Foundations of Urbanization Science:
Mapping and Measuring Global Urban Metabolism

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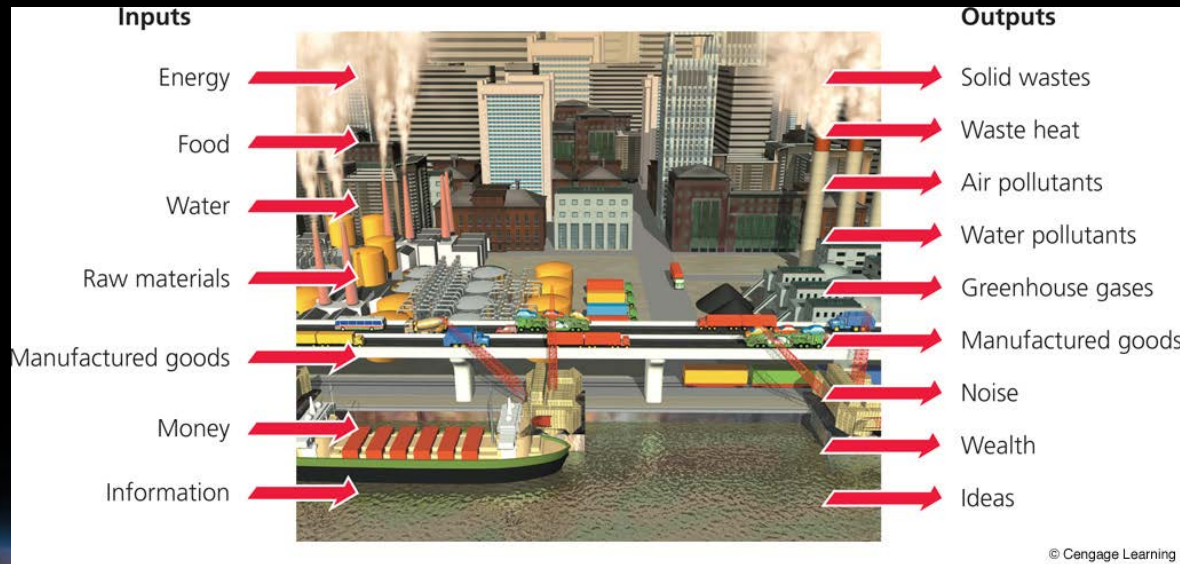**September 13, 2017**

Urbanization Science

"The science and policy communities increasingly recognize that cities, urban areas, and the underlying urbanization process are at the center of global climate change and sustainability challenges. Policymakers need facts, empirical evidence, and theories on how to plan and manage cities and urbanization during the contemporary era of rapid change and environmental uncertainty."

Solecki et al. (2013). It's time for an urbanization science. Environment 55(1), 12-16

As we all know – The proportion of the world's population living in cities is projected to increase to nearly 70% by 2050. This exacerbates the growing need to measure, monitor, and change how our cities function from an energetic, economic, and environmental perspective. A key question is:

What information is needed to characterize cities well enough to provide actionable information to inform many unique urban transformations?

2

URBAN METABOLISM is the complex suite of processes governing the flows and transformations of matter and energy that take place in the city at varying spatial and temporal scales. The complexity of these spatially and temporally variable processes and flows is formidable to try to measure and monitor.


Inputs		Outputs
Energy		Solid wastes
Food		Waste heat
Water		Air pollutants
Raw materials		Water pollutants
Manufactured goods		Greenhouse gases
Money		Manufactured goods
Information		Noise
		Wealth
		Ideas

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The Food Water Energy Nexus

Are there simple proxy measures of urban metabolism comparable to measures of human metabolism?

The Urban Vital Signs Global Dashboard
(Vital Signs of the Food-Water-Energy Nexus: A Global Urban Dashboard)
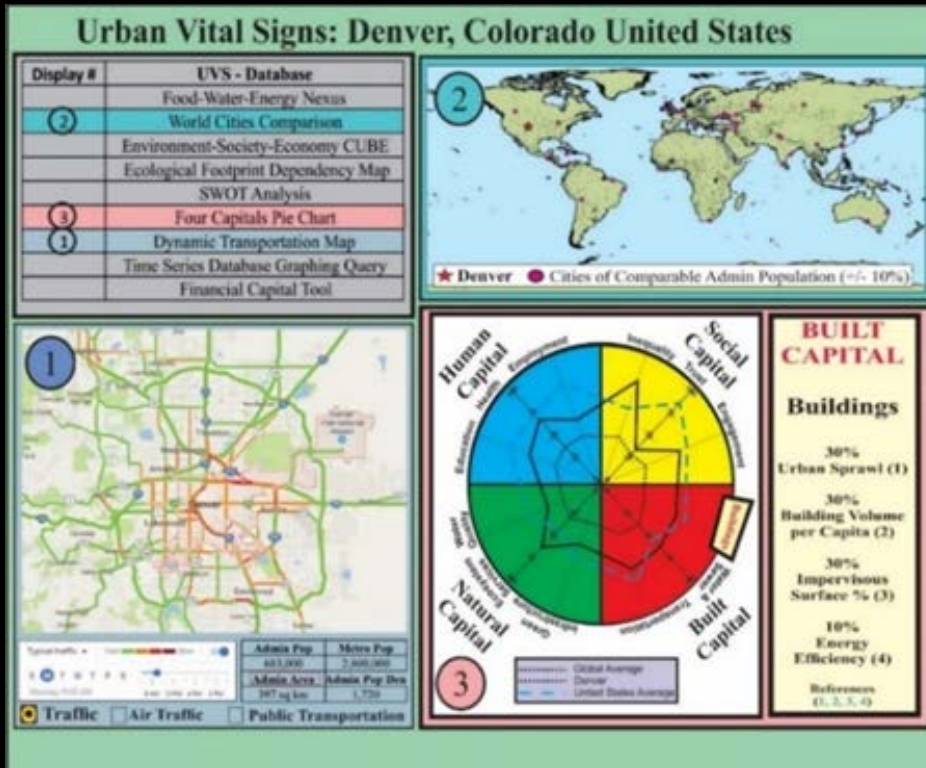
SUGI FWE Proposal to Belmont Forum & Urban Europe

Urban Definitions 'Key'
-Draws from GHSL

Global City Viewer
FWE Nexus Data Module
Environment-Society-Economy CUBE Module
Ecological Footprint Dependency Assessment
Four Capitals Interaction Module
Financial Capital Module
Dynamic Transportation Map Module

UVSGD Partners
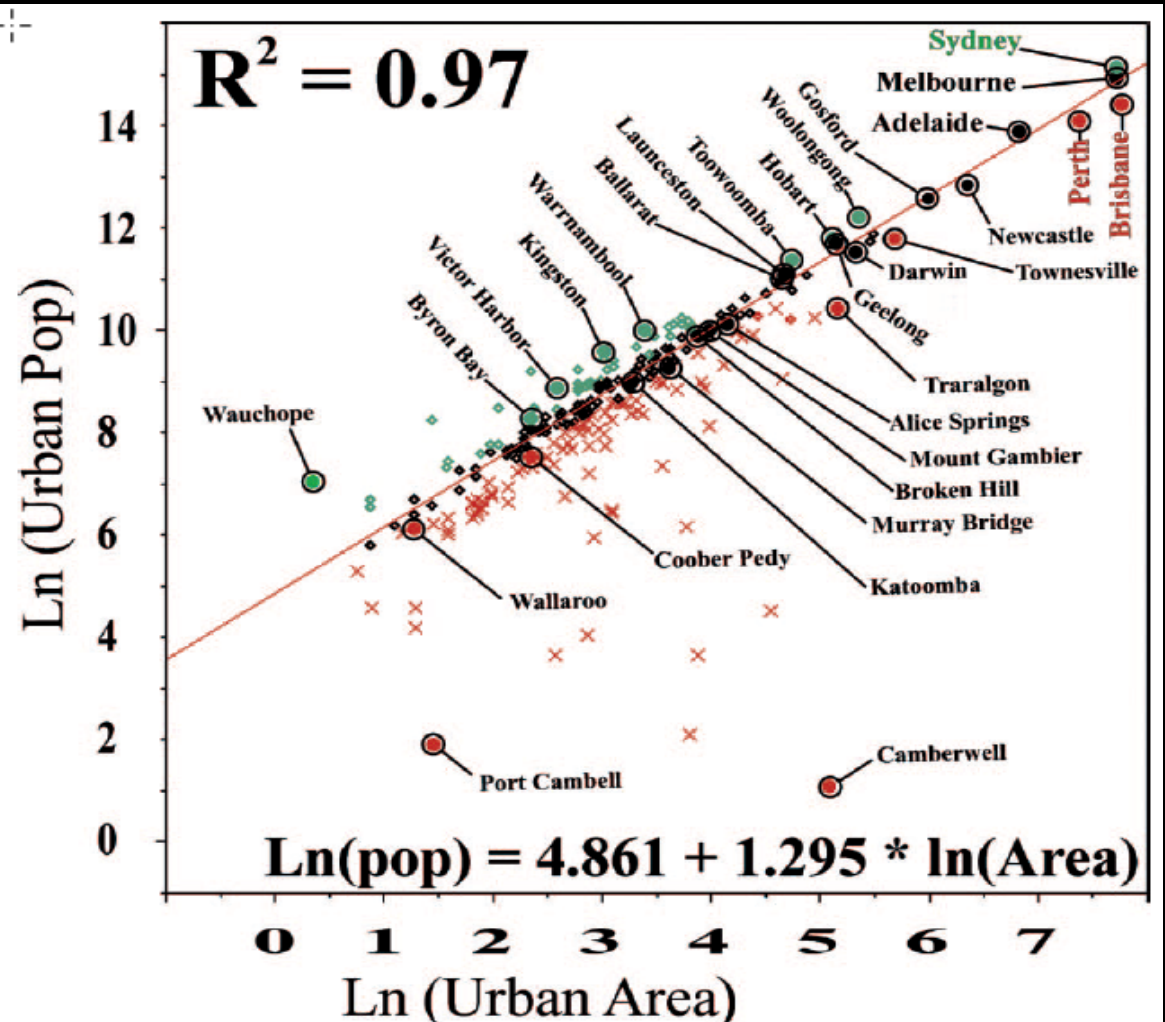## (providing a suite of sustainability perspectives)

1) **ICLEI – Local Governments for Sustainability** (outreach)
2) **Stockholm Resilience Center** (planetary boundaries)
3) **Global Footprint Network** (urban hinterland dependence)
4) **University of Leeds** (Human well-being & Social Justice)
5) **ODI Leeds** (Social Justice and Dashboard Development)
6) **Universidade Paulista** (Tradeoff visualization)
7) **Hamburg University of Applied Sciences** ('Fake Data')
8) **University of Denver** (synthesis & database development)
9) **Earth Observation Group (NOAA)** (NTL & GDP modeling)
10) **FEWSnet (USGS)** (food security)
11) **Center for Innovative Governance (South Africa)** (equity)
12) **School of Natural and Built Envts (UniSA)** (mass flow modeling)

Three Sample Metrics follow:
1) Scale Dependent Measure of Urban Sprawl
2) Ecological Footprint Dependency Mapping
3) SDGs, HDI, & Per Capita Eco-Footprints

A Scale Dependent Measure of Urban Sprawl For cities of Australia

$R^2 = 0.97$

Ln (Urban Pop)

Sydney
Melbourne
Adelaide
Gosford
Woolongong
Perth
Brisbane
Launceston
Toowoomba
Hobart
Warrnambool
Ballarat
Newcastle
Darwin
Townesville
Victor Harbor
Kingston
Geelong
Byron Bay
Traralgon
Wauchope
Alice Springs
Mount Gambier
Broken Hill
Murray Bridge
Coober Pedy
Katoomba
Wallaroo
Camberwell
Port Cambell

$Ln(pop) = 4.861 + 1.295 * ln(Area)$

Ln (Urban Area)

City name	Actual population	Areal extent (km²)	Sprawl line population	Sprawl index
Sydney	3,760,490	2,258	2,841,313	32
Melbourne	3,042,890	2,245	2,818,879	8
Brisbane	1,852,350	2,346	2,985,309	−38
Perth	1,318,010	1,596	1,813,558	−27
Adelaide	1,062,100	917	886,191	20

Urban Hinterland Dependency:
The Ecological Footprint of Adelaide, South Australia

Adelaide				
Total Pop "Metro"	**Urban Core Pop**	**Urban Pop (not core)**	**Exurban Pop**	**Exurban Area (km^2)**
1,160,510	1,062,100	14,441	83,969	2,982
Total Area (km^2)	**Urban Area (km^2)**	**Urban Pop Den**	**Exurban Pop Den**	**Sprawl Score**
3,981	999	1,078	28	20
Cropland Demand (km2)	**Grazeland Demand (km2)**	**Forest Demand (km2)**	**Carbon Demand (km2)**	**Fish Demand (km2)**
18,568	12,766	13,926	31,334	1,161
99 km Radius	226 km Radius	241 km Radius	299 km Radius	19 km Radius

According the Global Footprint Network the average Australian
Requires the following quantities of land to support their life:

1.4 ha Cropland, 1.1 ha Grazing land, 1.2 ha Forest, 2.7 ha for CO_2 absorption, and 0.1 ha of Ocean for Fish
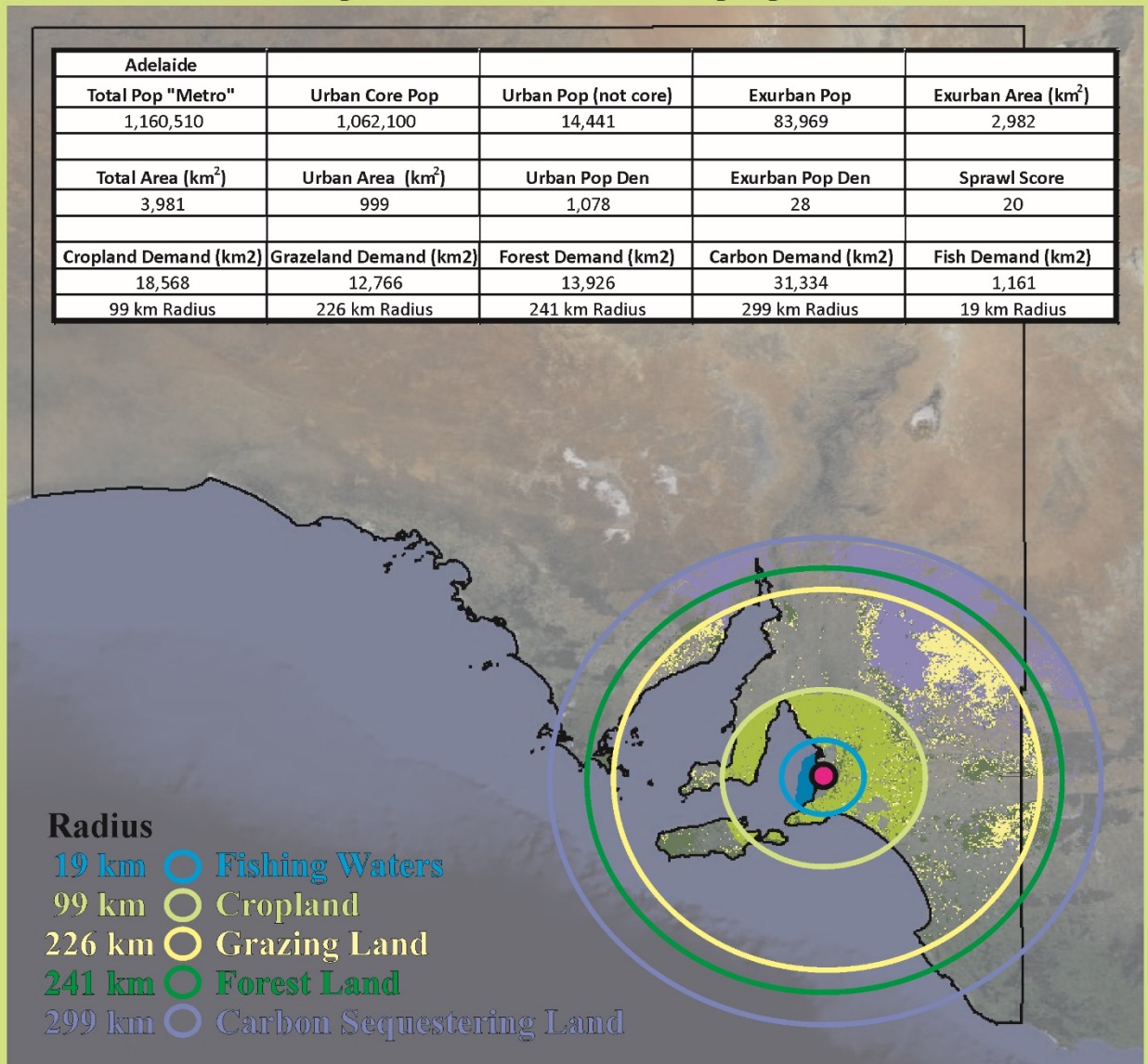
The urban hinterland footprint dependency of Sydney, Australia

| SYDNEY				
Total Pop "Metro"	**Urban Core Pop**	**Urban Pop (not core)**	**Exurban Pop**	**Exurban Area (km^2)**
5,137,760	3,760,490	1,000,750	376,520	9,232
Total Area (km^2)	**Urban Area (km^2)**	**Urban Pop Den**	**Exurban Pop Den**	**Sprawl Score**
13,501	4,269	1,115	41	32
Cropland Demand (km2)	**Grazeland Demand (km2)**	**Forest Demand (km2)**	**Carbon Demand (km2)**	**Water Demand (km2)**
82,204	56,515	61,653	138,720	5,138
337 km Radius	417 km Radius	226 km Radius	818 km Radius	87 km Radius
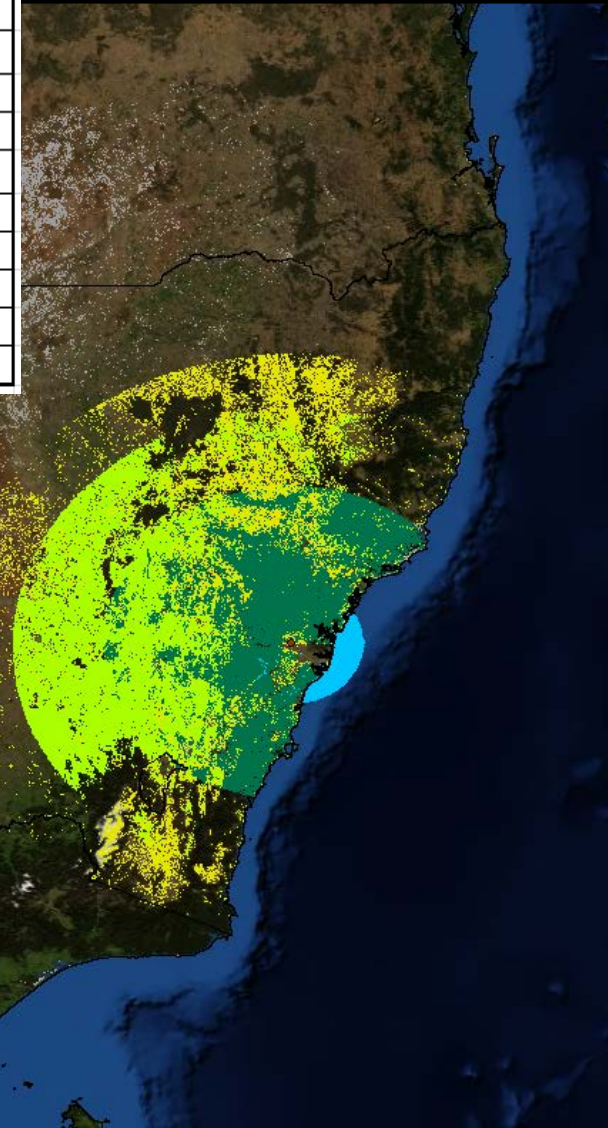
Note:
This analysis
Based on a
'Metro'
Population of
Sydney
That includes
many surrounding
Towns and cities.
~5.1 million
in the year 2000

Remember Adelaide? That '*Big Country Town*'

SDGs, HDI, & Ecological Footprint Oh My!
(note there are no countries in the Global Sustainable Development Quadrant)

Ecological Footprint per Person and HDI of Nations with SDG-I Ranking
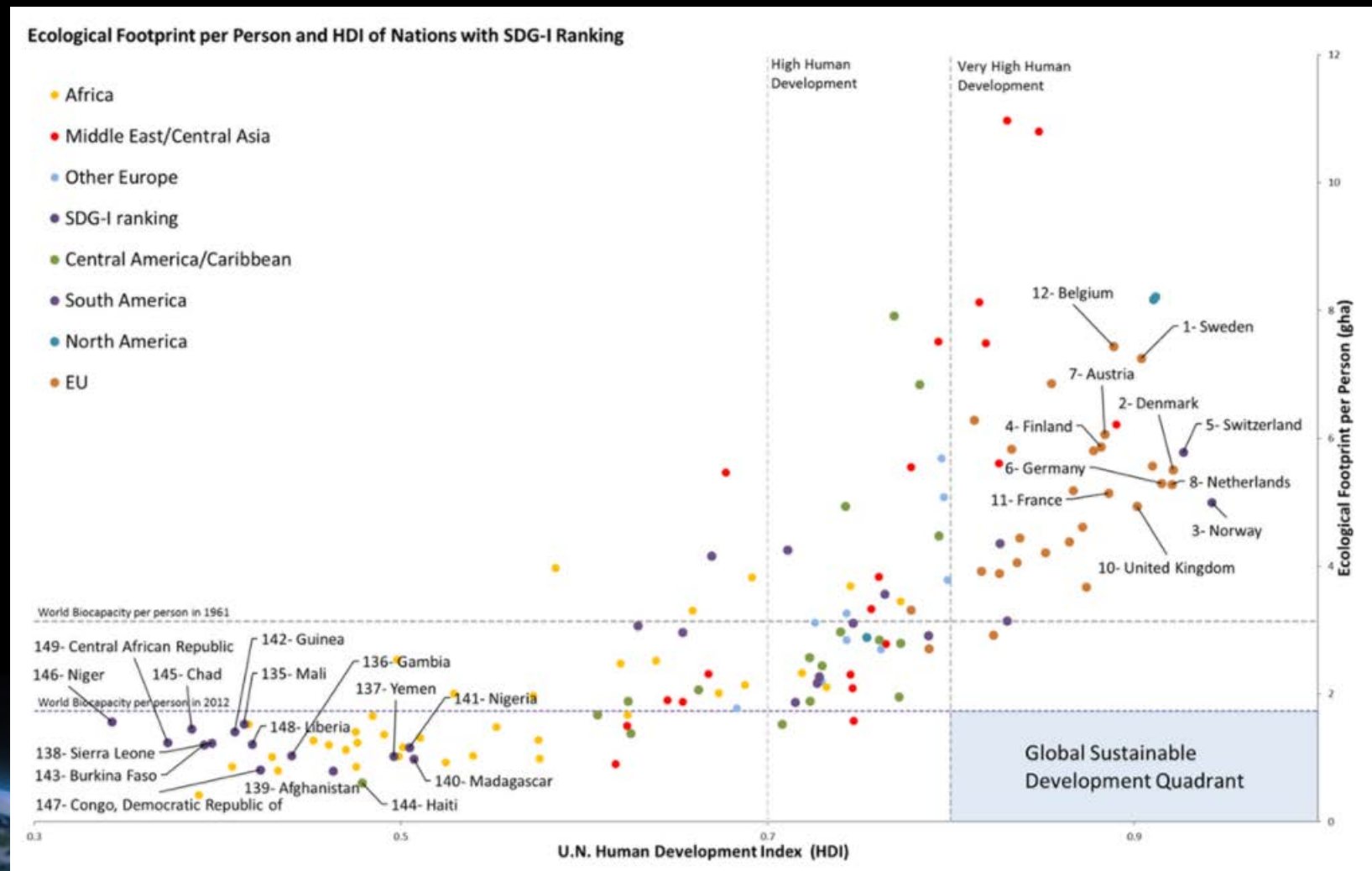
Applying these measures to the world's cities will likely show same national patterns

What is the contribution of UVSGD?

"A history of disassociation of biodiversity, ecosystems, and urban development alongside a belief in technological solutions gave rise to a logic of urban planning that made it possible to imagine that the governance of urban life could be separated from the provision of food, water and other ecosystem services on which all human life depends. As a result, urban areas today are both more tightly coupled to their ecological hinterlands than ever before and yet it is difficult for urban residents and their representatives to manage urbanization sustainably." (Seto & Elmqvist, 2013)

Guiding Principles of UVSGD

1) Grounded in bio-physical reality (SDGs & GFN)
2) Committed to social justice ('Veil of Ignorance')
3) Innovative Data Provenance and Curation
4) 'Apples to Apples' comparisons in space & time

Discussion Questions

1) Does the idea of finding simple '*apples to apples*' proxy measures of urban metabolism seem viable? (e.g. Sprawl, Green Infrastructure indices, Building volume/capita, Eco-Footprints, Traffic Flows, etc.)

2) What are the obstacles to developing the UVSGD?

3) What are the obstacles to getting stakeholders to embrace the UVSGD?

4) Ideas for additional metrics or indices?

5) Other comments and/or suggestions?