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# Groundwater-Energy-Food Nexus

## Conflict between groundwater use for energy and fishery production

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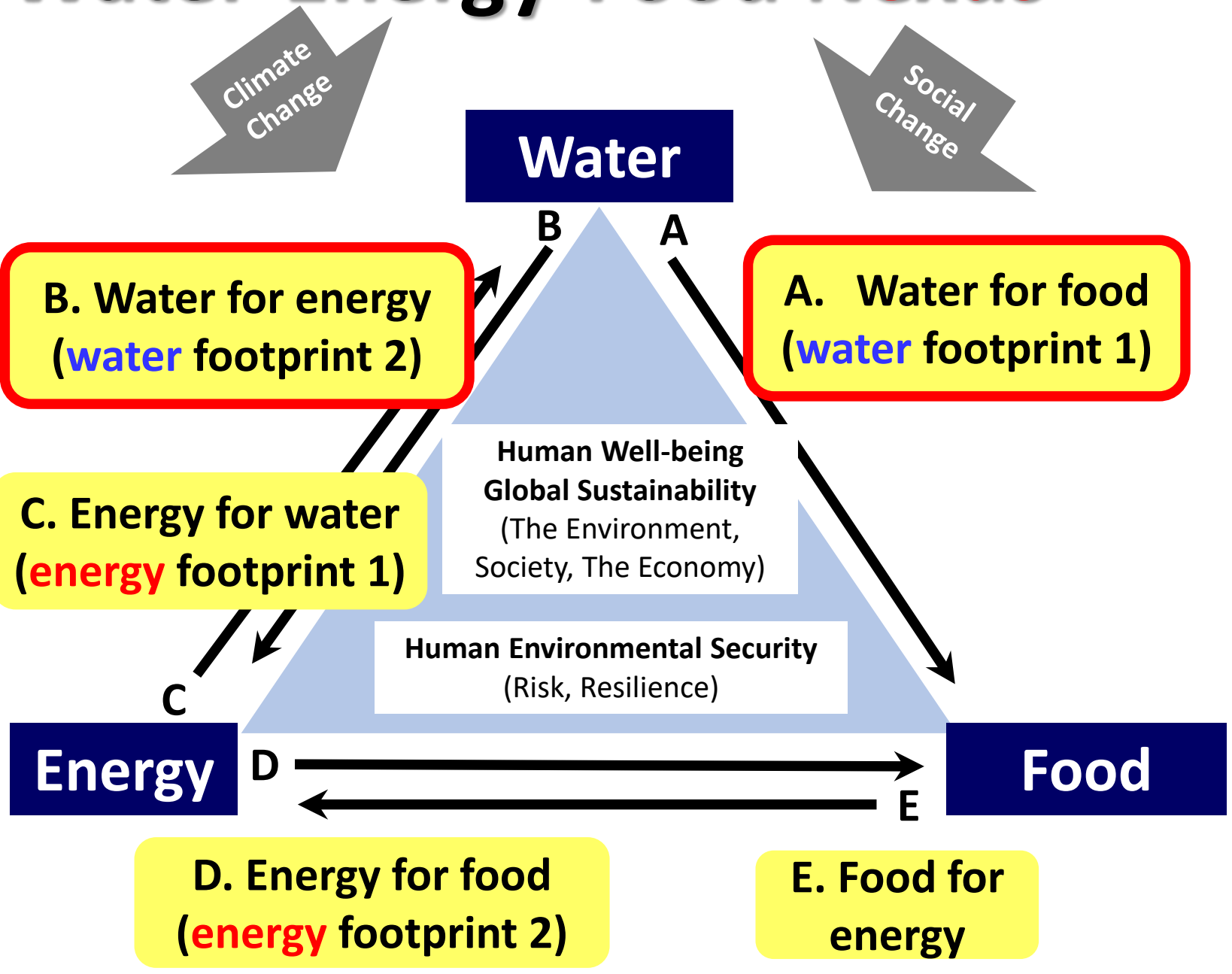
# Water-Energy-Food Nexus




## Background

Increase pressure on water, energy & food resources presenting communities with increased levels of tradeoffs and potential conflicts

Demands for water, energy & food are estimated to increase by 40%, 50% and 35% by 2030

## Purpose

**Design optimal policy to increase human-environmental security within the complexity of water-energy-food nexus system**

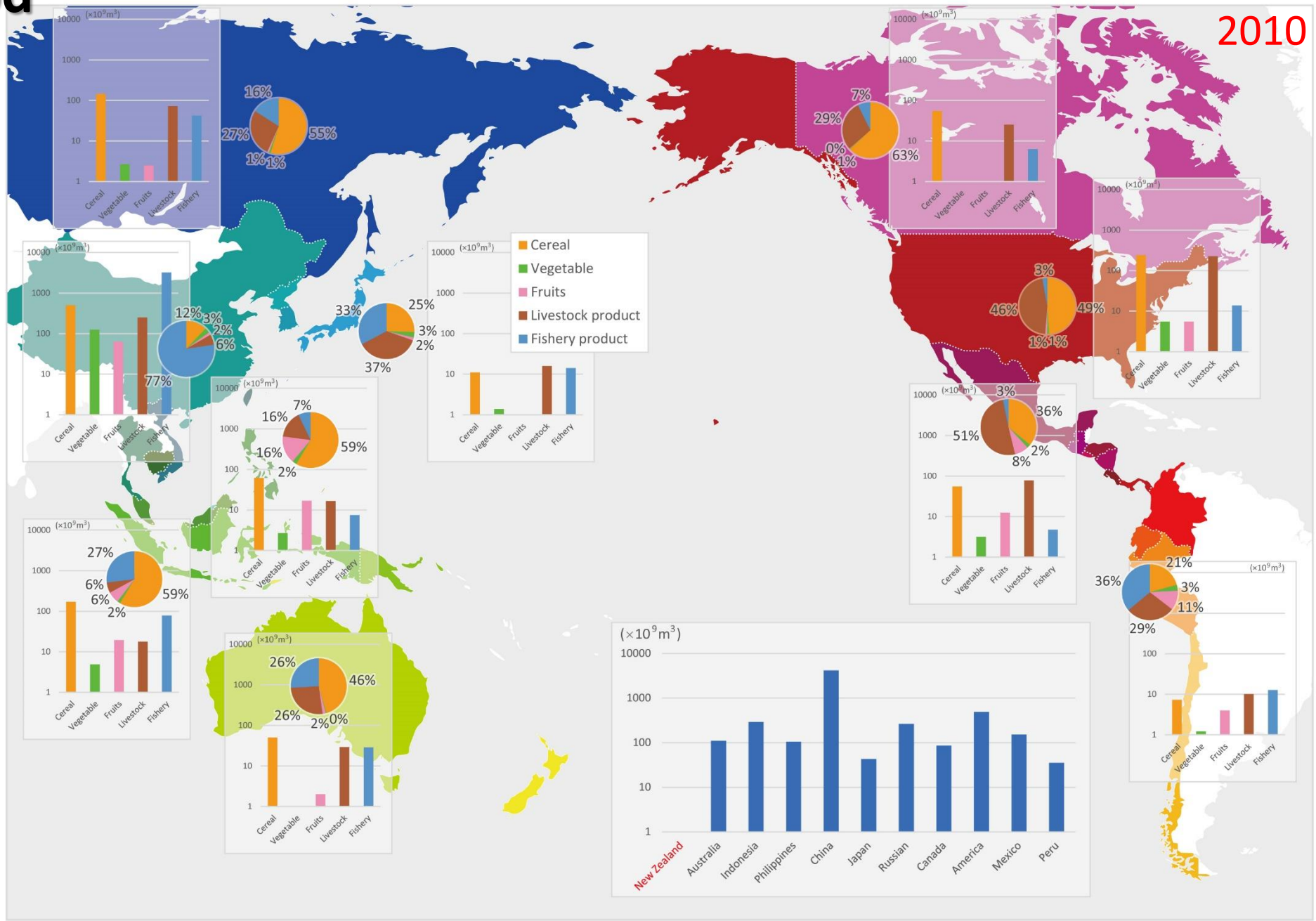
# A. Water for Food (water footprint)

Water consumption for food production as;

1) Cereal
2) Vegetable
3) Fruits
4) Livestock
5) Fishery

* Largest water use for food production is China, followed by US

* Large portion of water use for fishery are China, Peru, Japan, Indonesia.




Taniguchi et al (Submitted)

# B. Water for Energy (water footprint)

Water use for cooling system of
1) thermal power plant
2) Nuclear power plant
and
3) Hydro power plant

* Largest water use for energy production is US, followed by China

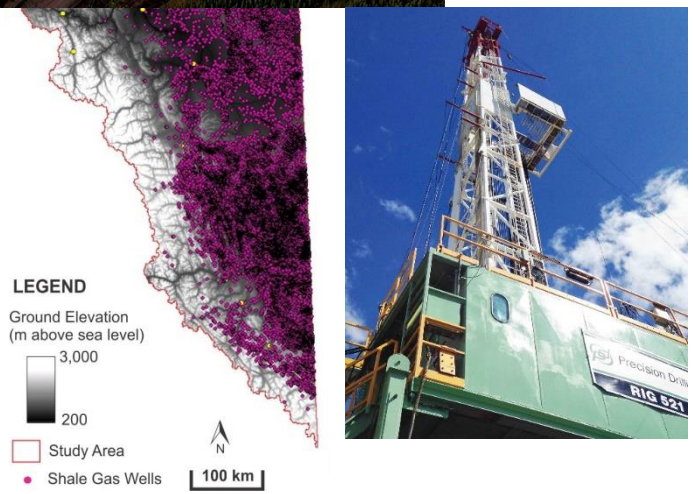
* Large portion of water use for hydropower are in New Zealand (41%), Canada (33%), and Peru (32%)


Taniguchi et al (Submitted)

# Water footprint for energy production

**How much energy is possible to produce per kg of water?**

## Shale gas NE BC (Canada)



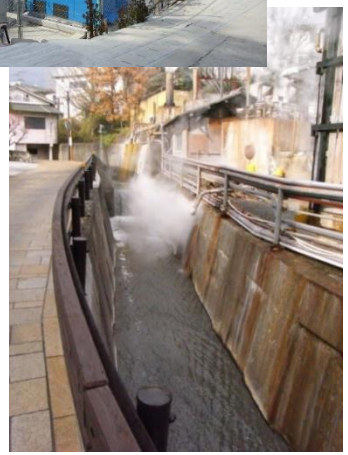

Fracking water in Montney Basin

2.79 million $m^3$/year

Gas production:18,946 million $m^3$/y

**66,000** kcal/kg-water

## Hot spring power generation in Beppu (Japan)

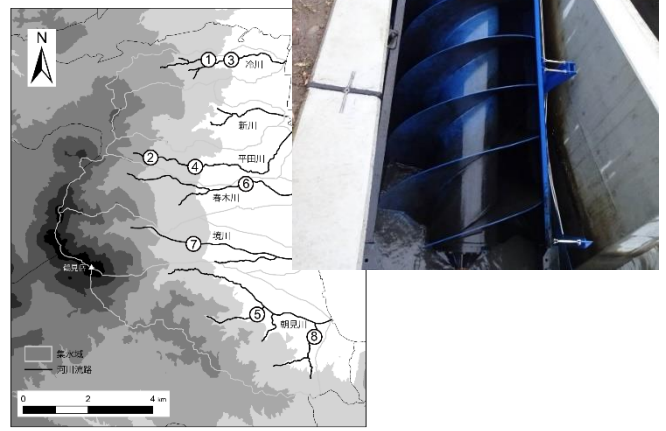


Energy production: 8,000kW

Hot spring water discharge

**16.3** kcal/kg-water

## micro hydropower plant in Beppu (Japan)






Energy production : 93 kW

River discharge : 1.1 $m^3$/s

**0.0164** kcal/kg-water

# Nexus

## 1) Consumption (Tradeoff)

There is a tradeoff between W-E-F Nexus

Ex. Shale gas extraction by fracking water:

Water cannot be used after fracking

## 2) Alteration (Interaction)

There is an interaction between W-E-F, however each resource does not be consumed but changed after producing other resources.

Ex. Water use for cooling power generator. Hot spring power generation:

Only water quality (temperature) is changed.

## 3) Linkage

There is a linkage between W-E-F, however each resource does not be consumed nor changed after producing other resources.

Ex. Hydropower generation

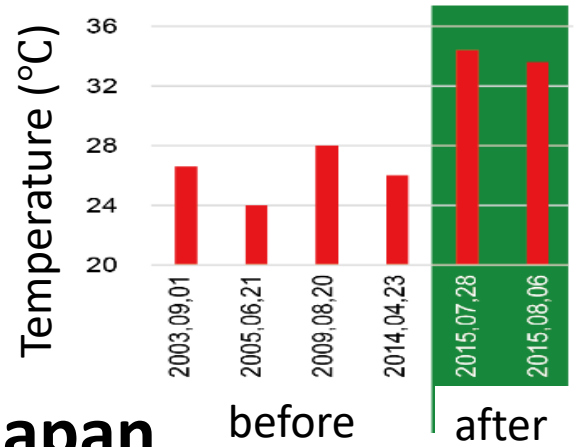
Neither water quantity and quality are not changed

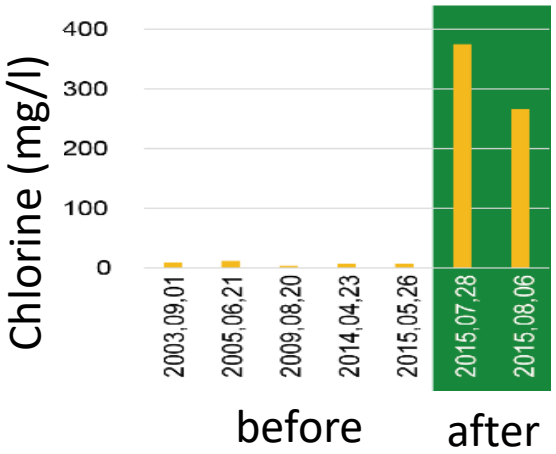
| Water for energy (Efficiency) | Environment Impacts |
|---|---|
| • Shale gas **66,000** kcal/kg−water | Water quality, impacts on ecology, CO2 emission ? |
| • Hot spring power generation **16.3** kcal/kg−water | Water quality, impacts on ecology |
| • Micro Hydropower **0.0164** kcal/kg−water | ? Impacts on ecology |

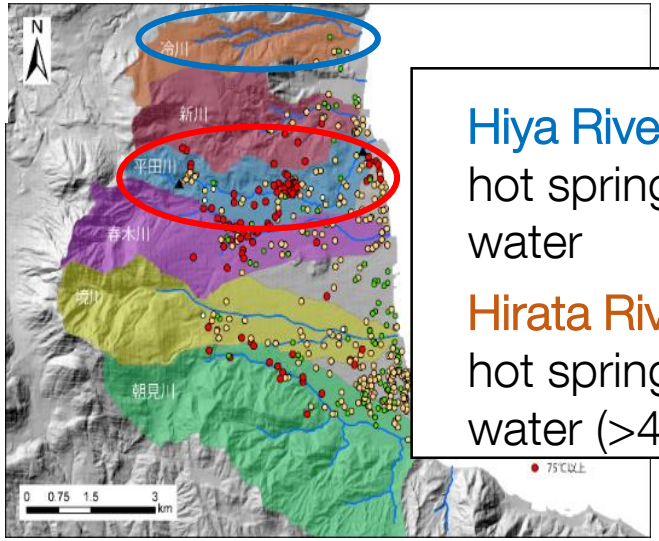
# GW-Energy nexus affects on ecosystem and fishery

Water temperature/ chlorine concentration in Haruki Riv.
before/after installation of electricity generation by hot spring water


**Beppu, Japan**




Hiya River :without hot spring waste water

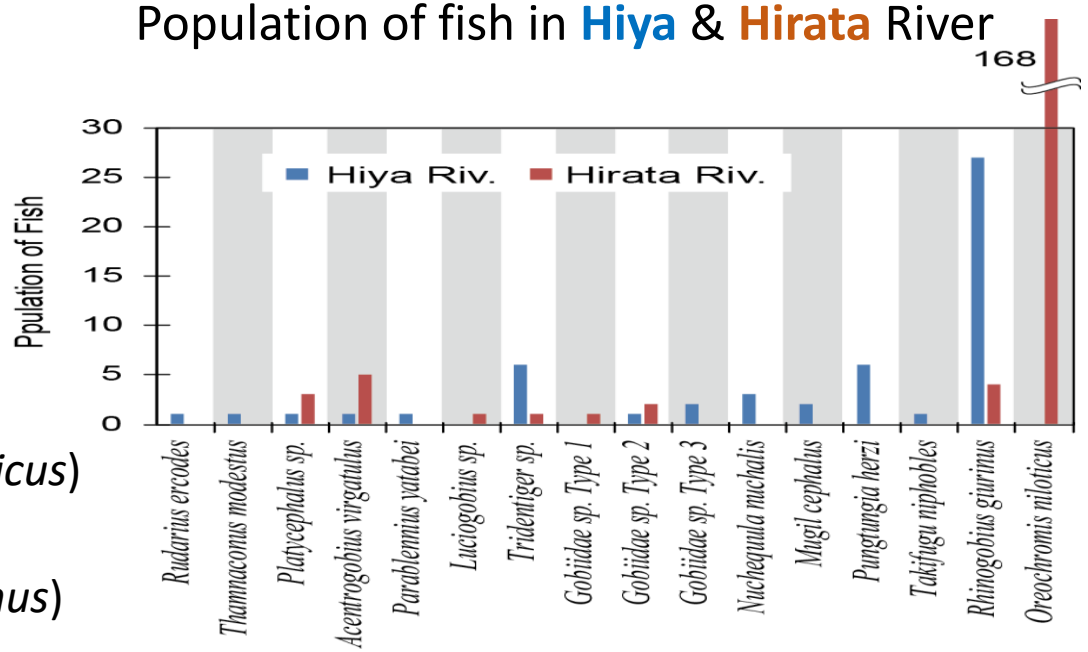
Hirata River : with hot spring waste water (>40℃)


Hot spring drainage creates a more suitable habitat for Nile Tilapia in Hirata river

**Hirata riv.** Nile Tilapia (*Oreochromis niloticus*)

**Hiya riv.** Barcheek Goby (*Rhinogobius giurinus*)

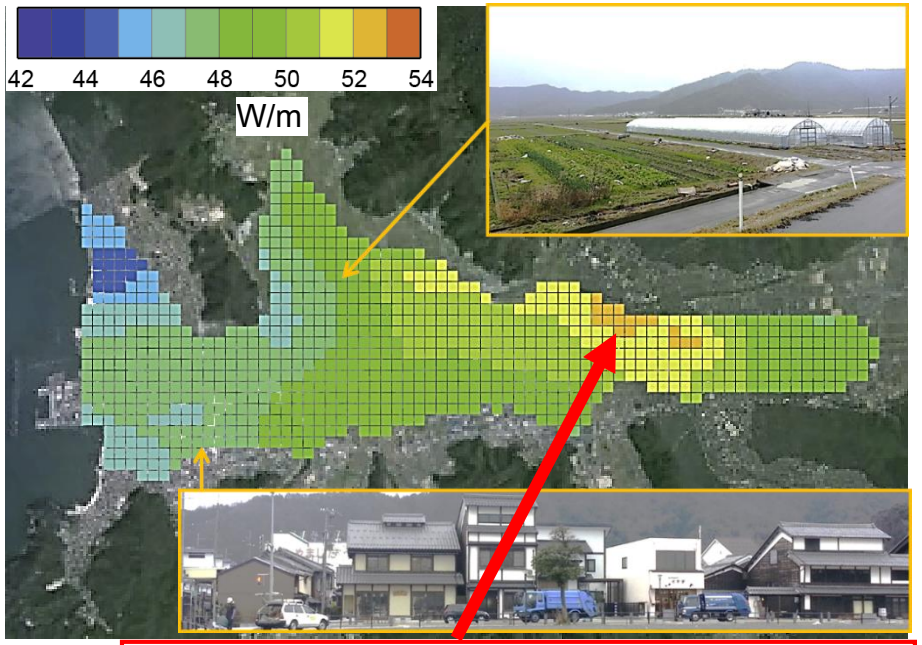
Population of fish in **Hiya** & **Hirata** River



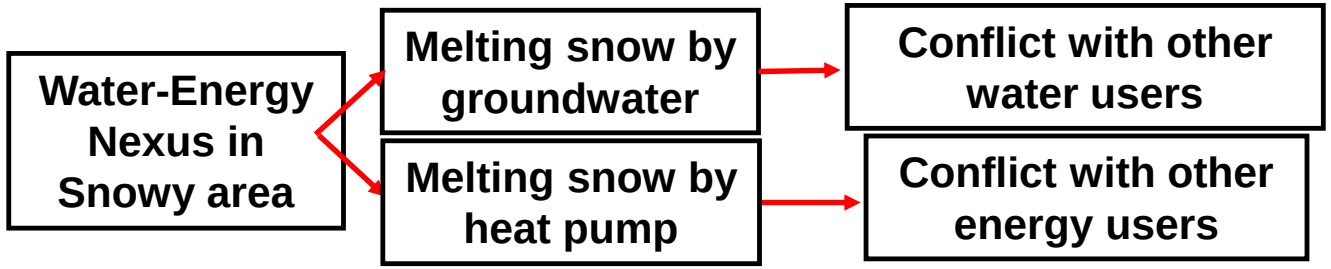
# Water-Energy Nexus affects on food (fishery) productions

## Obama, Japan


Snow-melting by groundwater

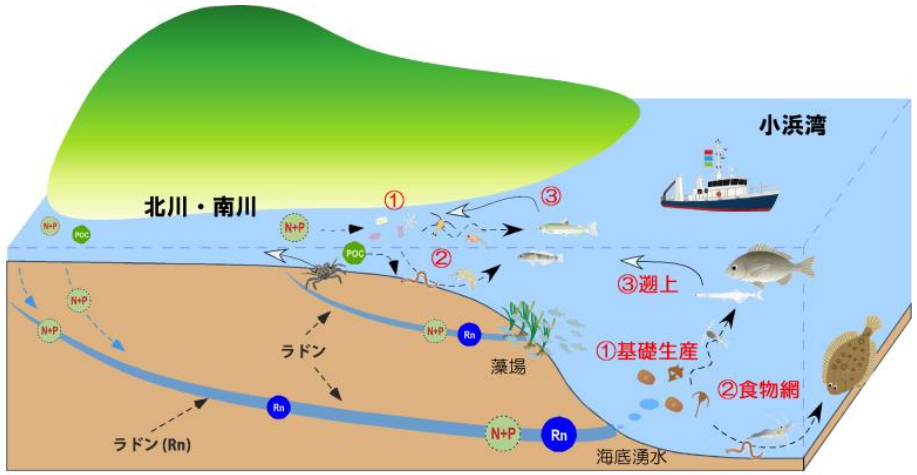


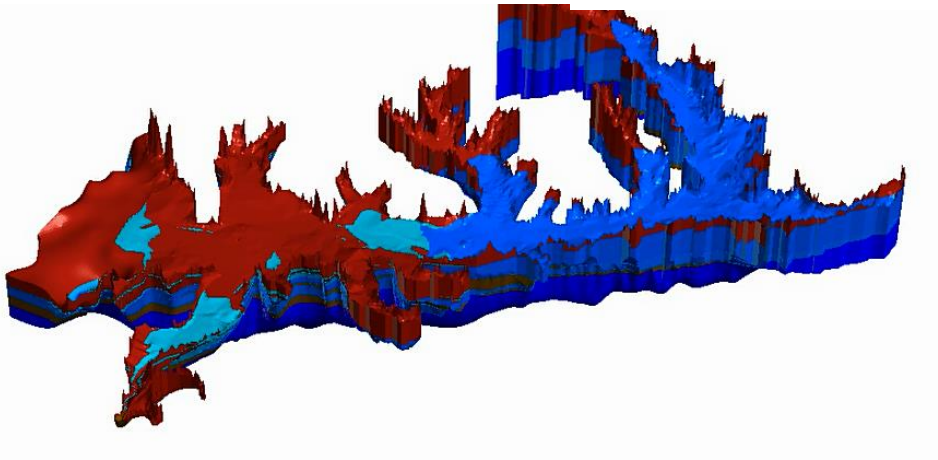

Ground heat equivalent to 900 households heating system(per hectare)(heat production capacity)



# Groundwater–fisheries Nexus

**Integrated model of water, dissolved material, heat, and primary production**

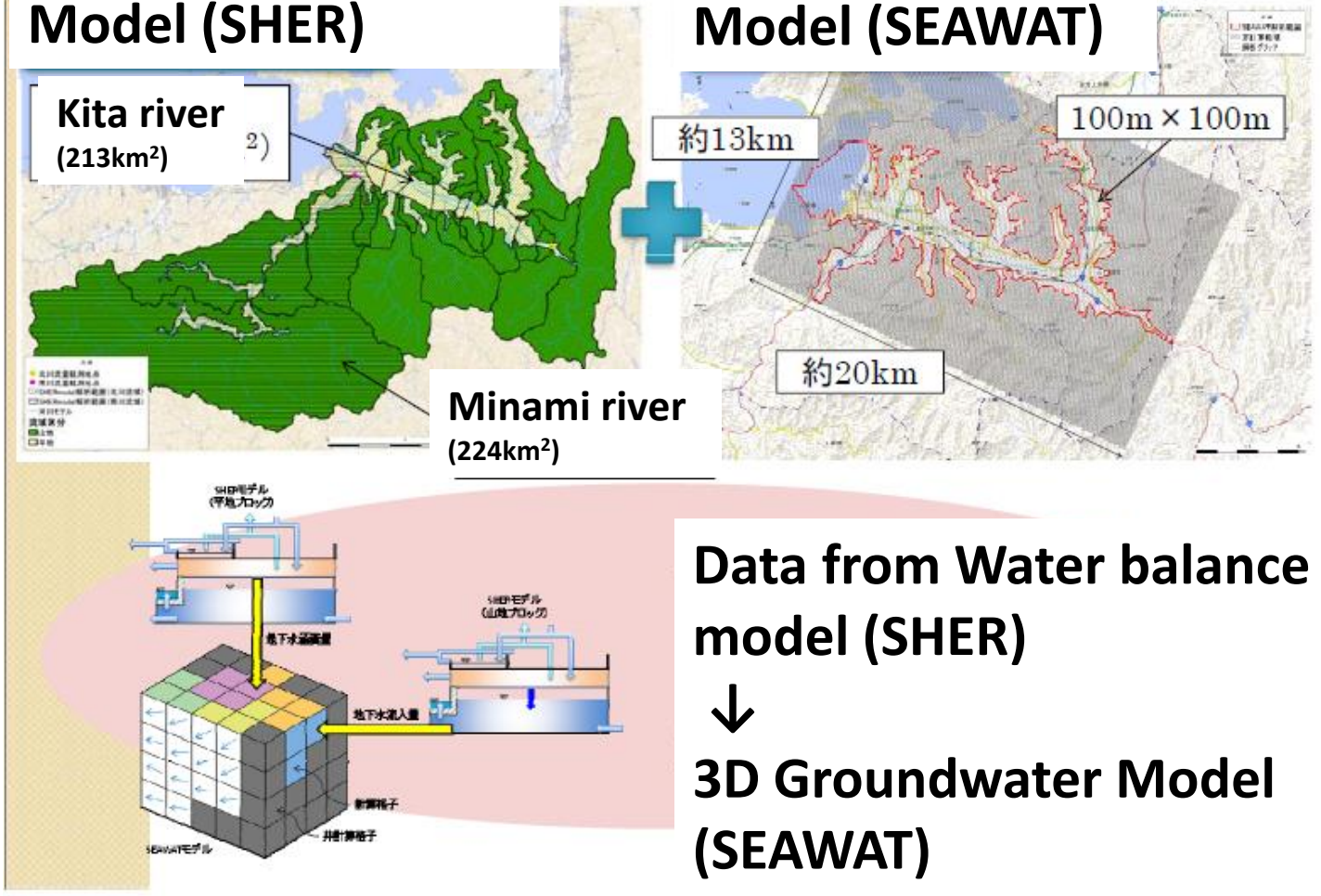


# Response analyses of the Nexus using integrated model

**Water Balance Model (SHER)**

**Groundwater Model (SEAWAT)**




**Data from Water balance model (SHER)**

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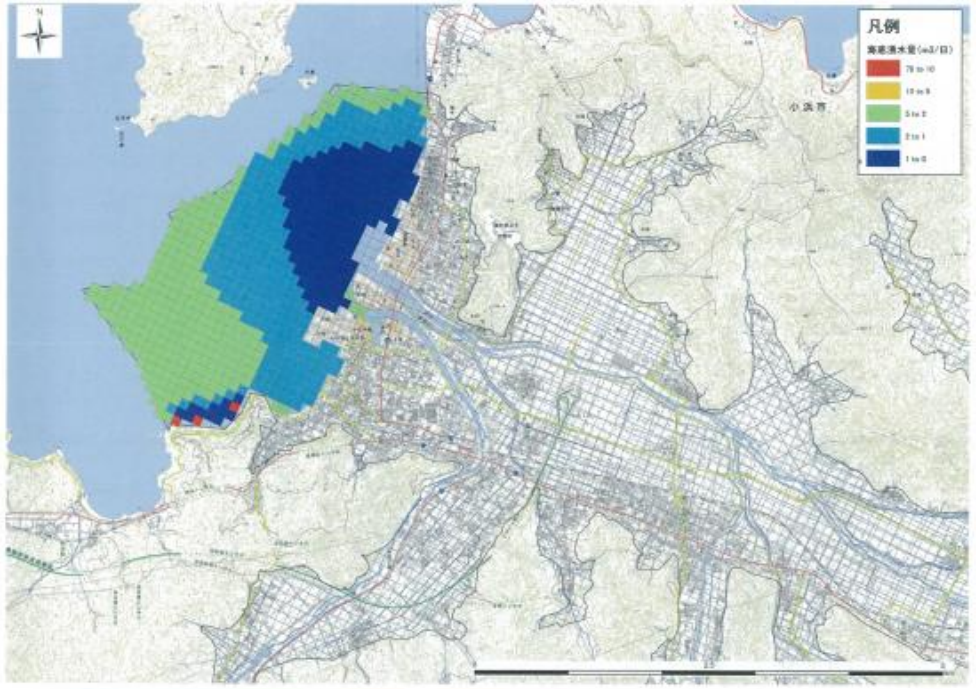
**3D Groundwater Model (SEAWAT)**

# Groundwater–fisheries Nexus




Increase in groundwater pumping on land

↓

Decrease in Submarine Groundwater Discharge

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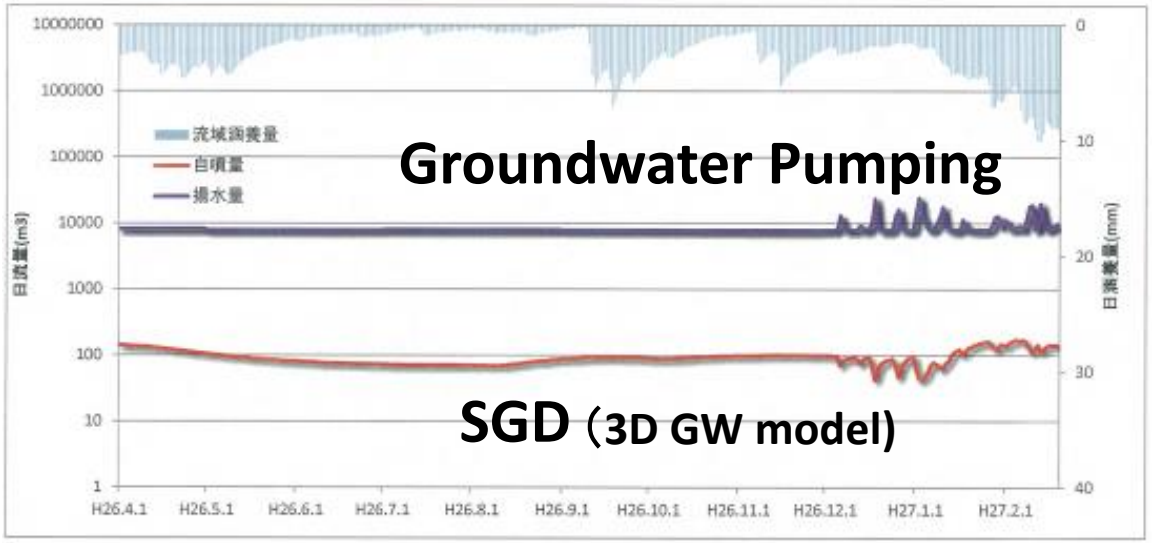
Decrease in Nutrients (P, N, Si) into the ocean

↓

Decrease in Chl-a & primary production

↓

Decrease in fisheries

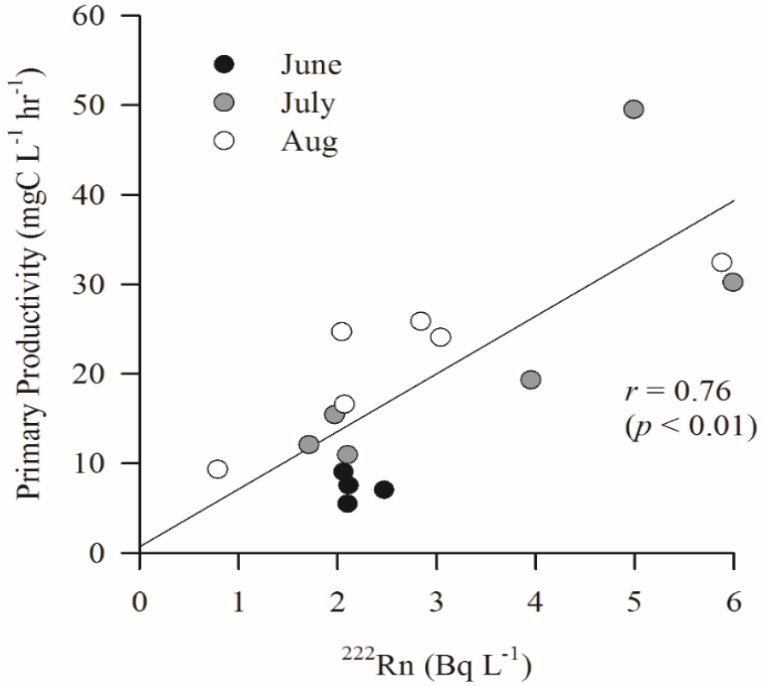



**Groundwater Pumping**

**SGD (3D GW model)**

図 49 自噴量と揚水量の時系列計算結果

**Relationships between $^{222}Rn$ and primary production**

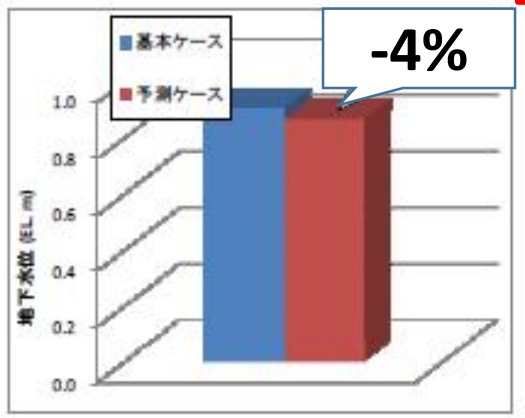


Results

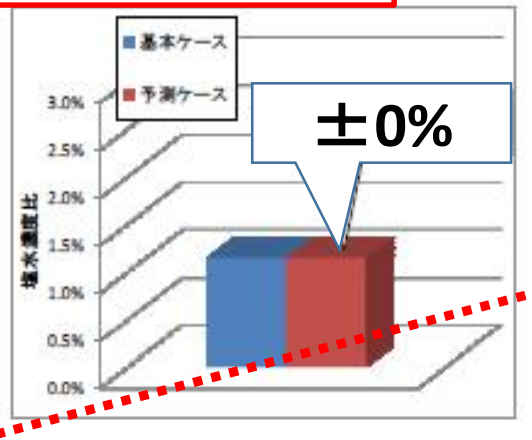
# Numerical simulation under the scenario of 1.5 times increase in demand of groundwater for melting snow

- Groundwater level and GW salinity in the coastal area have not been changed
- **Decrease in SGD by 5%, decrease in spring by 42%**

GW level




GW salinity



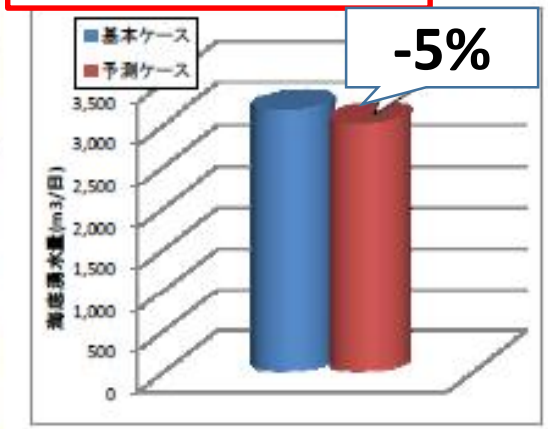

Decrease in nutrients discharge into the ocean and primary productions, then decrease in fisheries

SGD: −50000m$^3$

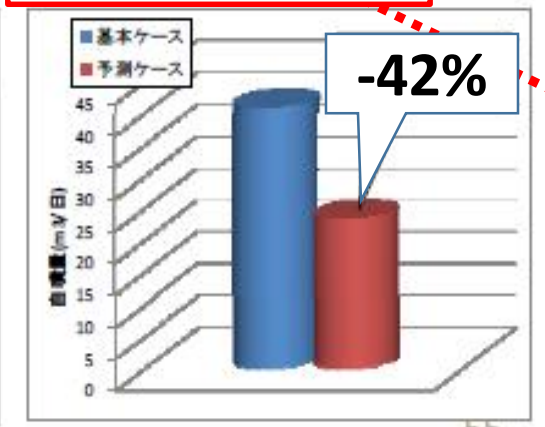
Fisheries: −75kg/1000m$^3$x50 = 3.7ton

**Food in ecosystem**

SGD




Spring




Additional energy is needed because of additional water allocation

# Summary

1) **Water footprints** are usually calculated for only water for food, however another water footprint as water for energy are analyzed as **Nexus** in the Asia Pacific region.
2) Different type of **Nexus** exist such as tradeoff, interaction, and linkage, depending on the change in quantity and quality of water resources, with difference of environment impacts.
3) Groundwater-energy relationship affects on ecosystem and food (fishery), making **groundwater-energy-food Nexus** as food (fishery) in ecosystem.