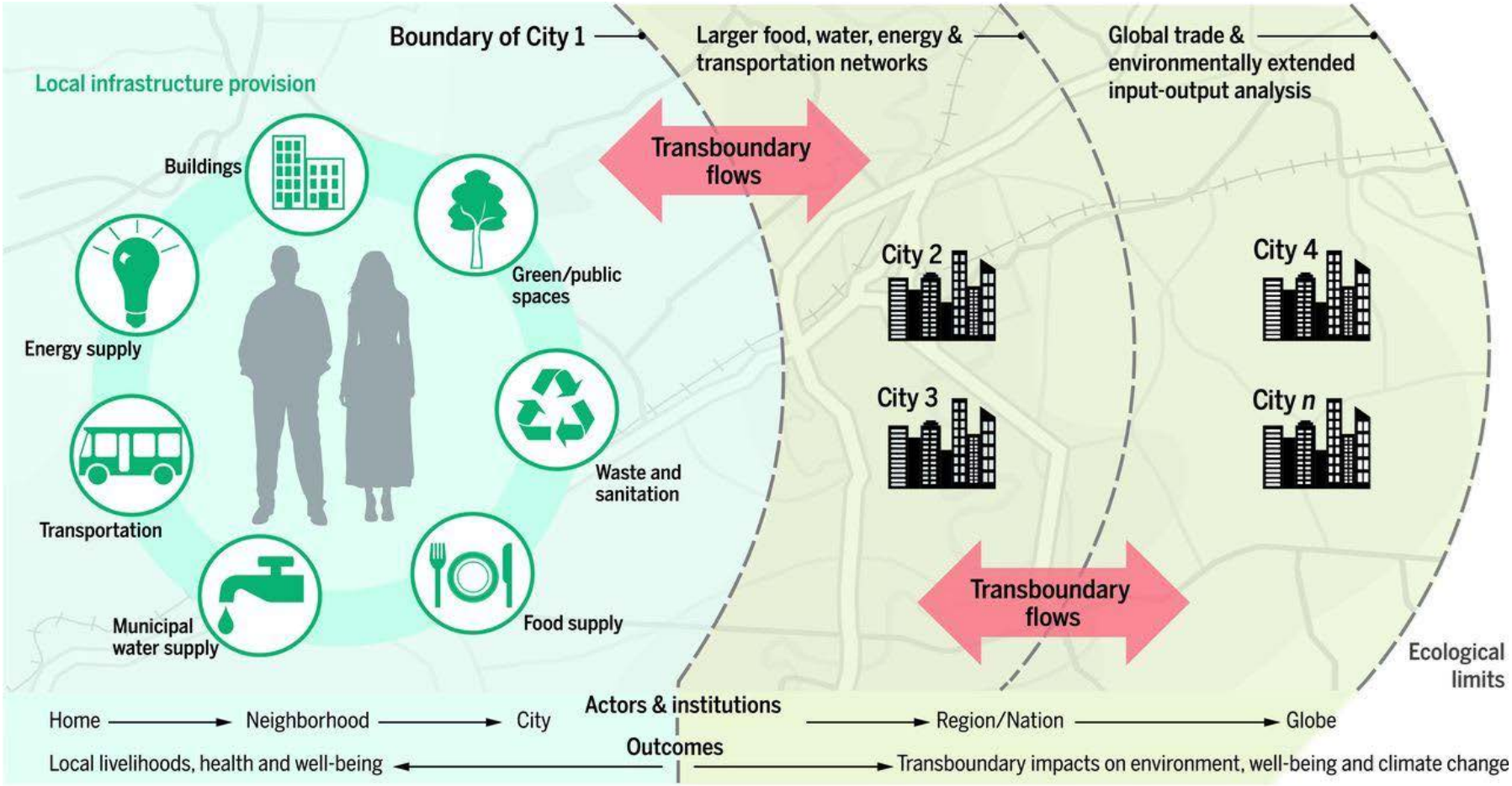
Interdisciplinary Social-Ecological-Infrastructural 4rban Systems (SEIUS) Framework



Ramaswami et al. 2016. *Science*.

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Wide Interest in Local Food

- Many international cities in the Milan Urban Food Pact
  - One of the objectives to increase urban agriculture

- Many US Cities have developed Food Action Plans
  - Diverse objectives: health, nutrition, economy, environment, equity/food justice, social cohesion
  - Localization and local agriculture presumed to provide many benefits
  - But quantification of localization itself is varied across studies

- Foodshed studies vs **Local Capacity studies**
  - Little standardization ➔ many case studies, ad hoc, varied
  - Direct vs embodied food demand (Fresh tomatoes vs Tomato Sauce)
  - Household or household+industry
  - Various boundaries considered local (city boundary or upto around 100 miles around an urban area)

- *No comprehensive assessment of current localization capacity across large numbers of US MSAs*

Defining Current Local Capacity

- Current local capacity of agricultural production in an urban boundary to meet household demand in that boundary

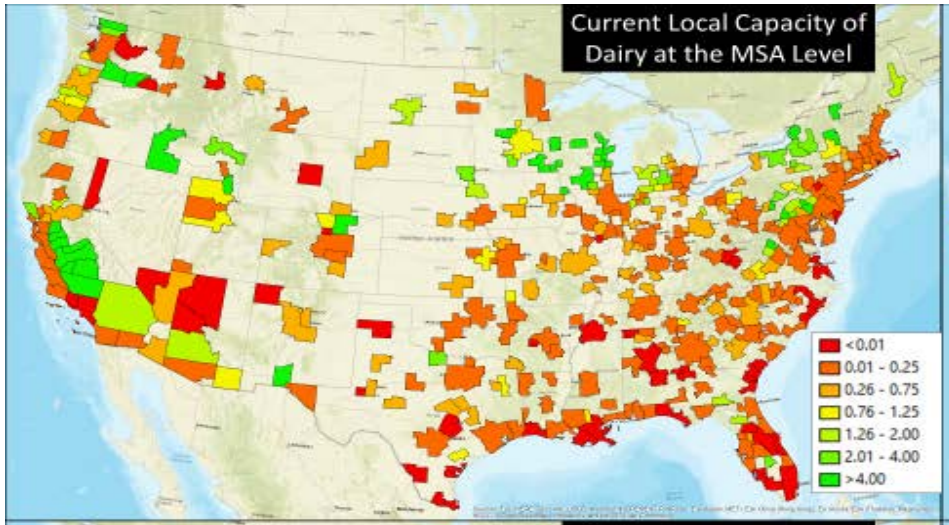
$$Current\ Local\ Capacity\ (CLC) = \frac{Current\ Local\ Production}{Current\ Local\ Demand} \qquad \text{(Eq. 1)}$$

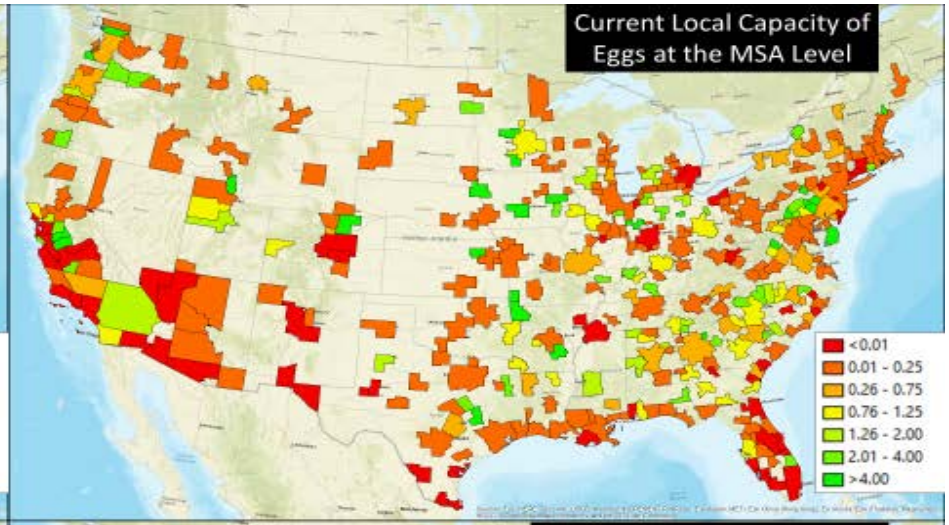
- Sensitivity to assumptions:
  - Household food demand (direct/"fresh" vs direct+embodied)
  - Food production:
    - strictly within the Metro Area
    - upto 100 miles around

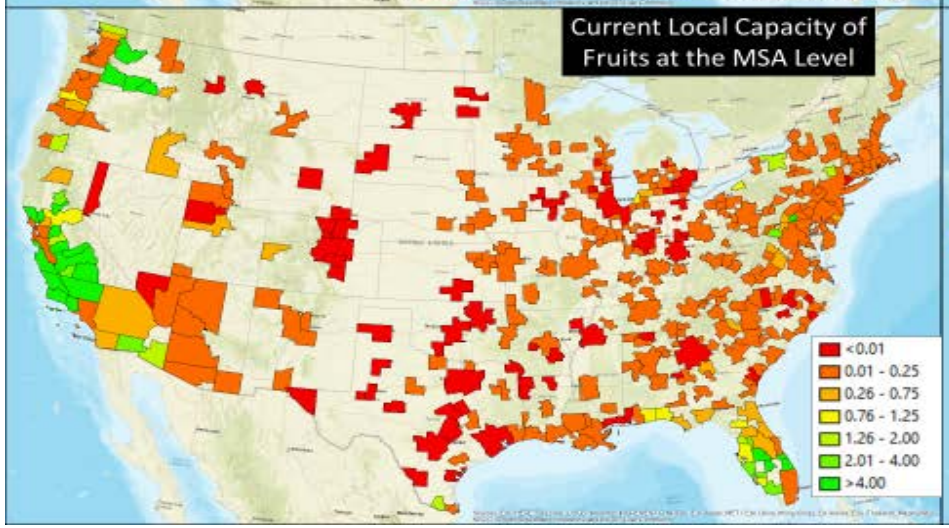
Direct (Fresh) versus Direct + Embodied

	Approximations of per capita direct food intake of select agrifoods (CEX vs. NHANES)		Approximations of total (direct + embodied + loss[1]) US consumption of select agrifoods per capita (bottom-up NHANES vs. FAD vs. USDA)		
Quick Description of data source	Consumer Expenditure Survey (for benchmarking purposes)), adjusted to account for SNAP/WIC spending using CE:PCE ratio[8]	National Health And Nutrition Examination and Survey (NHANES), filtered for direct intake only	NHANES direct-plus-embodied food intake data, translated to raw commodity weights, with losses[1] included	US Apparent Consumption from the USDA ERS Food Availability Dataset (for benchmarking purposes)	USDA-derived apparent per capita consumption of select agrifoods from production and net imports data[2]
Summary of method	Consumer Expenditures per capita, converted to mass[6], and adjusted for nonprofit spending.	Food items eaten by individuals, estimated from surveys (bottom-up): Focus on direct intake of four agrifoods.	Agrifood-equivalent demand exerted by an individual in the US (direct-plus-embodied), incorporating losses across the supply chain	US apparent consumption (production + net imports and stock changes) as reported by FAD	US apparent per capita agrifood consumption (US agrifood production plus net imports)[7], estimated from aggregated county production
Dairy (in raw milk-equivalents)	159 lbs.[3] (fluid milk only)	162 – 175 lbs.[3,5] (fluid milk only)	615 lbs.[4]	613 lbs.[4]	623 lbs.[4]
Eggs	16.4 lbs.	16 – 20.9 lbs.[5]	35 lbs.	33 lbs.	33 lbs.
Fruits	n/a	n/a	346 lbs.	244 lbs.	250 lbs.[5]
Apples	n/a	15 – 15.5 lbs.[5]	61 lbs.	44 lbs.	34 lbs.[5]
Vegetables	n/a	n/a	403 lbs.	391 lbs.	439 lbs.[5]
Tomatoes	n/a	11 – 22 lbs.[5]	73 lbs.	87 lbs.	90 lbs.[5]

Visualizing Current Local Capacity: Four Key Food Items across 377 US MSAs

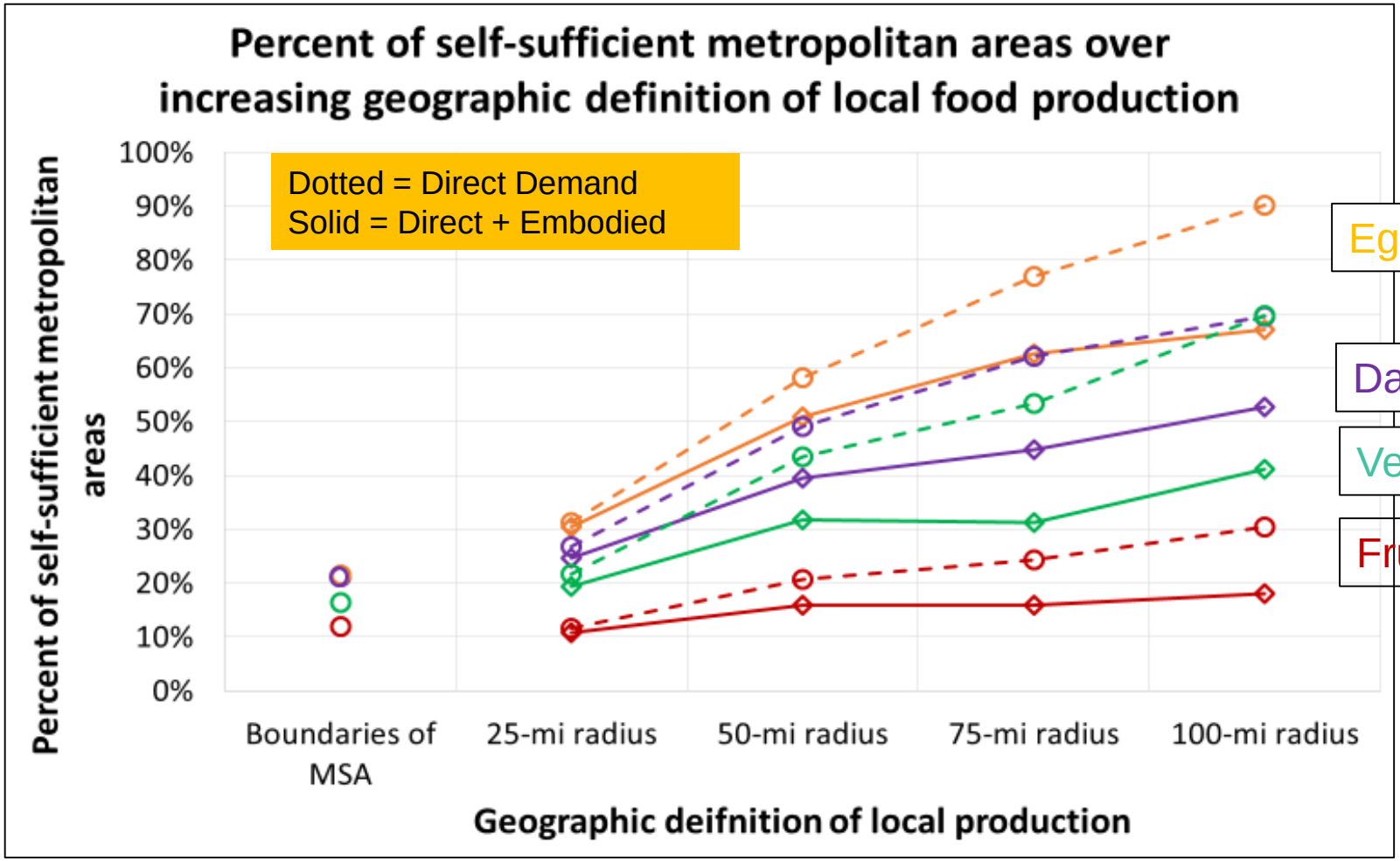






Nixon & Ramaswami, *Environ. Sci. Technol., 2018*

How Does Current Local Capacity Change When Agriculture Around Urban Areas is Considered



Nixon & Ramaswami, *Environ. Sci. Technol., 2018*

Key Conclusions

- 21% of US Metro Areas already have capacity today to be fully (100%) self reliant in Dairy and Eggs (including direct and embodied in other food items)
  - These numbers are about 16% and 11% for Fruits & Veggies
- If we only consider fresh demand, the current local capacity increases further
- If we consider agriculture around urban areas, the local capacity increases further
- So key message ➔ If we seek to enhance local supply and self reliance, *production per se* is not so much a limitation, but rather the way supply chains are aligned today
- Clarifying WHY we seek locally sourced food will clarify where and which agri food items must be locally produced or sourced

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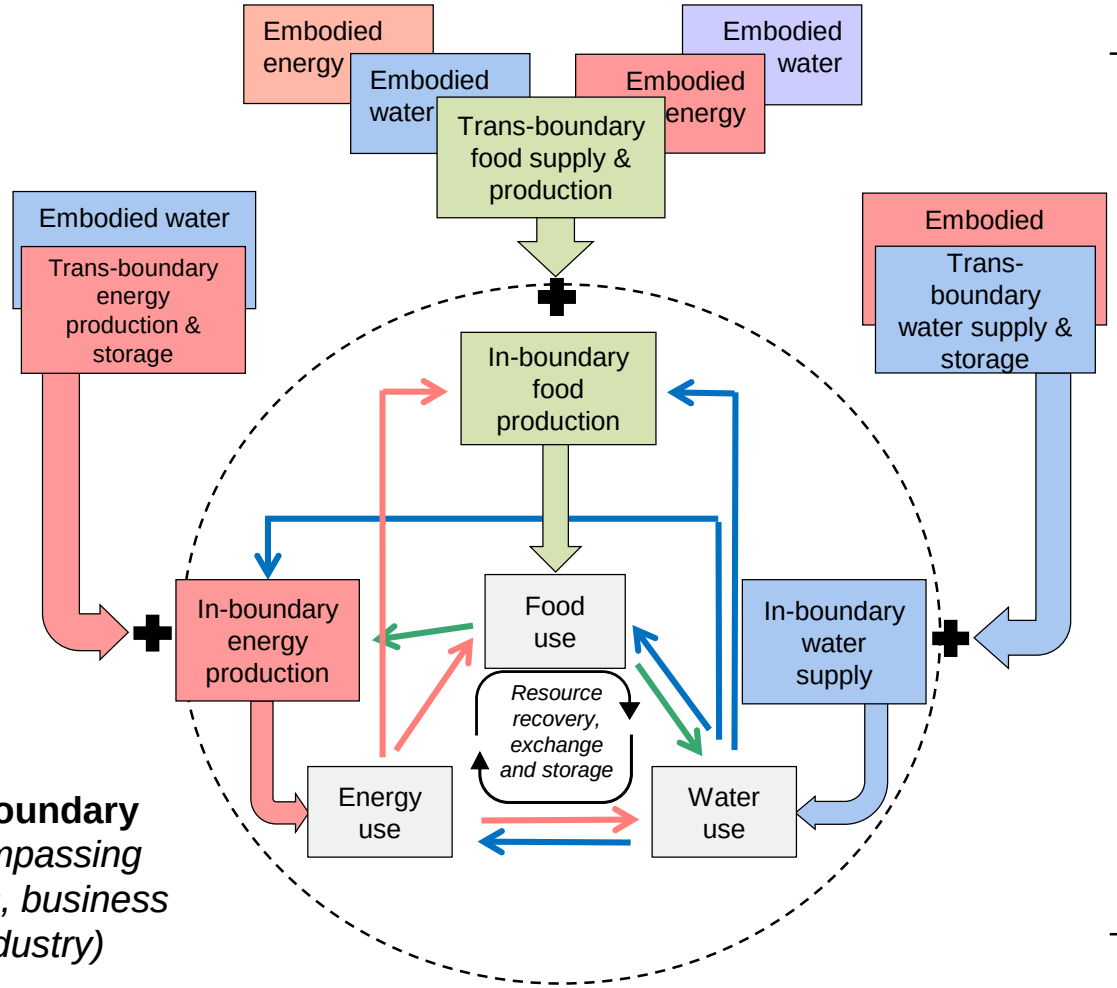
Transboundary Footprinting: Community-wide Water, Energy & GHG footprints of Food-Energy-Water (FEW) Supply to Cities



City boundary *(encompassing homes, business and industry)*

Community-wide water, energy & GHG footprints of Food-Energy-Water demand-supply in cities

Food sub-system interactions with other sectors important

Ramaswami et al. 2017, Environmental Research Letters

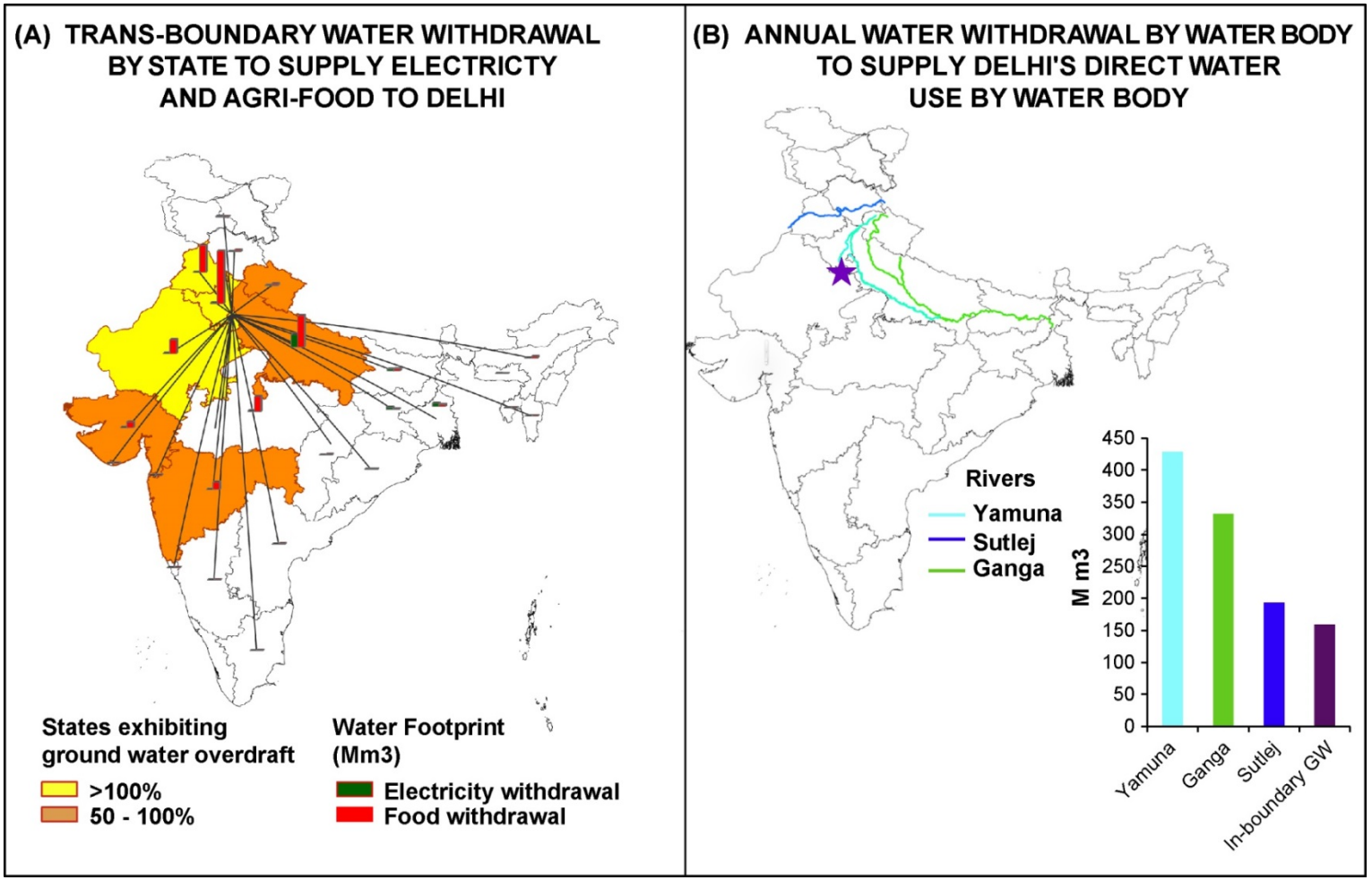
Exploring the Food-Energy-Water Nexus from an Urban Systems Perspective

Delhi, India

Population: 16 million

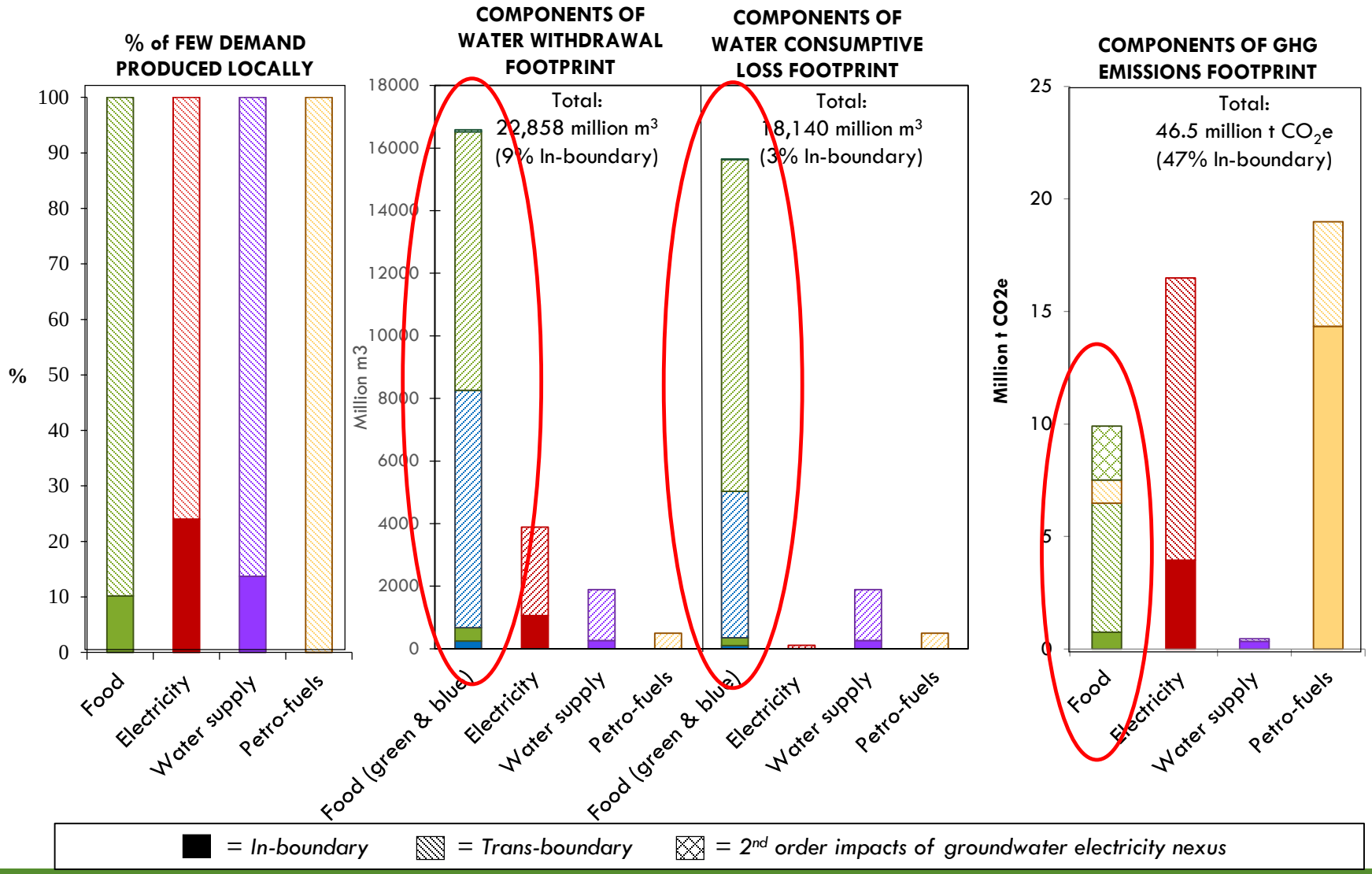
- **20% lacking sufficient calories**
- **25% lacking water from treated source**
- **10% lacking clean cooking fuel (LPG)**

Spatially disaggregated water withdrawal footprint to support the demand of FEW in Delhi



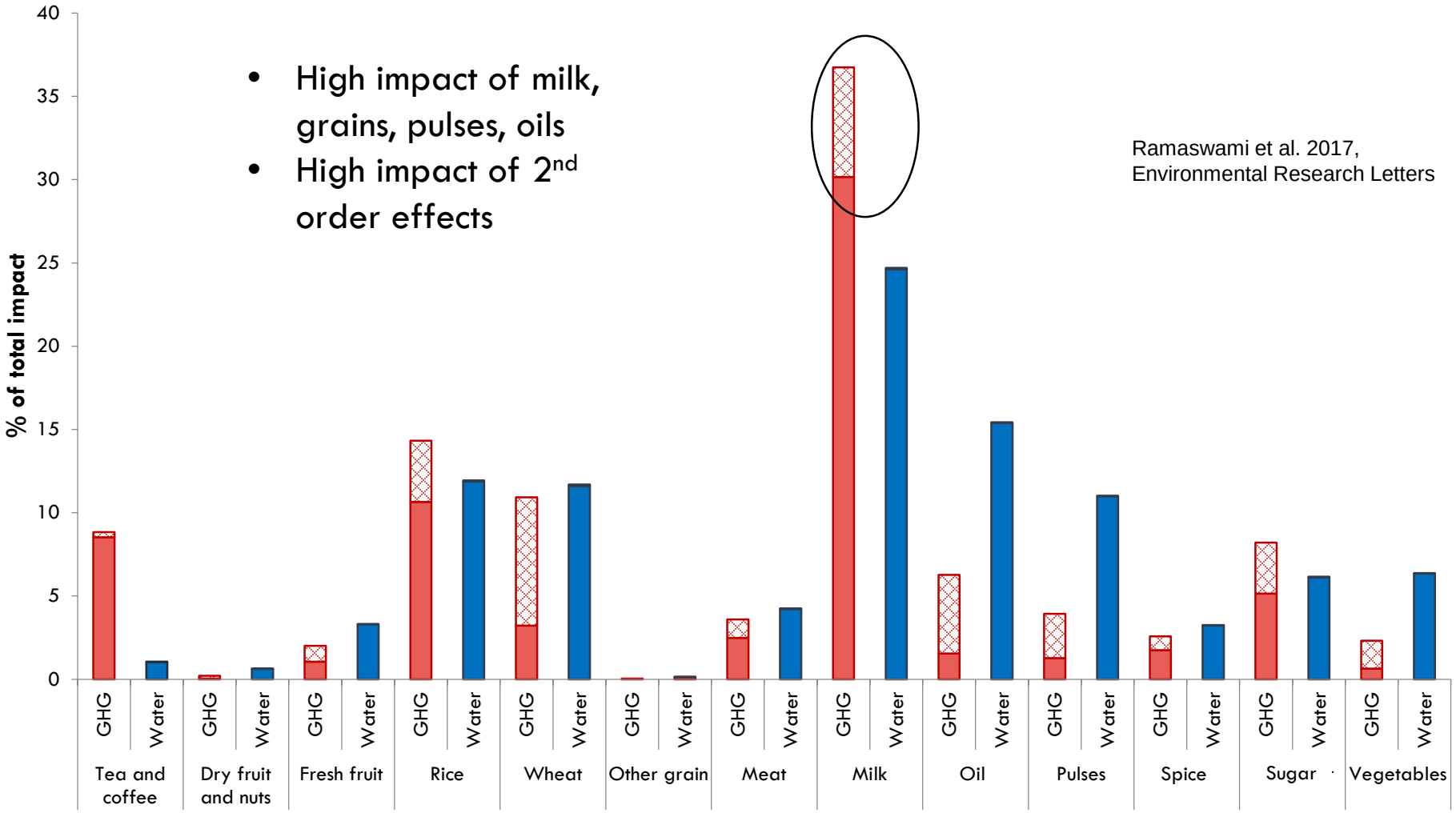
Ramaswami et al. 2017

Coupled water- energy/GHG footprints of FEW provisions to Delhi



Ramaswami et al. 2017

GHG and Consumptive Water Loss Footprint of Specific Food Items Supplied to Delhi



- High impact of milk, grains, pulses, oils
- High impact of 2nd order effects

Ramaswami et al. 2017, Environmental Research Letters

Traditionally quantified agri- impacts

2nd order impact of electricity and diesel for farm activities and irrigation

Application to inform policy

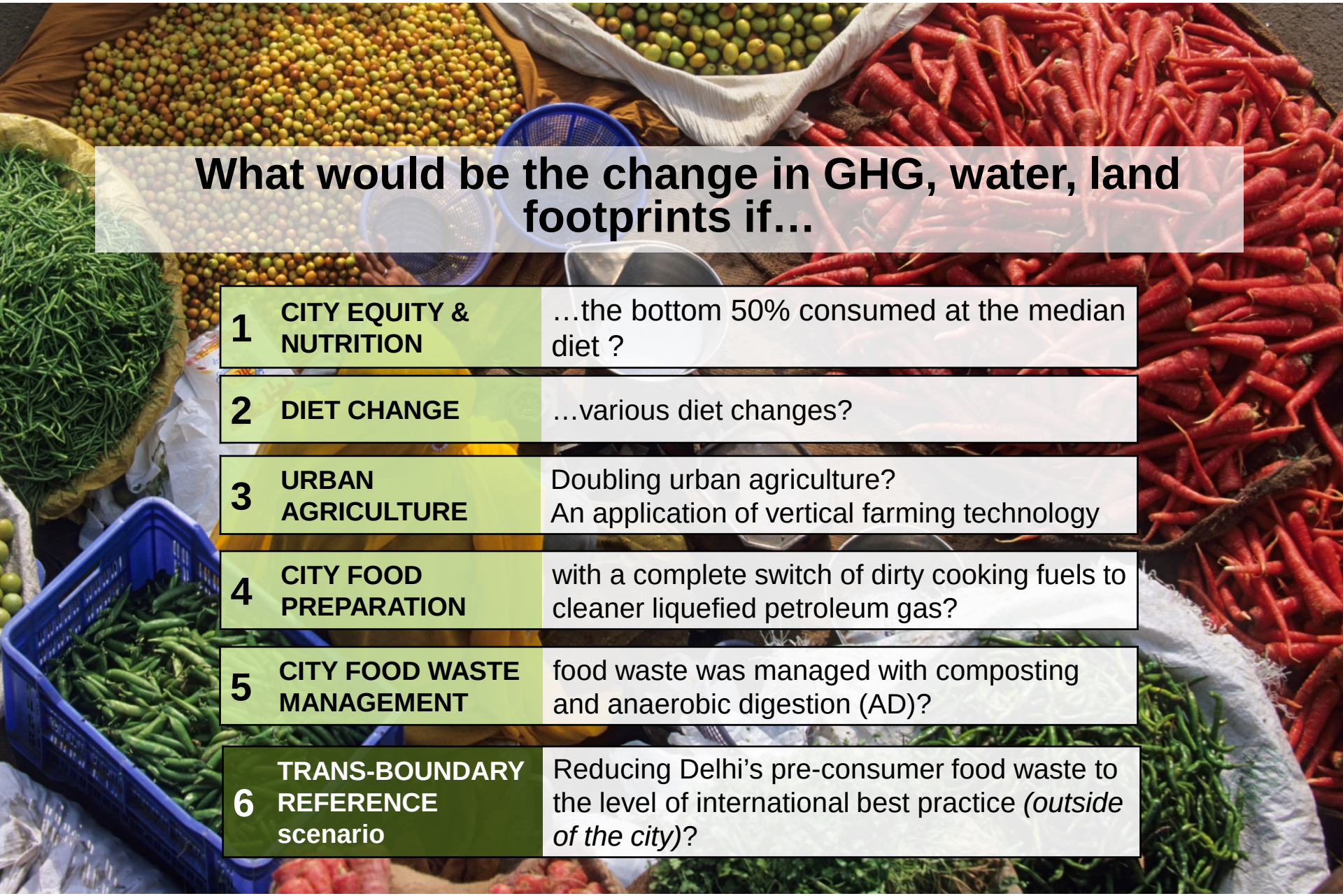
Environmental Science & Technology

Article

pubs.acs.org/est

What Is the Contribution of City-Scale Actions to the Overall Food System's Environmental Impacts?: Assessing Water, Greenhouse Gas, and Land Impacts of Future Urban Food Scenarios

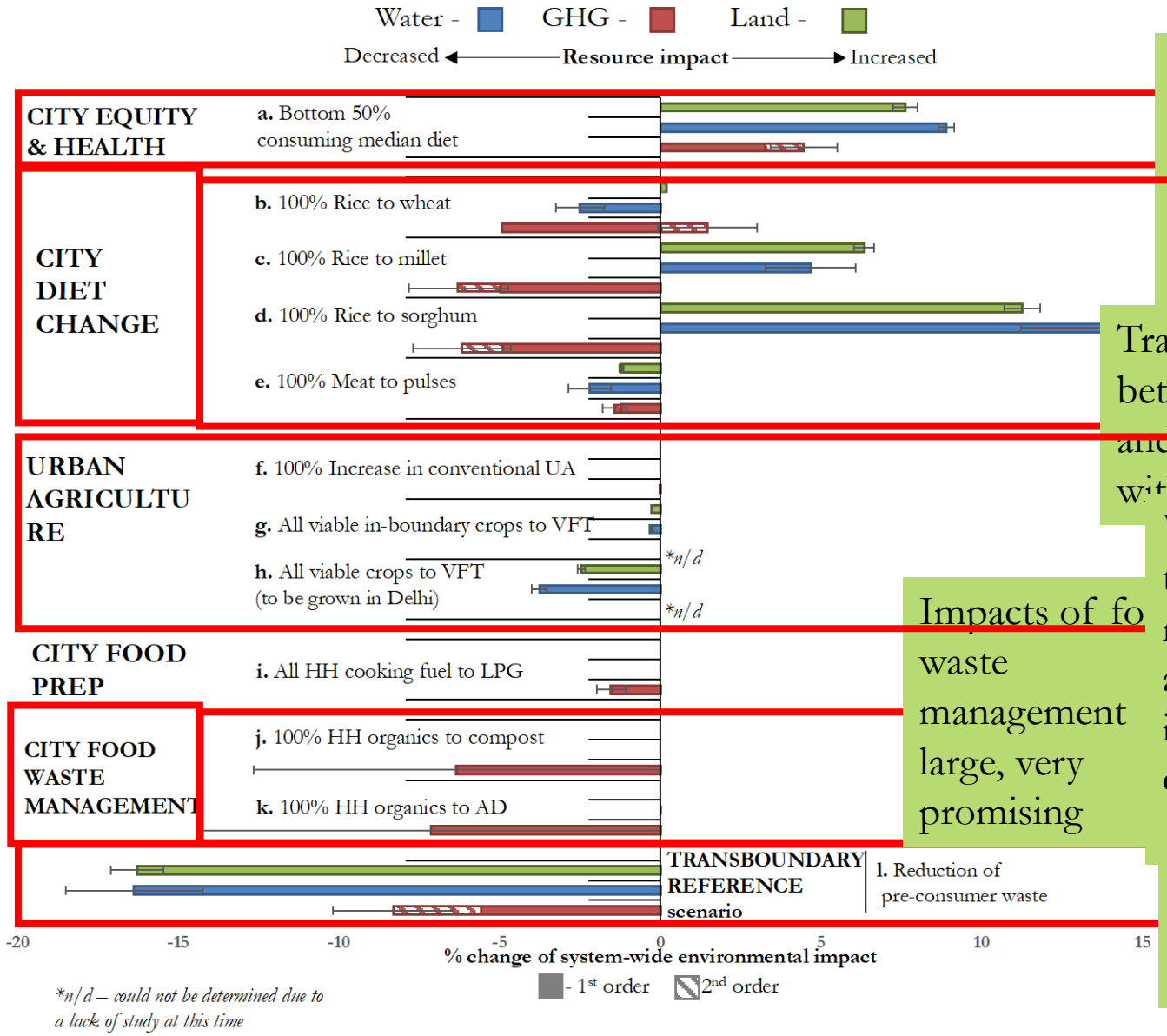
Dana Boyer*[,†] and Anu Ramaswami[†]



What would be the change in GHG, water, land footprints if…

1	**CITY EQUITY & NUTRITION**	…the bottom 50% consumed at the median diet ?
2	**DIET CHANGE**	…various diet changes?
3	**URBAN AGRICULTURE**	Doubling urban agriculture? An application of vertical farming technology
4	**CITY FOOD PREPARATION**	with a complete switch of dirty cooking fuels to cleaner liquefied petroleum gas?
5	**CITY FOOD WASTE MANAGEMENT**	food waste was managed with composting and anaerobic digestion (AD)?
6	**TRANS-BOUNDARY REFERENCE scenario**	Reducing Delhi's pre-consumer food waste to the level of international best practice *(outside of the city)*?

CHANGE OF FOOD's SYSTEM-WIDE ENVIRONMENTAL IMPACTS



*n/d – could not be determined due to a lack of study at this time

Increased diet equity results in modest increase of resource

Trade offs between GHG and water/land with diet changes

Impacts of fo waste management large, very promising

Vertical farming technology does not have large aggregate water impact for currently viable

City action can rival trans-boundary action

Key Findings:
City Food Actions Trade-offs & Co-Benefits

- **City action can rival trans-boundary action**
  - **No single action can match in all three environmental impacts**
  - Impacts of food waste management large, very promising
- **Vertical farming applied to all currently viable crops does not have large aggregate water impact**
  - Due to water dominance of non-VFT viable crops (grains, and animal product)
- **Increased resource requirements of increased diet equity are relatively small and can be off-set by efficiency**
- **Large in-boundary resource impact on water scarce cities**
- **Resource and GHG benefits of urban ag likely small/uncertain. Other benefits like heat island impacts may be more important.**

Boyer & Ramaswami, ES&T, 2017

City Food Actions Trade-offs & Co-Benefits Example Results Delhi, India

Increasing Food Consumption to Median Diets

Changing Diets (Meats to Pulses)

Cooking fuel interventions

Food Waste Management (HH Organics to Compost)

GHG

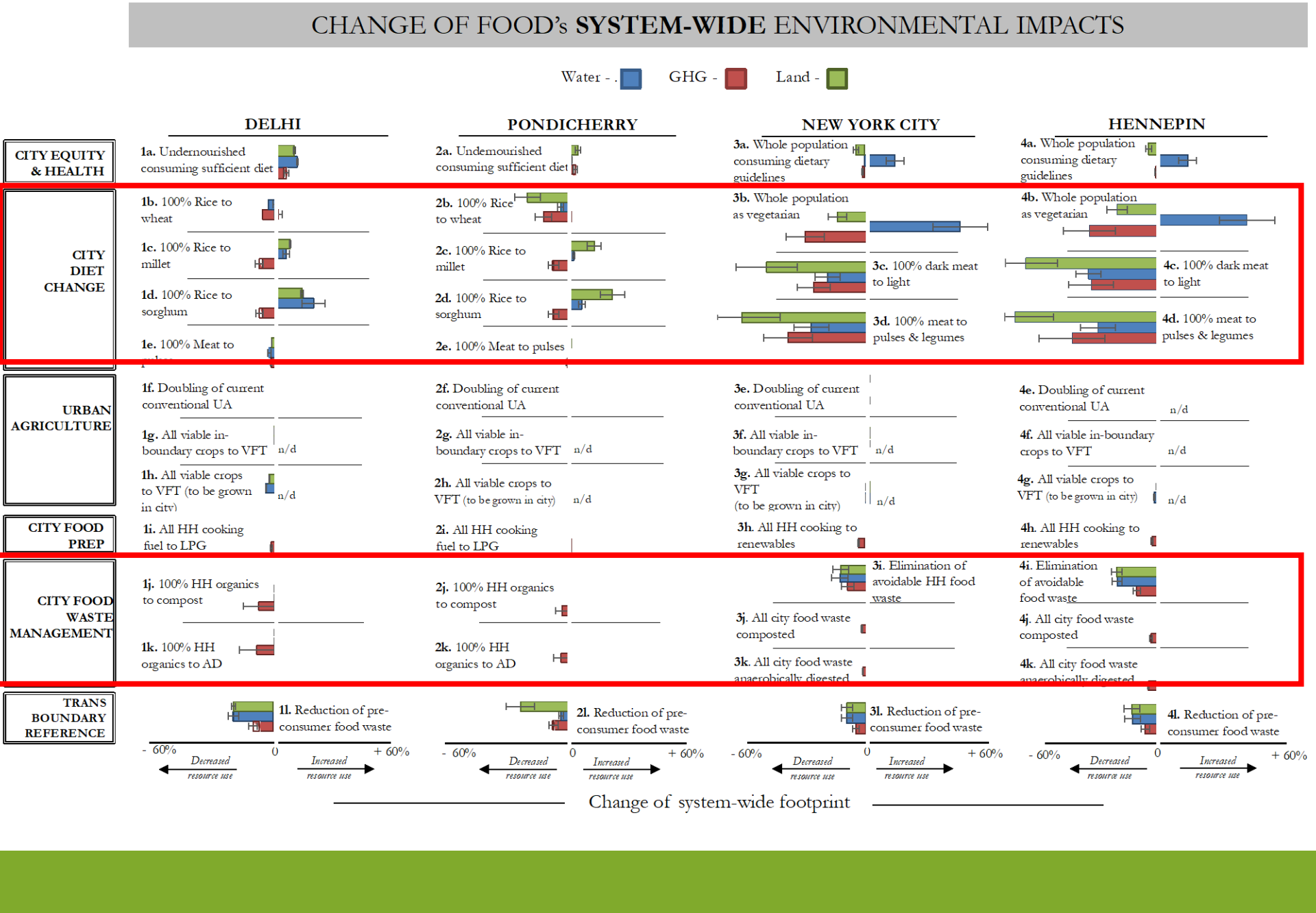
Land

Water

Health

Boyer & Ramaswami, ES&T, 2017

COMPARING US & INDIA



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Bringing it all together for food action planning in Minneapolis (next 18 months)

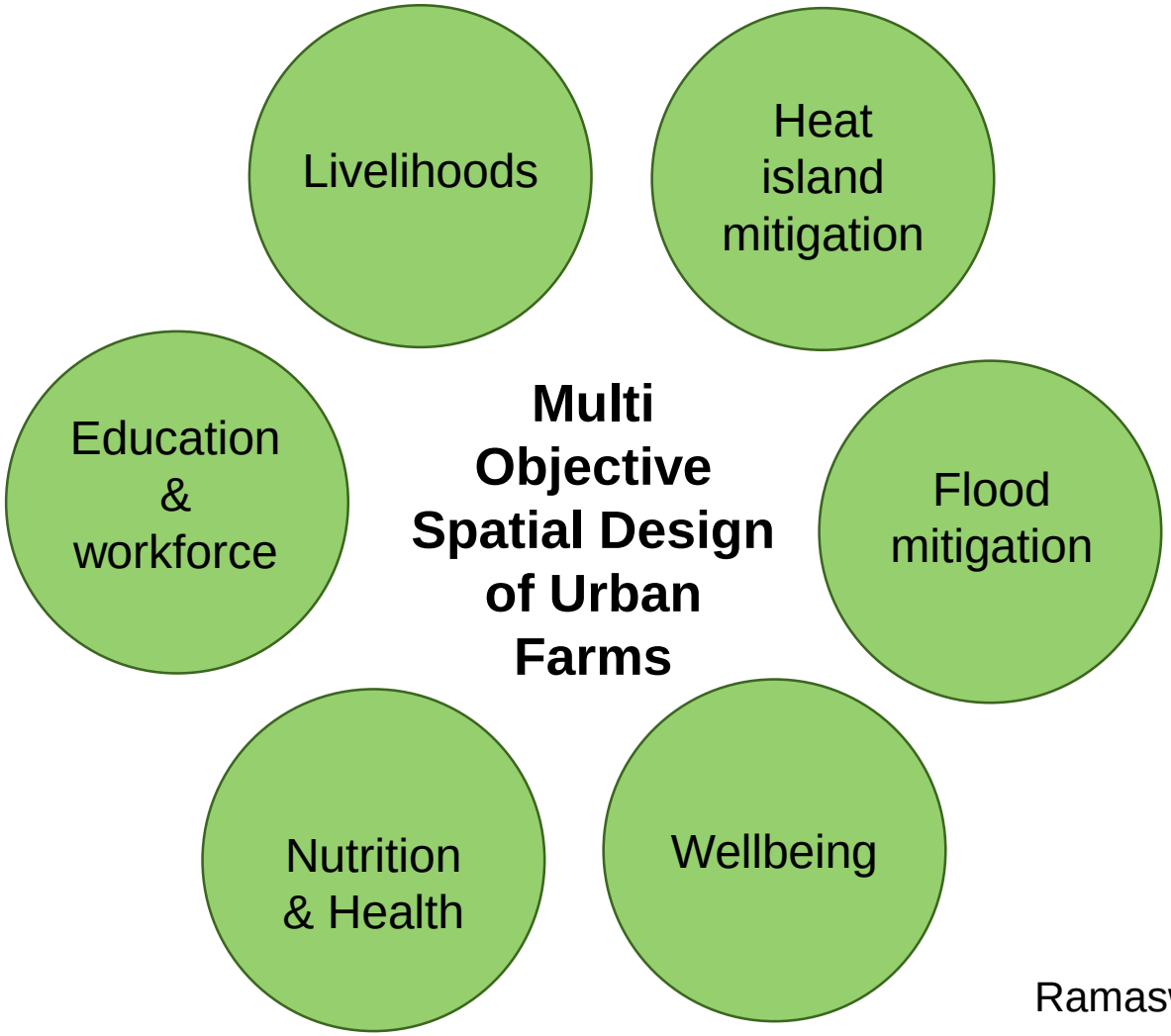
Launch of food action planning April, 2019

Minneapolis Food Action Plan Overall Goal Statement

The City of Minneapolis is developing a roadmap toward a more equitable, climate resilient, just and sustainable local food system and local food economy.

The goal of the Minneapolis Food Action Plan (MFAP) is to develop a 2030 roadmap for Minneapolis food systems action, building on previous efforts and plans, aligning with Milan Urban Food Policy Pact and incorporating data and community input.

Spatial Design of Urban Farms: It is not just about food



Ramaswami et al., 2019

Many Ongoing Research Questions

- **Spatial location of urban farms to maximize multiple benefits**
- **Size/Scale of urban farms – household, community or larger commercial farms**
  - **How do they impact nutrition, well-being, community development, heat island, flood mitigation..etc?**
- **Innovations: joint solar PV & Urban Farms**
- **Exploring the business case for urban farms is also more than "just food".**
- **Prioritizing among various levers: multi-objective local farms; diets & behavioral interventions; food waste management**

Photo: Univ. of Massachusetts

Thank you!

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