Sustainable Groundwater Management towards SDGs

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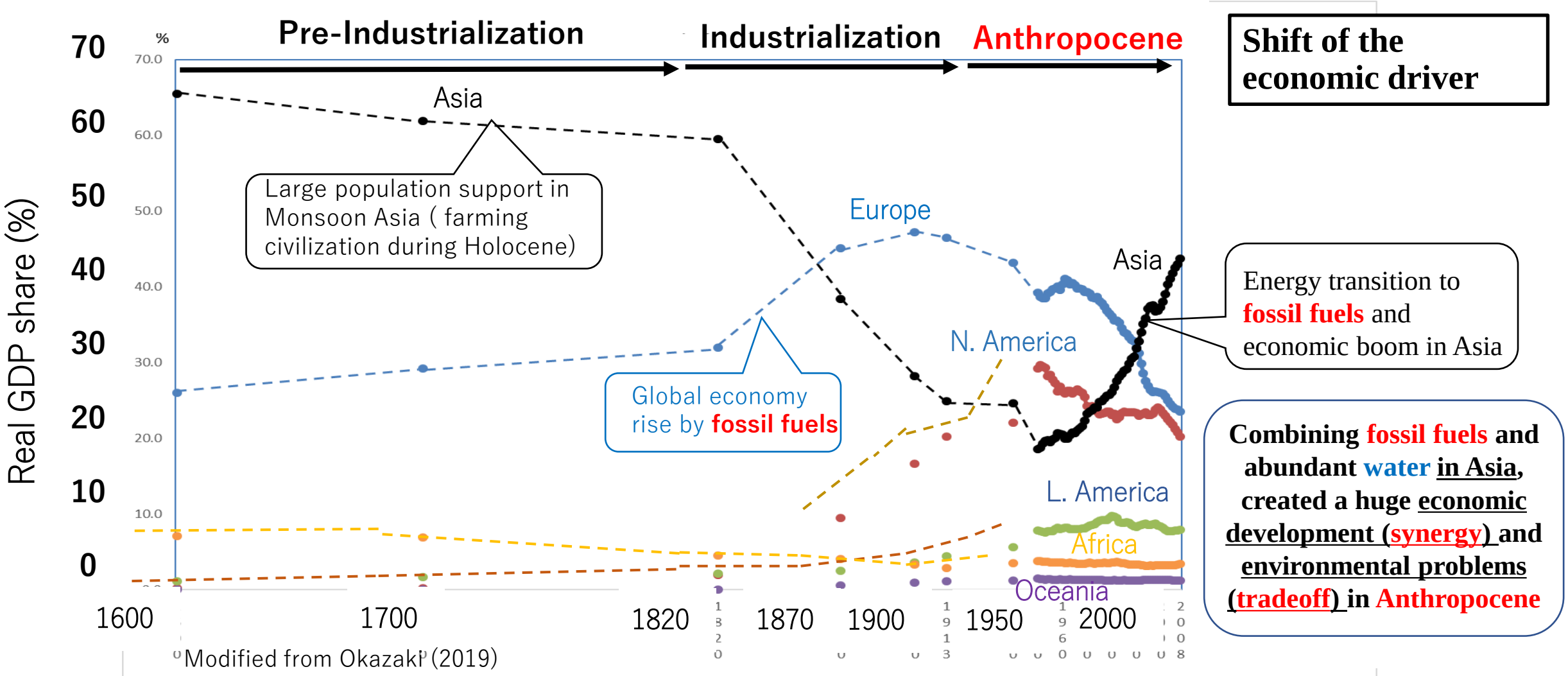
(1) Industrialization & Nexus (Water-Energy)



Shift of the economic driver

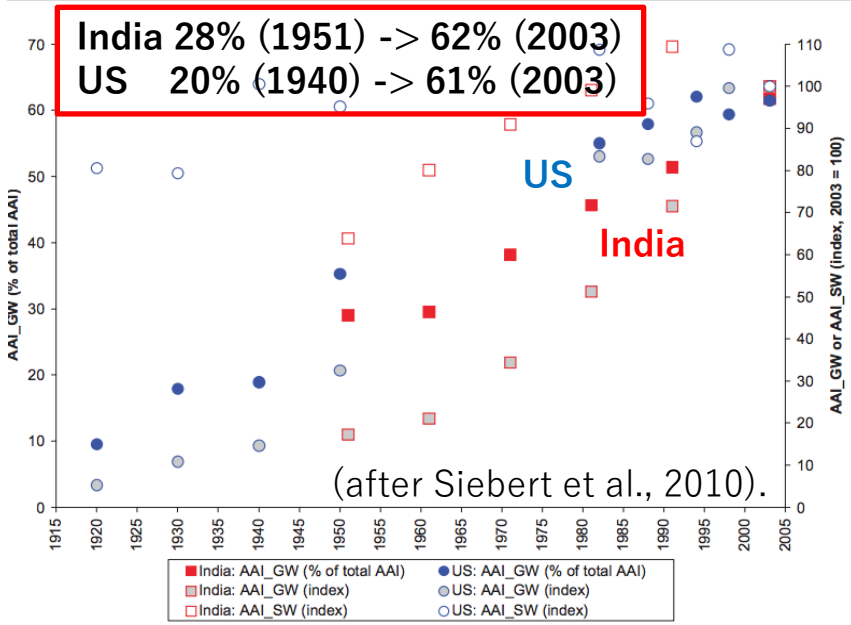
Energy transition to **fossil fuels** and economic boom in Asia

Combining fossil fuels and abundant water in Asia, created a huge economic development (synergy) and environmental problems (tradeoff) in Anthropocene

(2) Green revolution & Nexus (Water-Food)

HB →Chem. fertilizer ⇧ →Food production ⇧ → Water consumption ⇧

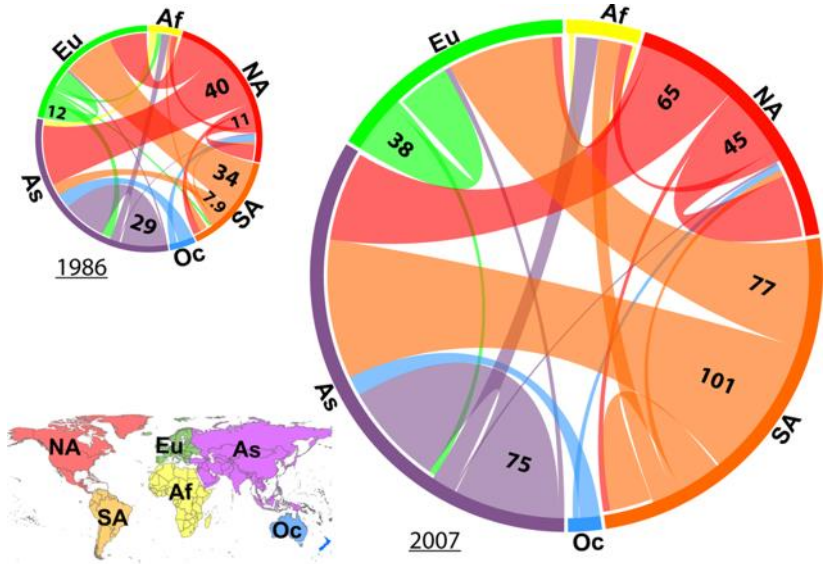
Increase of GW irrigation for food production during Anthropocene



- **70%** of human freshwater consumption is through **agriculture**,
- Increase in groundwater consumption for irrigation in **Anthropocene**

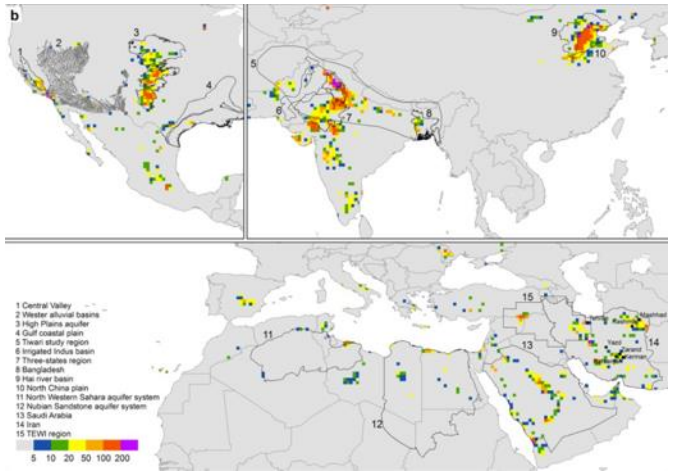
Acceleration of GW depletion

-12.6 billion ton/year (1960) → **-28.3** billion ton/year (2000)



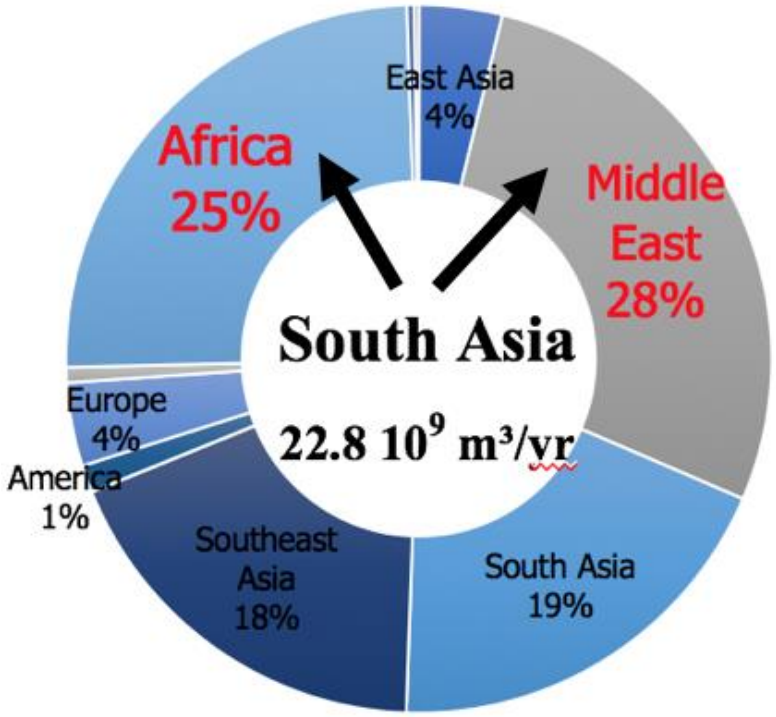
Virtual groundwater flow through global food trade

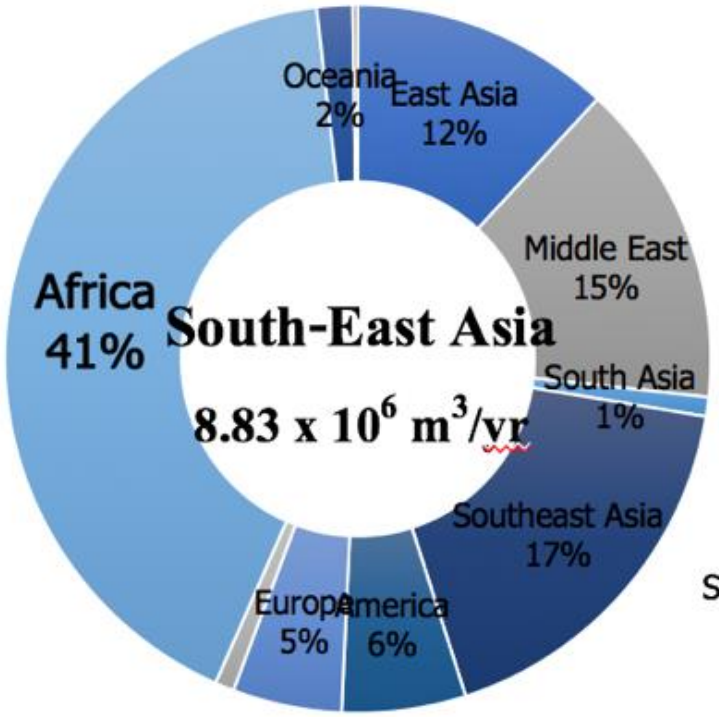
(Dallin, Taniguchi, Green, *Global Sustainability, 2020*)

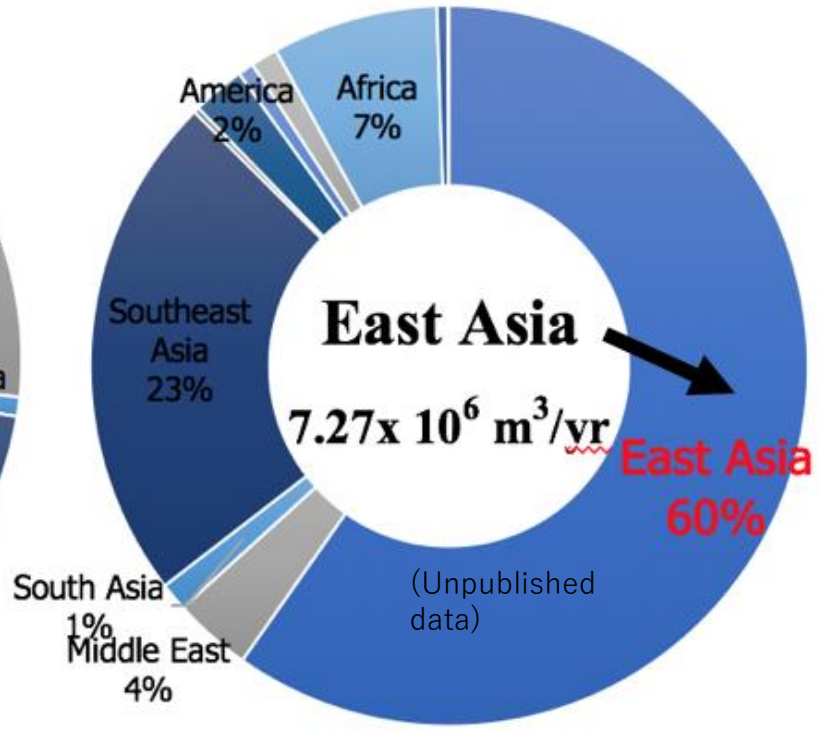


GW depletion (mm/y)
(1980-2009, Döll *et al*. (2014))

Virtual water export via food trade from sub-region in Asia



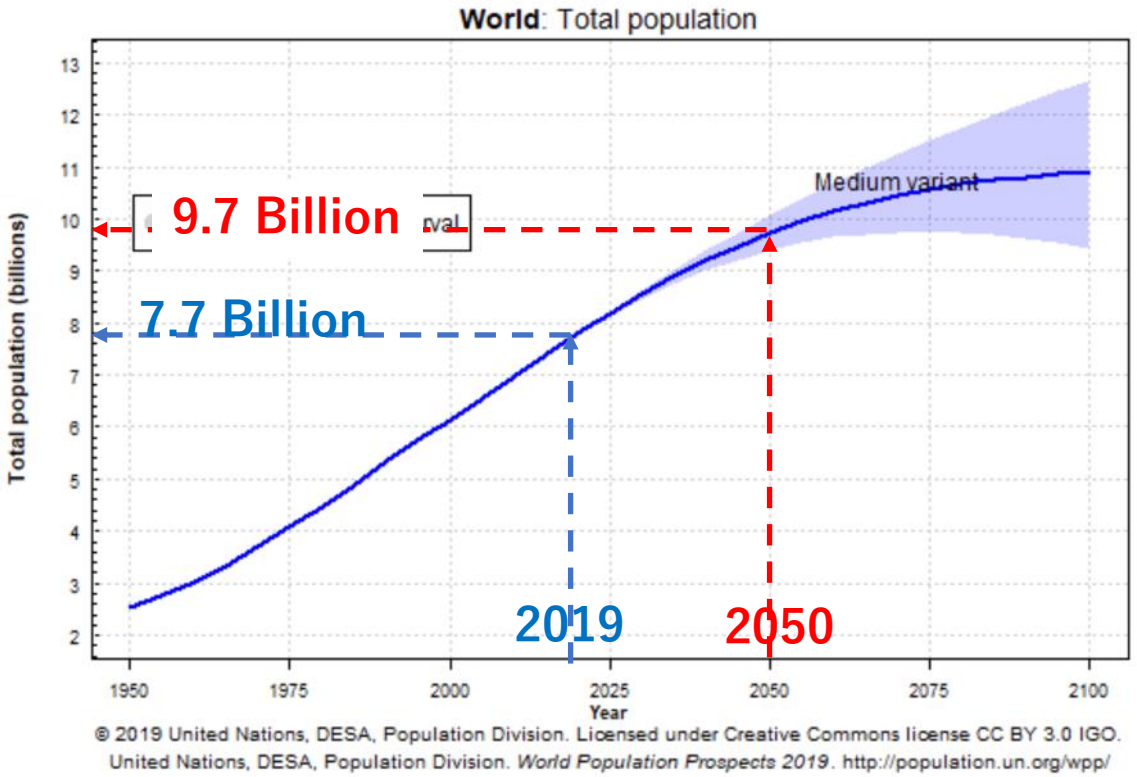




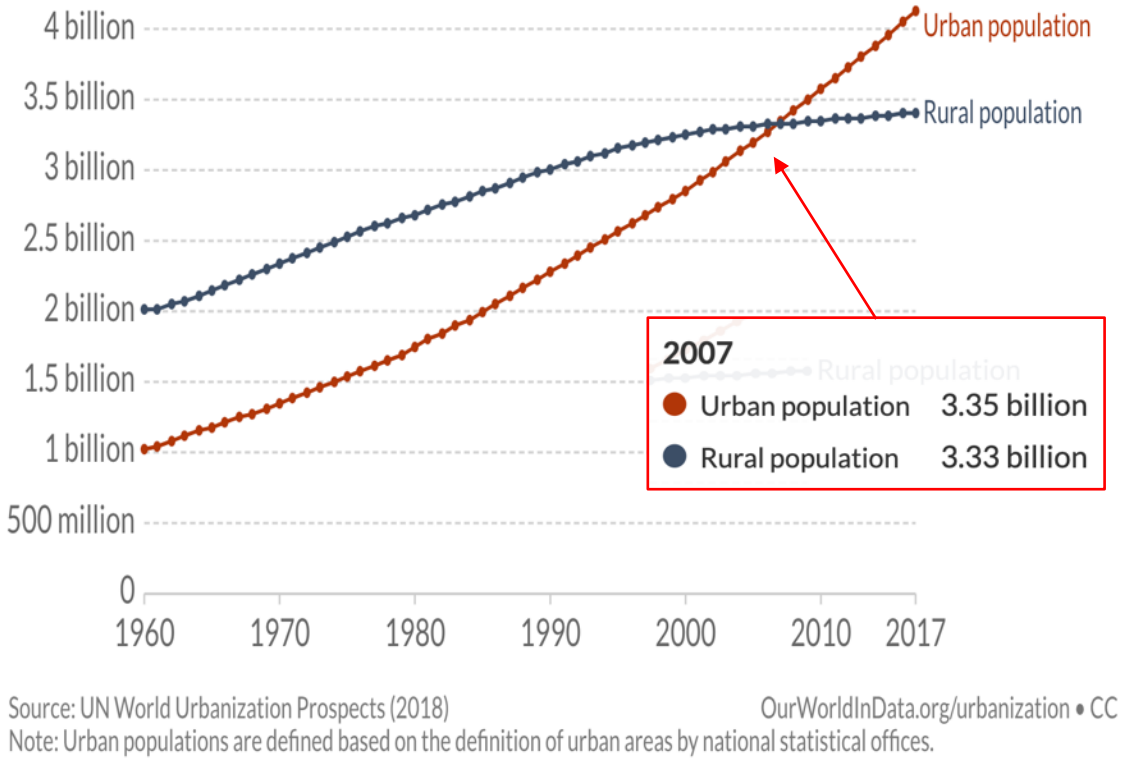
- "**Footprints**" which can visualize the tele-connection and internalize the external environment, are good tools for analyzing multi-scale stewardship and sustainability.
- Resources (food, water, energy, etc.) and environment are connected, and should be governed by integrated manner

(3) **Urbanization** & Water-Energy-Food **Nexus**

World Population ↑



Urbanization ↑



Population in Urban

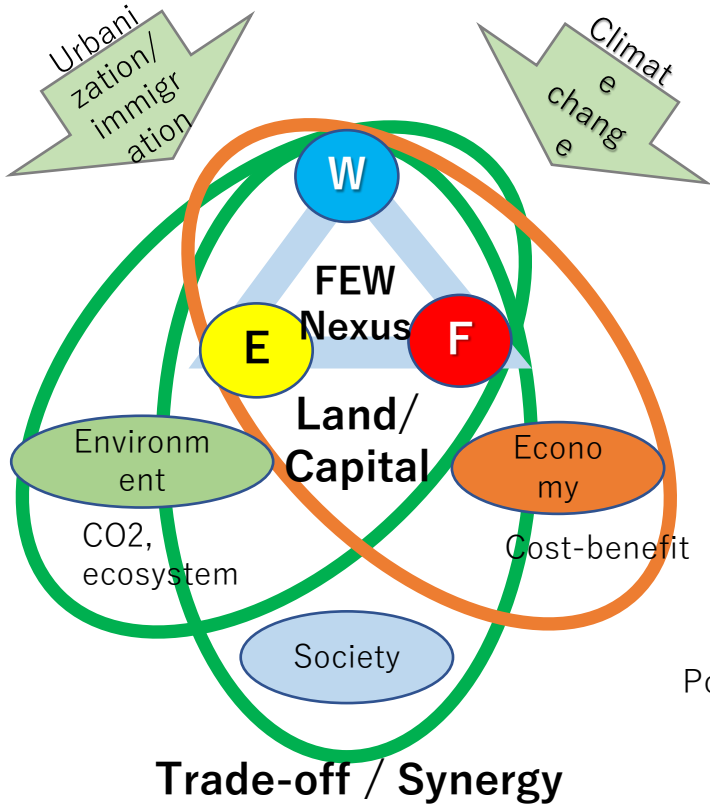
30 % at 1950

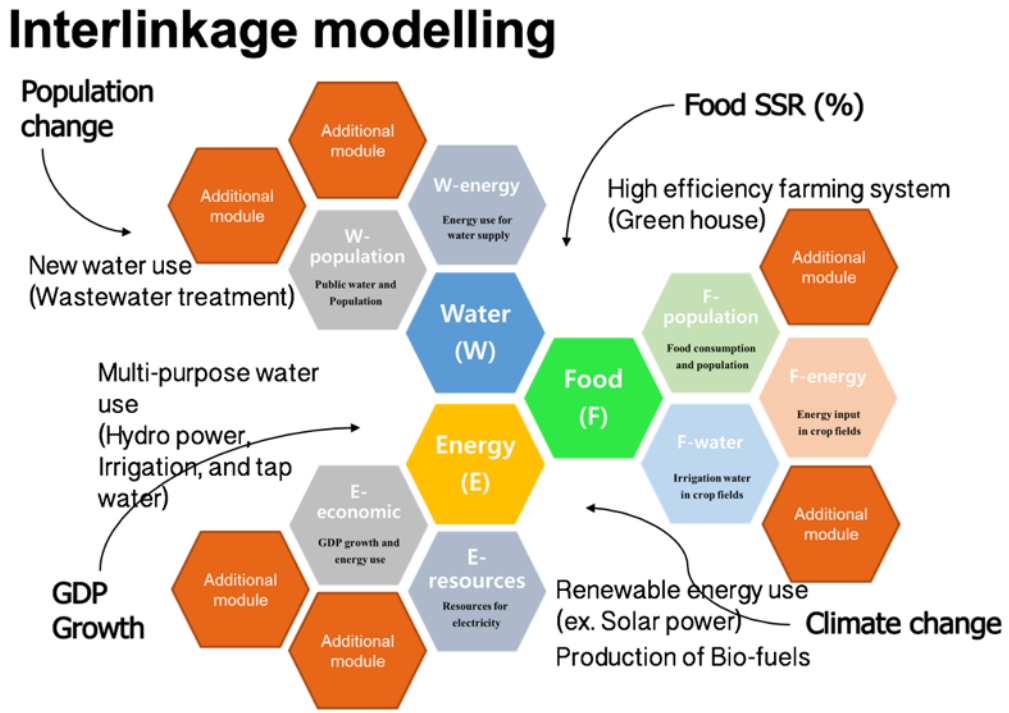
68 % at 2050

Belmont Forum projects "Sustainable Urbanization Global Initiative: Food-Water-Energy Nexus"

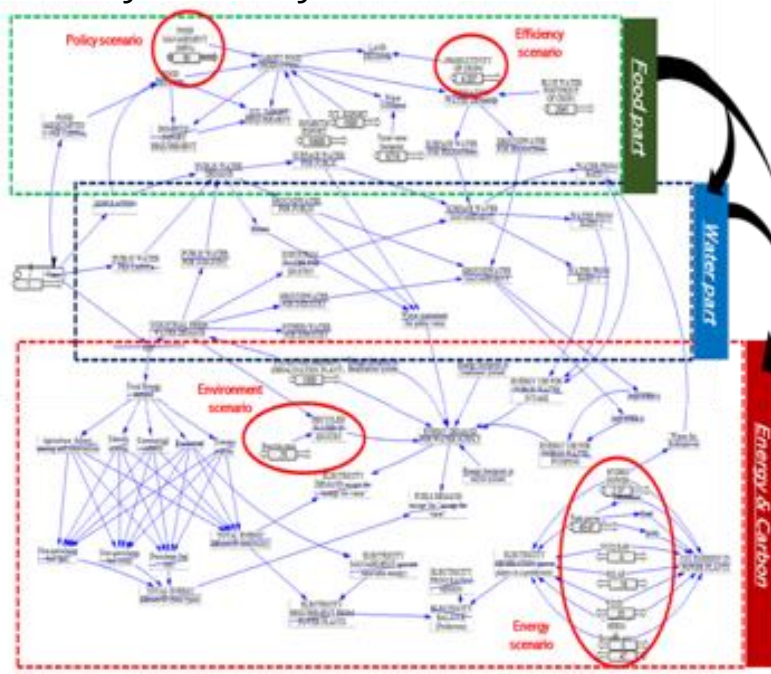
Intelligent Urban Metabolic Systems for Green Cities of Tomorrow: an FWE Nexus-based Approach (2018-2021)

Taipei	Chicago
F. Chang	L. Rodriguez
Kyoto	**Sao Paulo**
M. Taniguchi	J. Filho

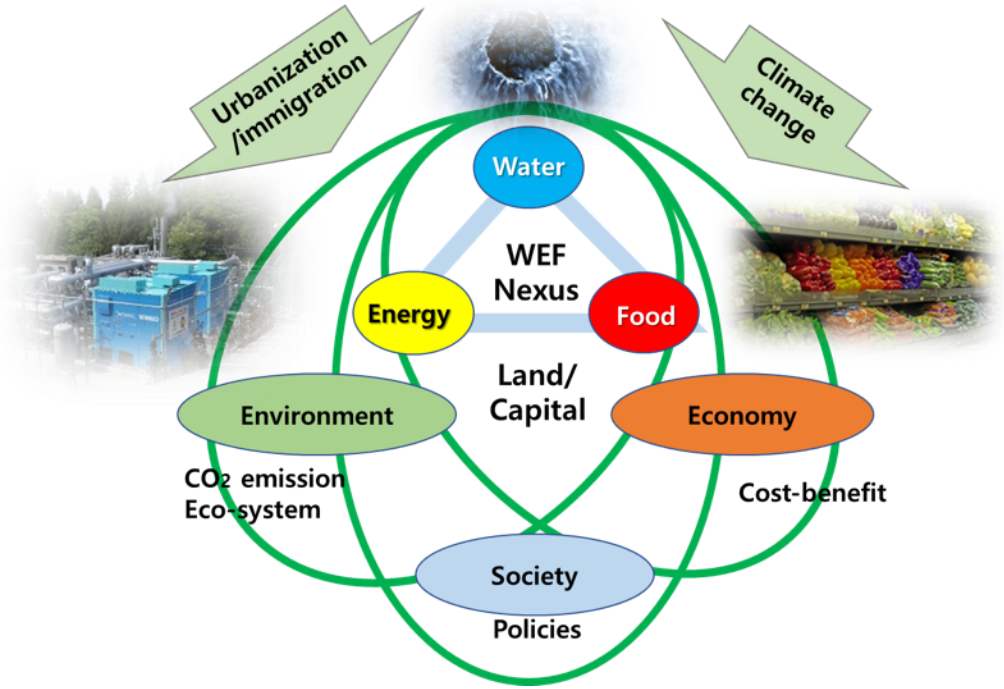




System dynamic model



Nexus Approach
for system dynamic



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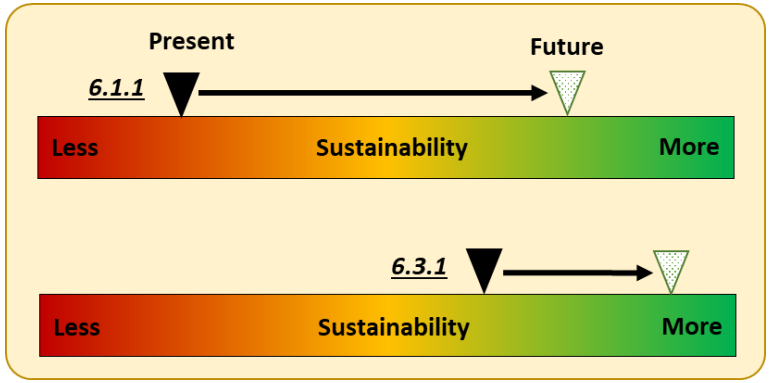
SDGs
for goals and scenarios

Tradeoff and synergy between:

- Resources (water, energy, food, land, etc.)
- Society, Economy, Environment
- Local, National, Global
- Past, Present, Future

SDGs indicators



Disconnection of governances/institutions

Conservation vs Development

Ministry of Environment ⟷ Ministry of Economy, Trade and Industry

Consumption vs Production

Consumption of resources ⟷ Production of resources

Water

Ministry of Land, Infrastructure and Transport

Energy

Food

Ministry of Economy, Trade and Industry ⟷ Ministry of Agriculture, Forest and fishery

New Comers

*Hot spring power generation

*Micro hydropower

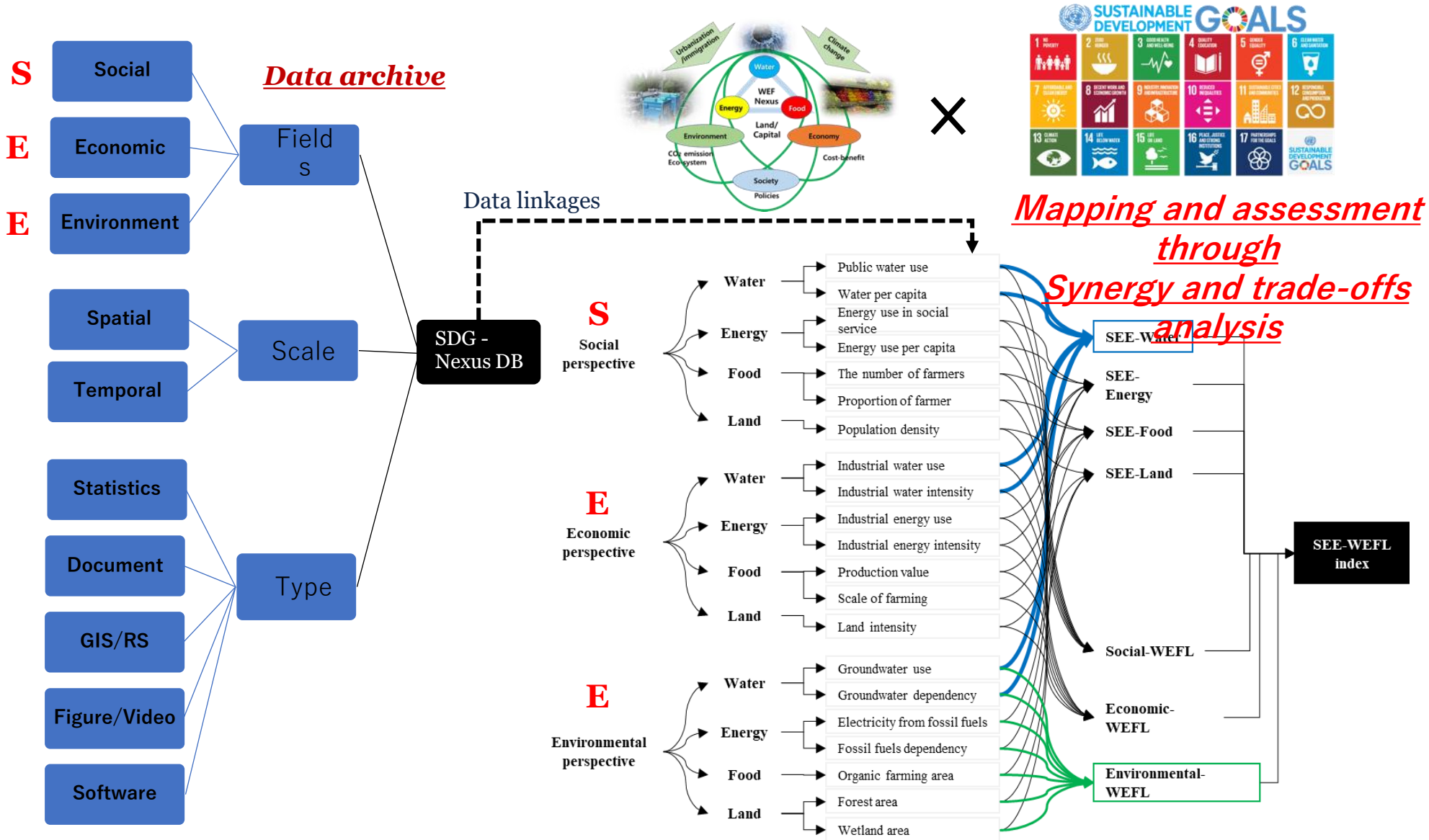
(Energy vs Water)

Global vs National vs Municipal

International bodies ⟷ Ministry ⟷ Municipal authority

A framework of SDGs-Nexus

SEE (Social, Economy, Environment) -WEFL (Water, Energy, Food, Land)



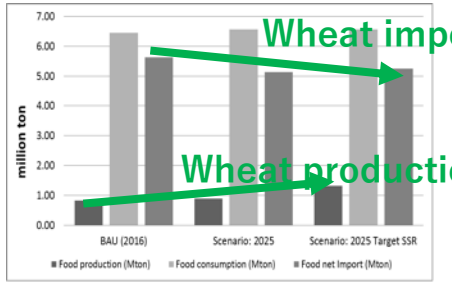
Water, Energy, Food, Land

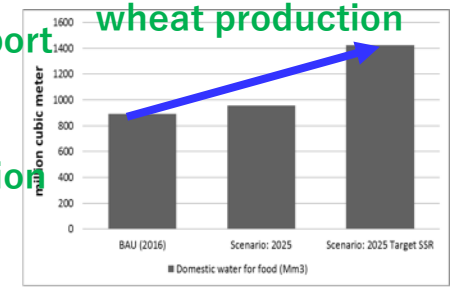
Lee, Taniguchi, Masuhara (Unpublished)

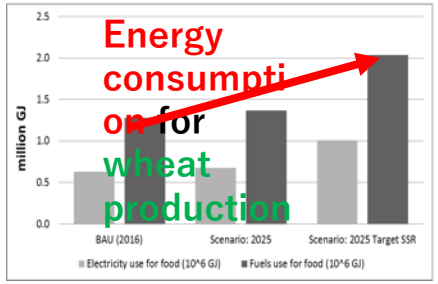
(4) Nexus analyses with scenarios

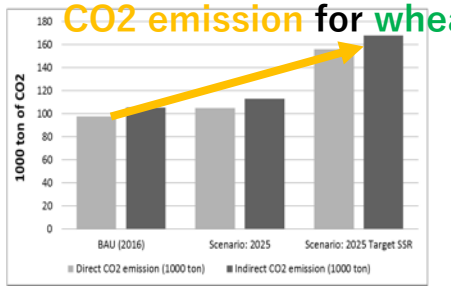
Food policy

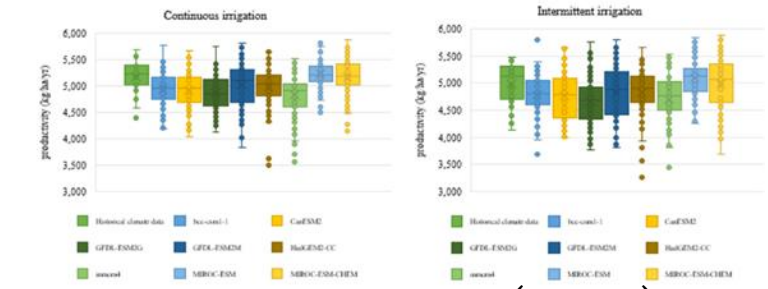
Variables (wheat)	Business as usual	Scenario 2025	Scenario: 2025 Target SSR
Food consumption	2016	2025	2025
Land use	2016	2025	2025
Target for food self-sufficiency (%)	13%	13%	20%



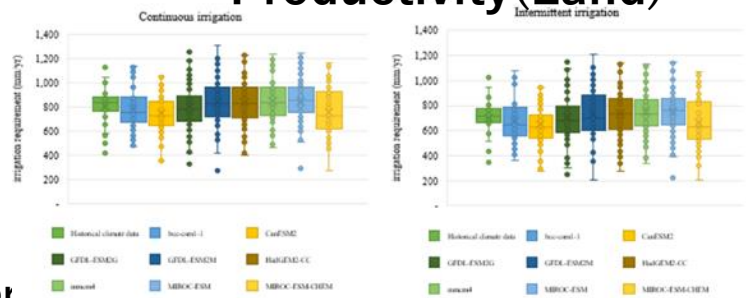




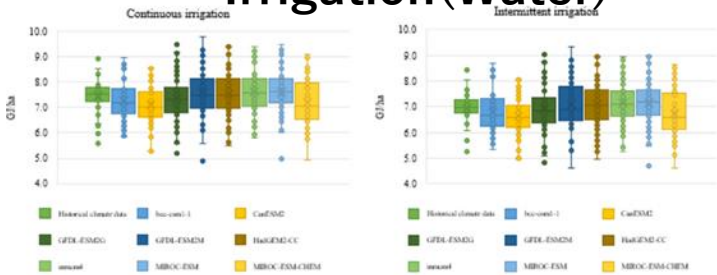




Productivity(Land)



Irrigation(Water)



Energy input

Continuous irrigation

Intermittent irrigation

8 GCMs

Climate change

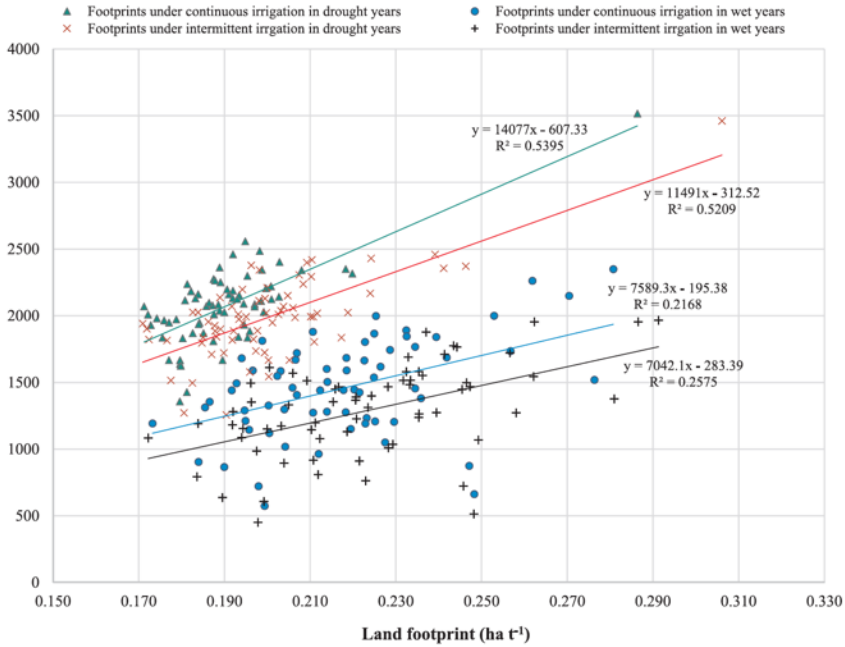


Fig. 6. Water and land footprints in the dry and wet season from eight GCMs during 2020 – 2099.

Water – Land footprint

(Lee et al, 2020)

△ continuous irrigation (drought)

X intermittent irrigation (drought)

○ continuous irrigation (wet)

＋ intermittent irrigation (wet)

SEE-WEFL SDGs-Nexus indicators

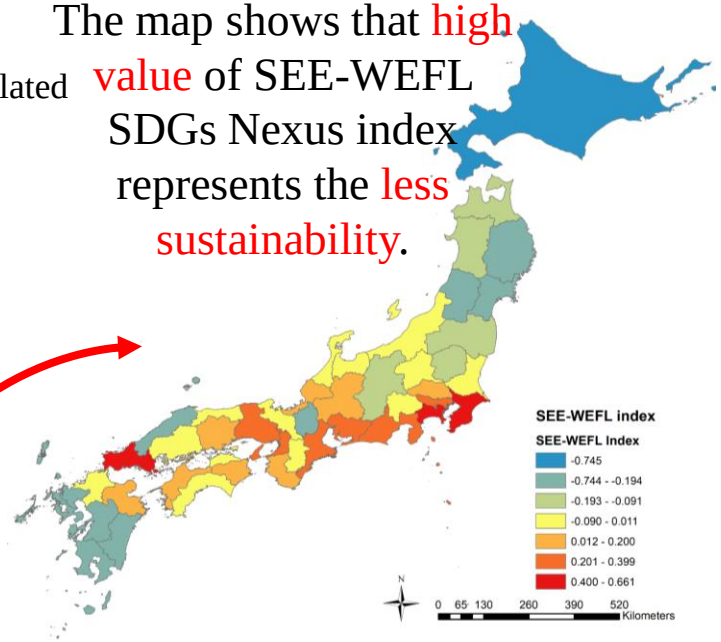
SEE (Social, Economy, Environment) -WEFL (Water, Energy, Food, Land)

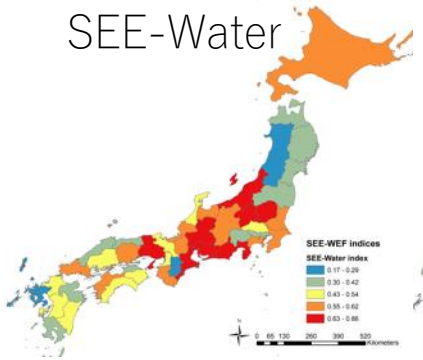
SEE-WEFL Nexus

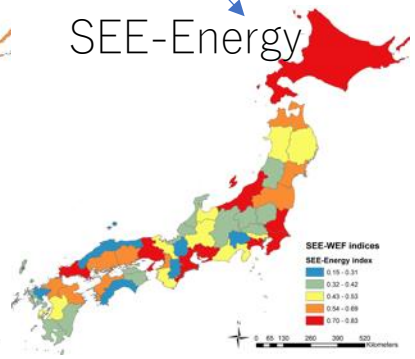
Step 1: The SEE-WEFL Nexus variables are identified,.
Step 2: Each value are normalized for SEE-WEFL Nexus index.
Step 3: The SEE-Water, SEE-Energy, SEE-Food, SEE-Land, and SEE-WEFL indices are calculated

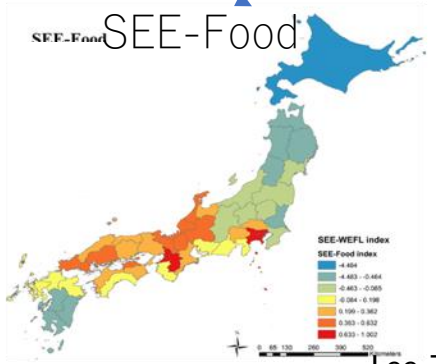
SEE-WEFL	Water		Energy		Food		Land		Indices
Social	Water use in social service	Water intensity in social service	Energy use in residential and transportation	Energy intensity in residential and transportation	Farming area per a farmer	The number and proportion of farmers	Population density		WEFL-Social index
Economic	Water use in industries	Water intensity in industries	Energy use in industries	Energy intensity in industries	Agricultural production (price) and farming area per a farmer	Farming area	Land intensity for economy		WEFL-Economic index
Environmental	Total use of groundwater	A ratio groundwater use in total water use	Electricity generation by fossil fuels	A ratio of fossil fuels in total electricity generation	Organic farm area		Area of forest area and wetland	Proportion of forest area	WEFL Environmental index
Indices	**SEE-Water index**		**SEE-Energy index**		**SEE-Food index**		**SEE-Land index**		**SEE-WEFL index**

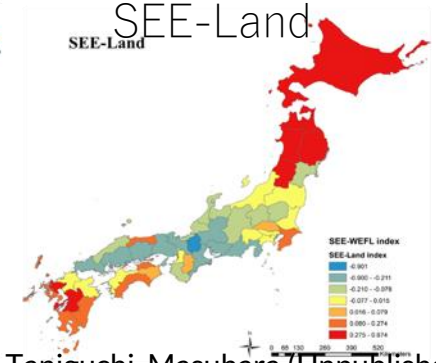
The map shows that high value of SEE-WEFL SDGs Nexus index represents the less sustainability.







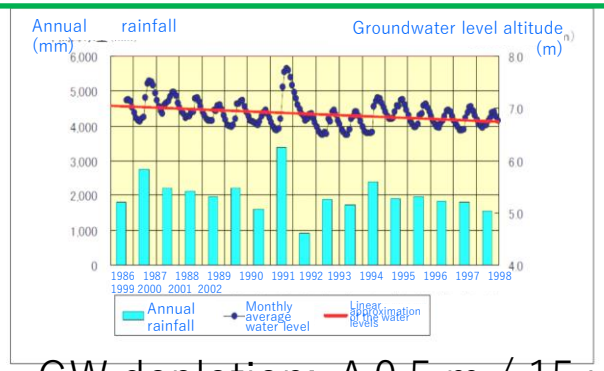




Lee, Taniguchi, Masuhara (Unpublished)

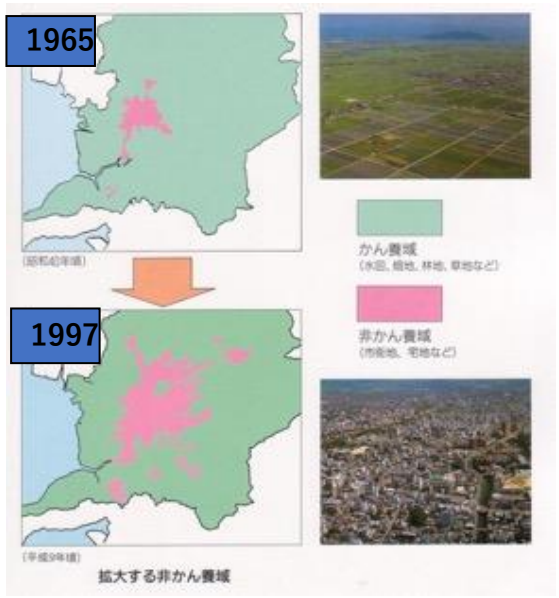
Recovery of lost synergy of water-energy-food nexus

Kumamoto city depends on 100 % of groundwater as water resources which is recharged at outside of the Kumamoto city



GW depletion: Δ0.5 m / 15 yr

(However GW pumping: Δ40 Mt/20yr)

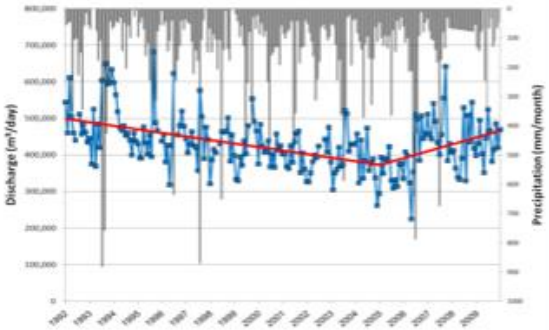


Increase in impermeable area (90→**230km²**) due to urbanization and unused paddy fields

→ **Decrease in GW recharge rate**

Transboundary governance

Kumamoto city pays subsidies to farmers who **put water** into their paddy fields outside of Kumamoto



Increase in GW level and discharge from Ezu Lake

✓ Nexus Synergy: Rice productions with groundwater recharge in upstream as well as groundwater use in downstream without any additional energy for water allocation.

Taniguchi et al. 2019, Frontiers in Env. Sci.

Multiscale Stewardship

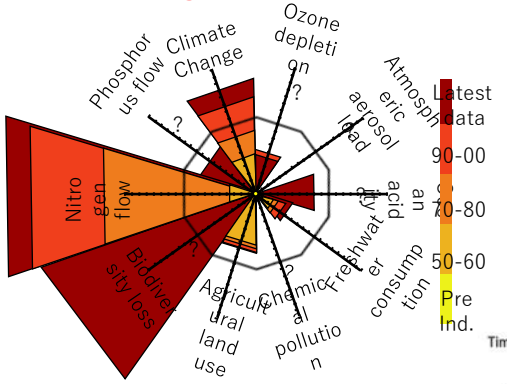
Global to local (Top down)
（Warning, Risk asses.）

Local to global (Bottom up)
(Trust/Ethic/Empathy)

Regional

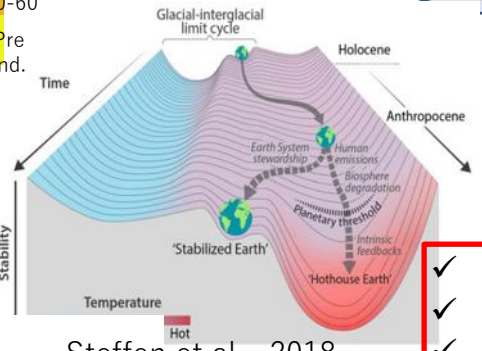
National

Planetary Boundaries



Rockström et al. (2009)

Hothouse Earth



Steffen et al. 2018

Multi-scale Stewardship
(e.g. SDGs-Nexus)

SDGs THE GLOBAL GOALS For Sustainable Development

- ✓ Trust
- ✓ Openness/Transparency
- ✓ Ethics (Fairness/ Equity/Justice)
- ✓ Sociality/Altruism/Empathy
- ✓ Humility/Recursive
- ✓ Tradeoff/Synergy
- ✓ Multi-scale connection & feedback/System dynamics
- ✓ Regime shift/Tipping points/Transformation

Taniguchi (2019)

Water-energy-food nexus serious game for multiscale stewardship

Summary

- Food and industrial materials/goods which consumes groundwater are globally traded, then distant areas and countries are indirectly connected with groundwater footprint. Therefore, groundwater issue is not only local but also global issue.
- For achieving the sustainable development goals (SDGs), it is important to manage groundwater as nexus, which connects direct and indirect, local and global, water-energy-food, and economy-environment-society.
- Increasing efficiency of groundwater use makes reduction of energy consumption, then it creates a synergy among water and energy for carbon neutrality and sustainable groundwater management.
- A good practice with synergy of nexus and transboundary governance of groundwater is important for achieving SDGs not only locally but also globally.