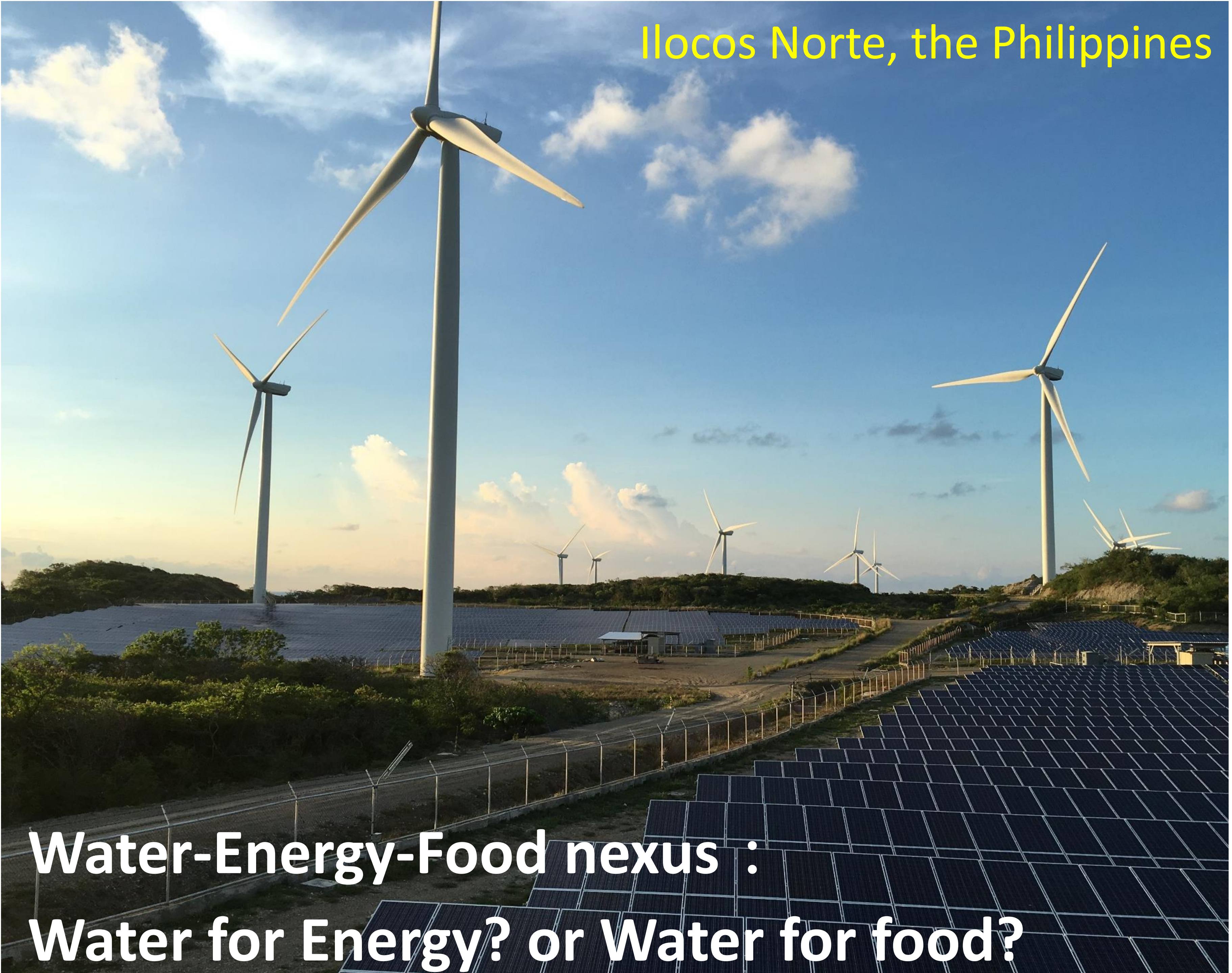
UNESCAP REGIONAL CONSULTATION ON INNOVATION STRATEGIES FOR SUSTAINABLE DEVELOPMENT THROUGH WATER-ENERGY-FOOD NEXUS
UNCC, 28-29 June 2017

Human-Environmental Security in Asia-Pacific Ring of Fire
- Water-Energy-Food Nexus -

Aiko ENDO, Research Institute for Humanity and Nature (RIHN)



◆ **Water for Energy**

Solar panels need to be cleaned with high-quality water every 3 month and every month in the dry months

◆ **Water for Food**

Use water for producing agricultural productions such as garlic and dragon fruits

✔**Tradeoff**

Water resources for producing energy vs for producing food?

✔**Conflict**

Energy developers vs Farmers

Energy-Food-Land nexus:
Land for Energy? or Land for Food?

◆ **Land for Energy**

Land use for generating wind energy

◆ **Land for Food**

Land use for livestock pasturing

✔**Tradeoff**

Land resources for generating energy vs for producing food

✔**Conflict**

Energy developer vs Farmers

✔**Coexistence**

Energy generation vs agricultural activities

Water-Energy-Food nexus :
Water for Energy? or Water for Food?

Jatiluhur Dam, Purwakarta, Indonesia

◆ Water for Energy

Water use for hydropower

◆ Water for Food

aquaculture in the dam using Floating Fish Net

→contribute to the deterioration of its water quality

→efficiency of energy production using contaminated water has become worse

✔Tradeoffs

Water for energy？VS water for food？

✔Conflicts

Energy developer VS aquaculture

Groundwater-Food-Environment nexus
Groundwater for Food?
or Groundwater for Environment?

Pajaro Valley in CA, USA

:◆ **Groundwater for Food**

Use groundwater and recycle water treated household wastewater in San Francisco for agricultural productions

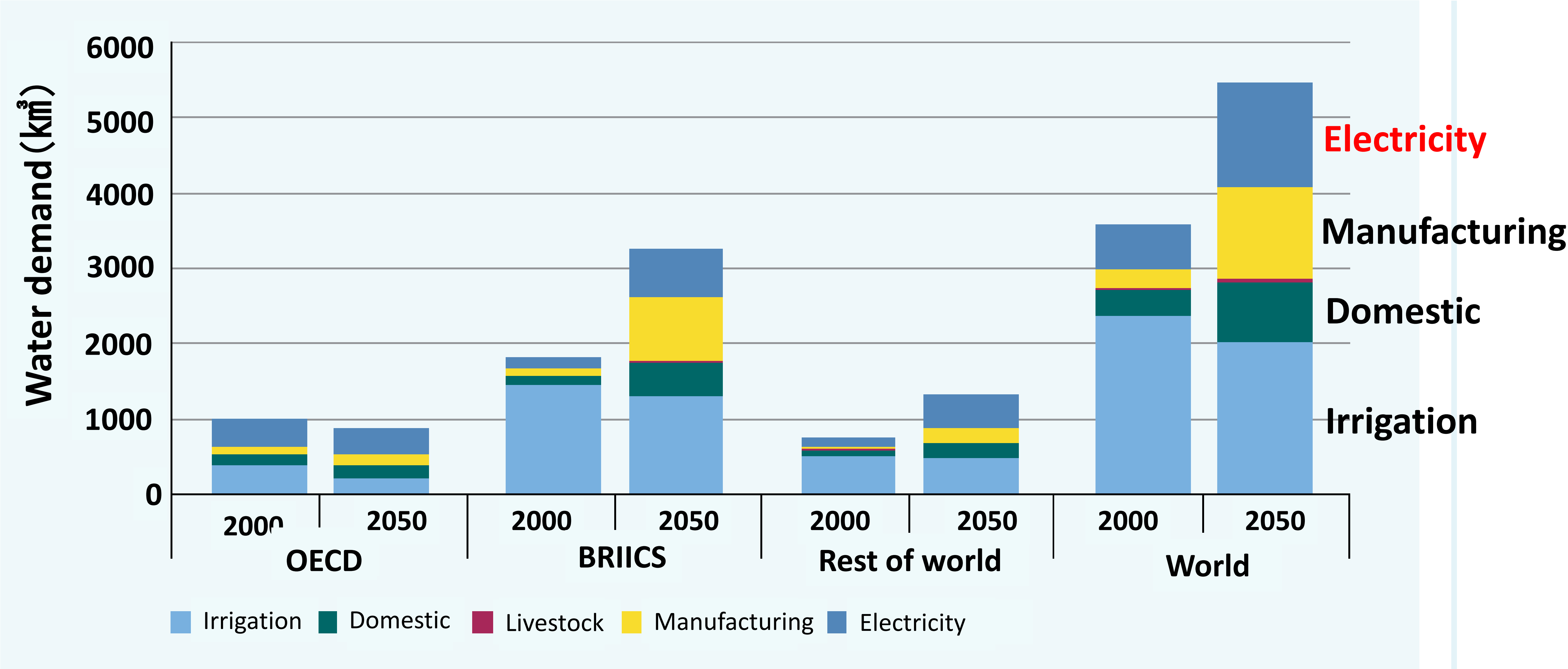
◆ **Groundwater for Environment**

・Serious water scarcity because of drought since 2012
・Decrease in groundwater storage and salination caused by overdraft
・Use energy for pumping, wastewater treatment, and allocate recycled water

✔Tradeoff

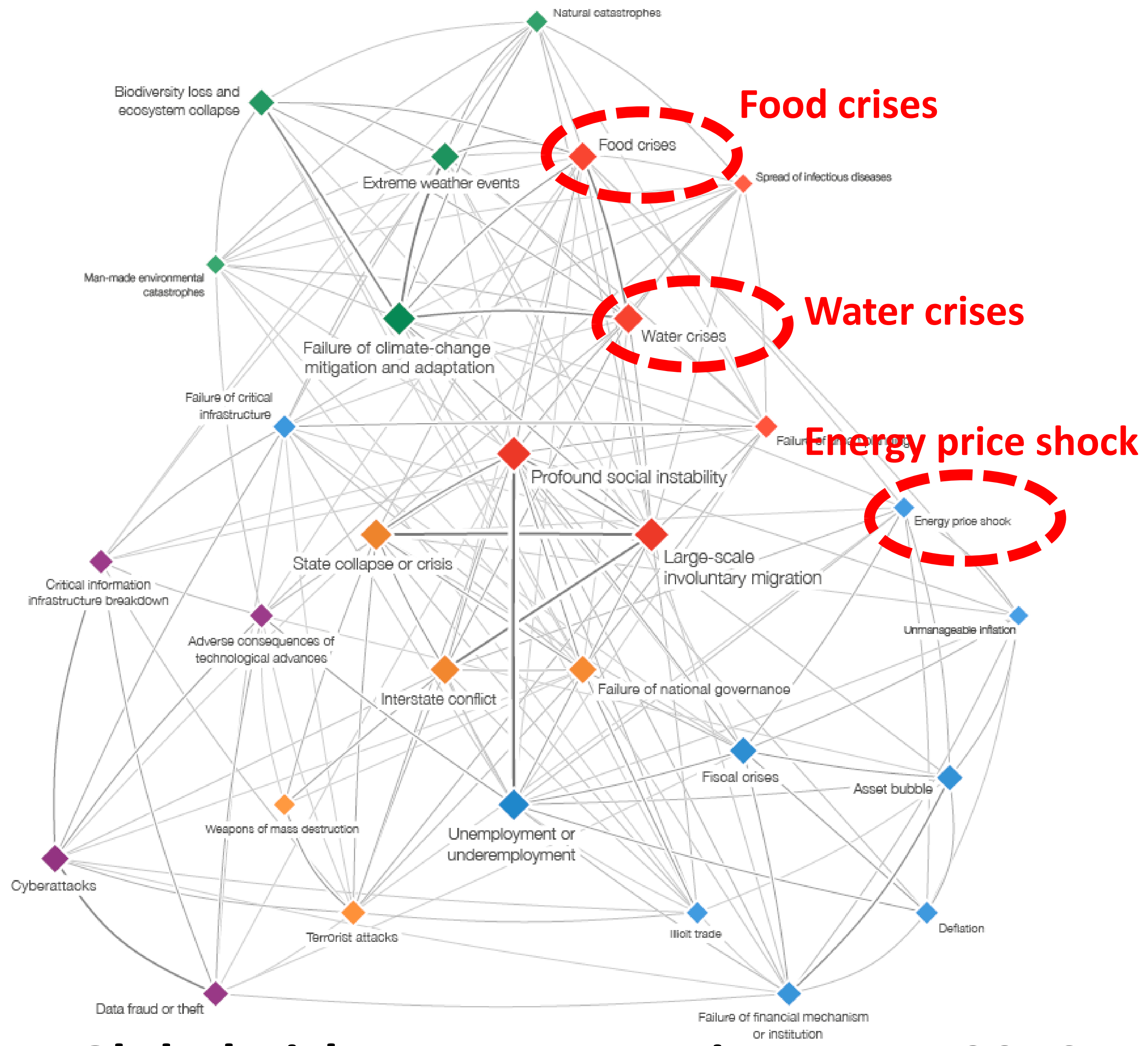
Groundwater resource for food production vs for environment

Global water demand (Freshwater withdrawals):



BRIICS : Brazil, Russia, India, Indonesia, China, South Africa)

The United Nations World Water Development Report 2016



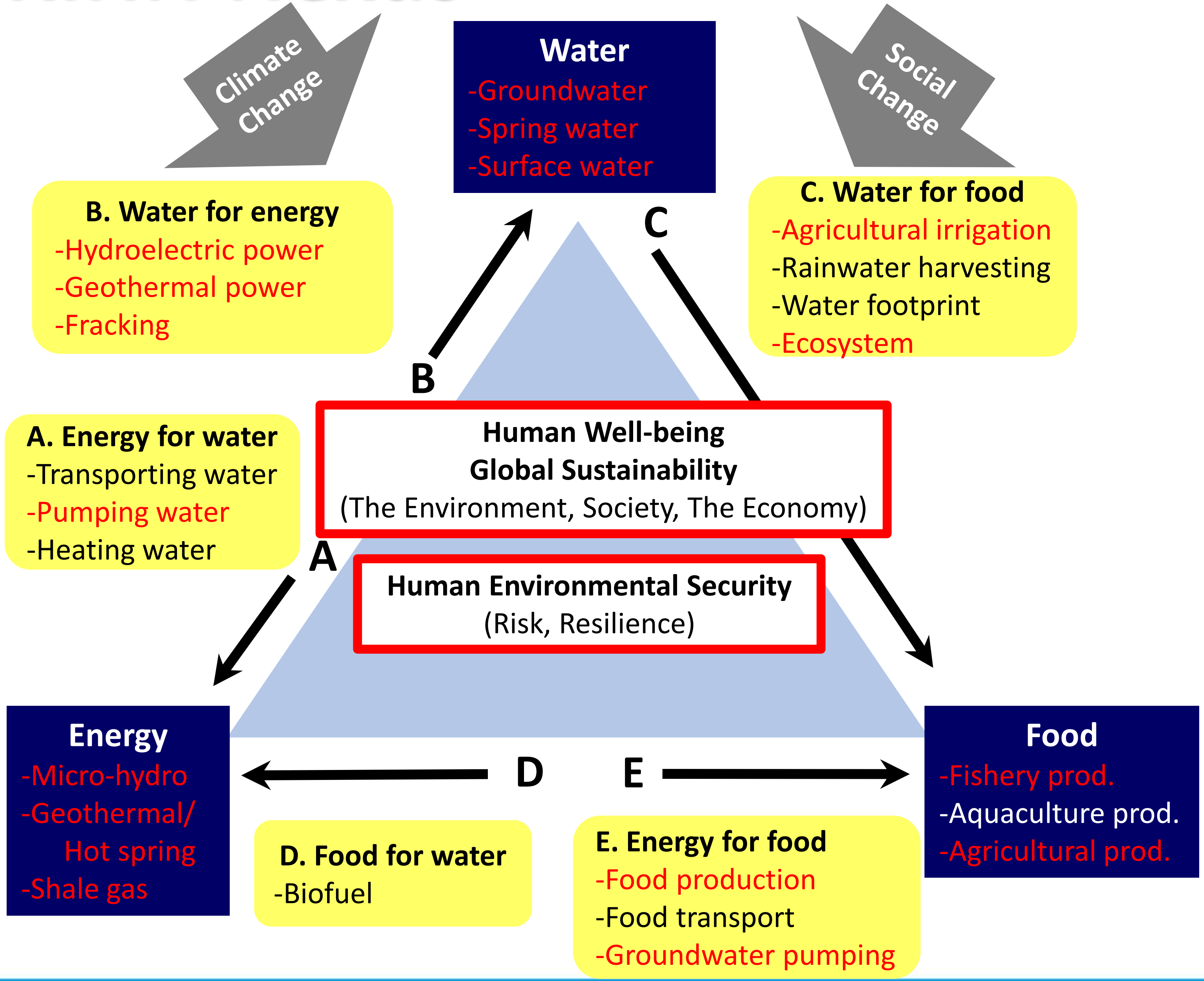
Global Risks Interconnections Map 2016

(WEF2016)

- ✔Food crises, water crises, and energy price shock were identified as interconnected global risks（WEF2016)
- ✔Social and climate change put pressure on water, energy, food resources
- ✔Demands for water, energy and food are estimated to increase by 40%, 50%, 35% by 2030（USNIC 2012）
- ✔Increase in number of tradeoffs and potential conflicts among these resources that have complex interactions
- ✔Nexus approach can enhance water, energy and food security by **increasing efficiency, reducing trade-offs, building synergies and improving governance across sectors**

Understanding the complexity of WEF nexus system

RIHN Nexus



Purpose

Understand the complexity of WEF nexus system, and to create policy options to reduce tradeoffs among resources and to solve the conflicts of resource users, under scientific evidence and uncertainty

Water-Energy-Food nexus:

Water for land? or Water for coasts?

Submarine Groundwater Discharge (SGD)

◆ Water for Land

Water use for producing and consuming food and energy on land

◆ Water for coasts

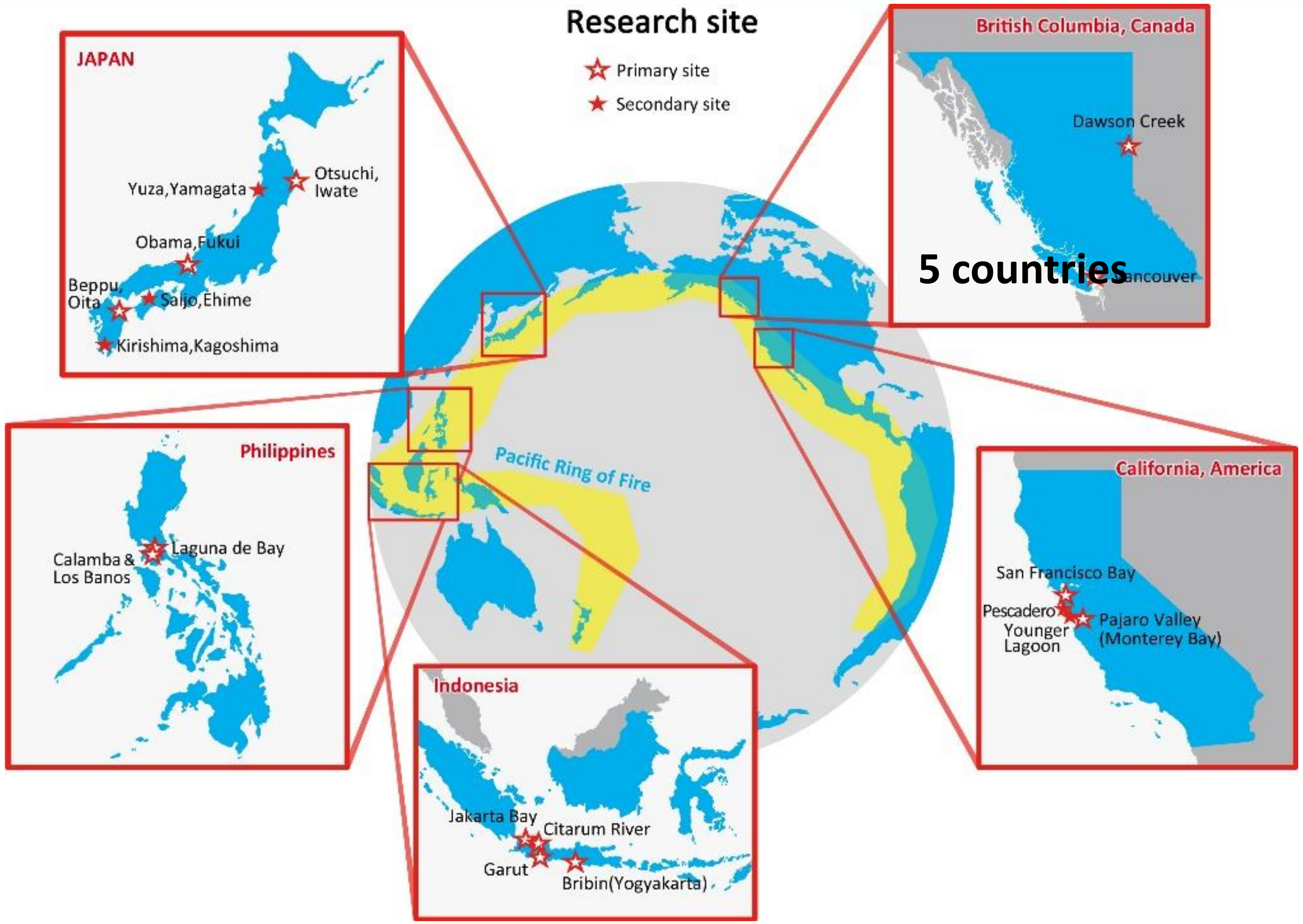
The flow of nutrients from the land to the ocean affects the coastal ecosystem

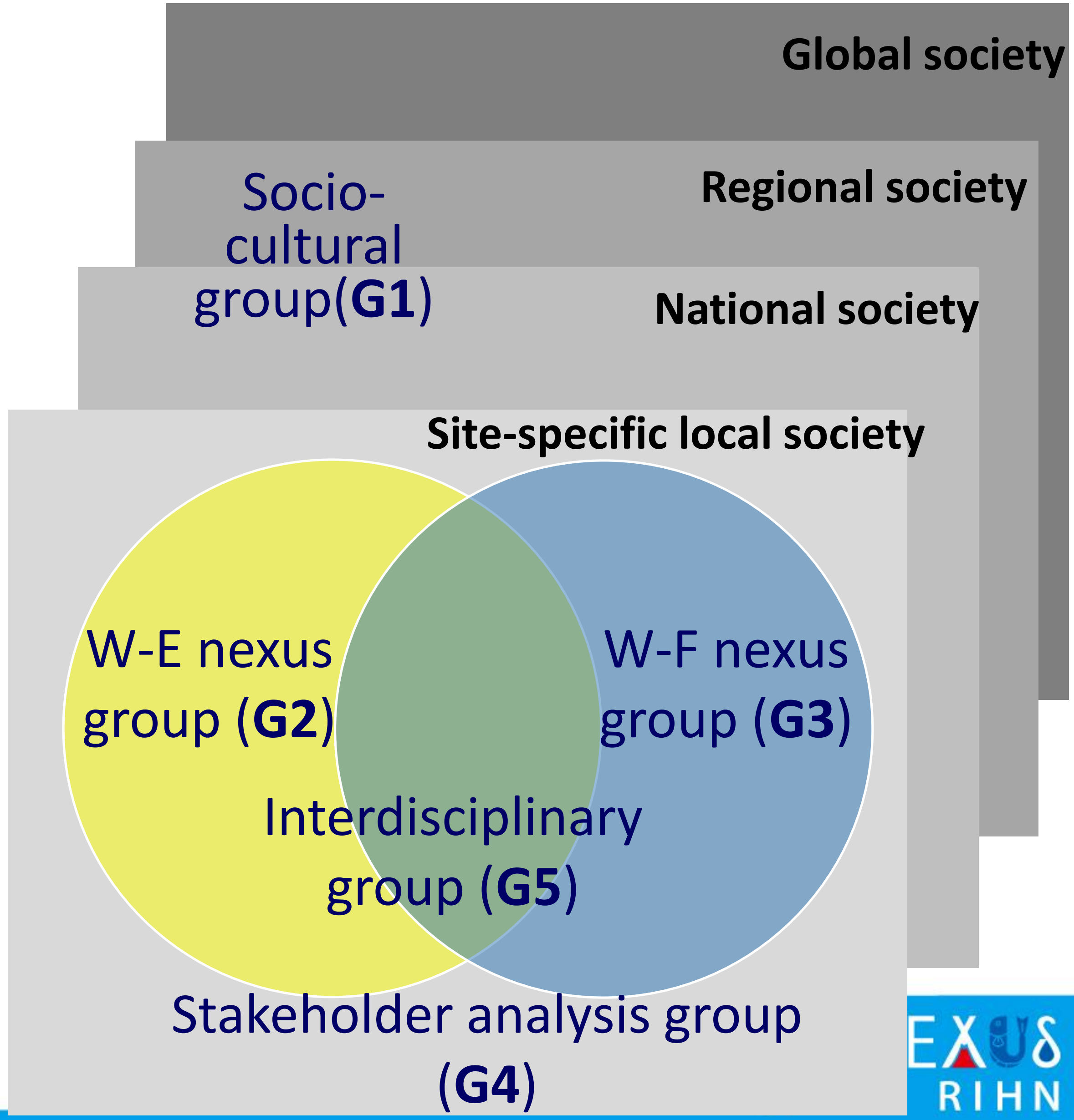
✔Tradeoffs

-Water for land vs water for coastal environment

-Water use for producing and consuming food and energy on land might affect fishery production in coastal areas

Spatial scale





-Japan (Obama, Otsuchi, Beppu & others)
US, Canada, Indonesia, the Philippines
-60 researchers in different disciplines

Target areas

We are here!

Initial stage — Developing stage — Policy planning stage

Water-Energy nexus: G2

A.1 Analyze underground environmental system

A.2 Analyze effective potential energy production using water

A.3 Examine the changes in river & coastal ecosystems caused by the changes in heat environment

A.4 Diversify renewable energy sources

A.5 cascade use of water for food & energy

Water-Food nexus: G3

A.5 Examine the interlinkages between GW & fishery production

Socio-cultural: G1

B.1 Study socio-cultural history of GW use

Stakeholder analysis: G4

B.2 Build governance for coexistence between hot spring energy development & conservation

B.3 Visualize social network of hot spring SHs

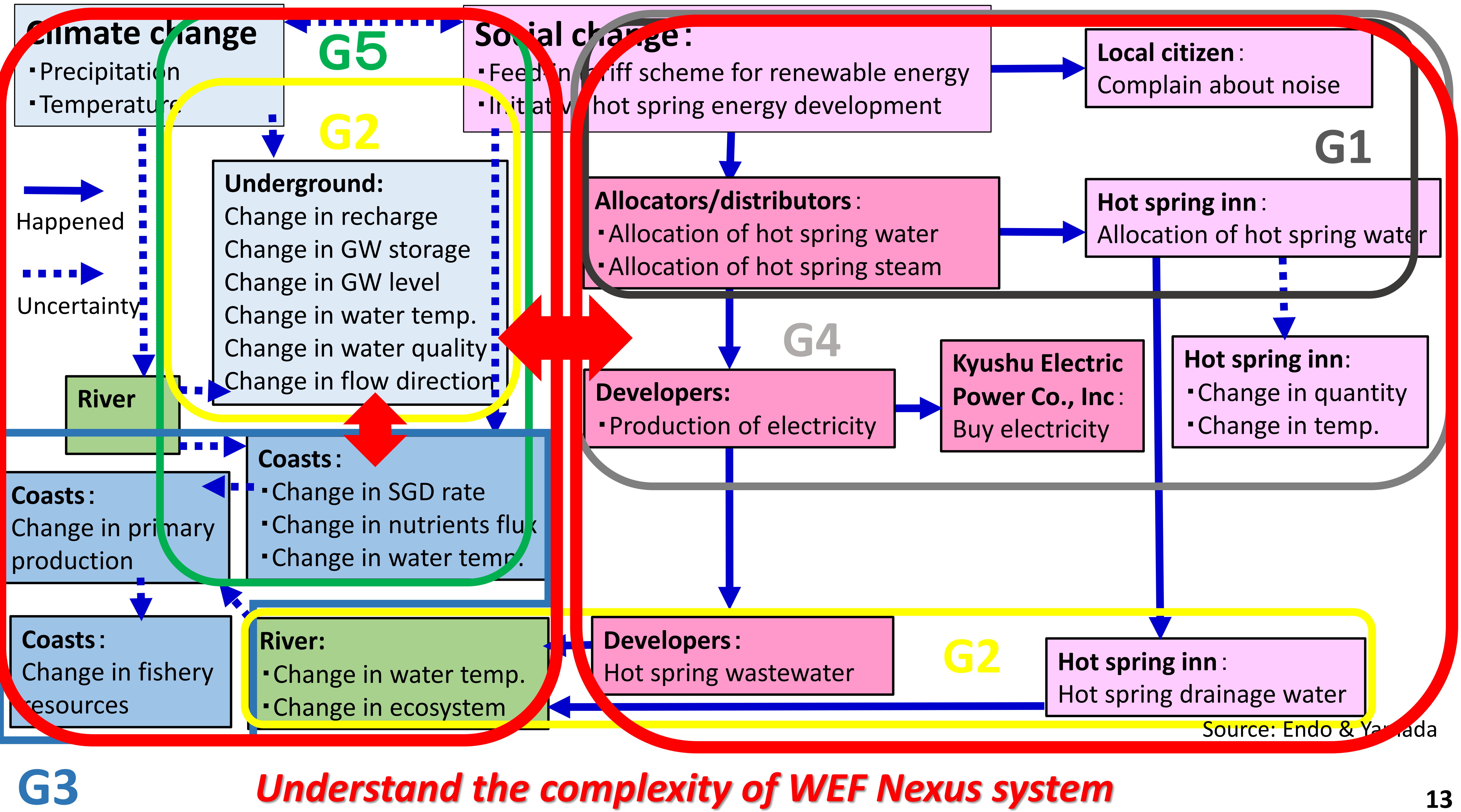
B.4 Scenario planning

Interdisciplinary: G5

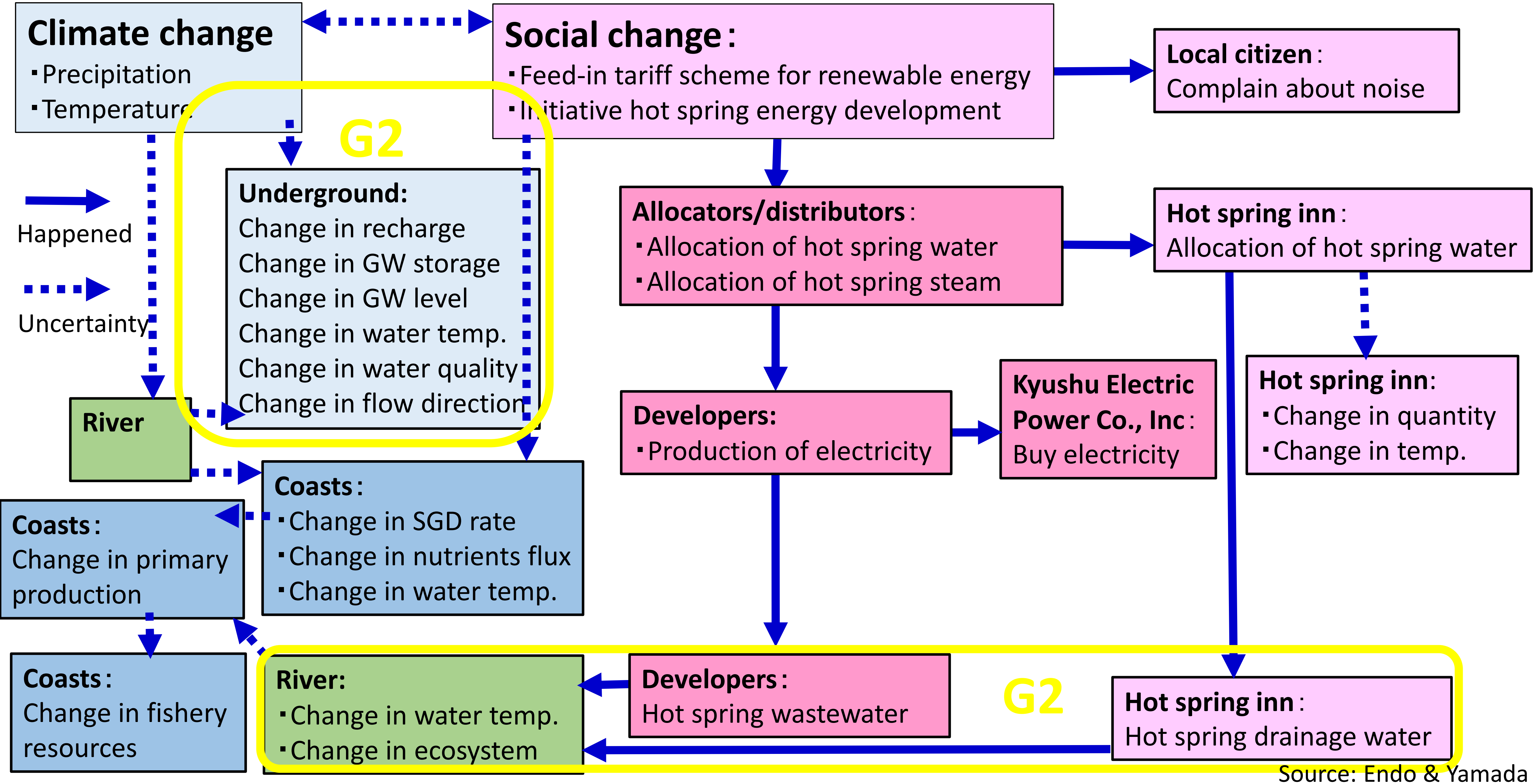
B.5 Develop integrated methods for ID & TD

B.6 Design and visualize nexus system

Identify tradeoffs & conflicts → **A.** Understand the complexity of WEF nexus system → **Scientific uncertainty** / **Scientific evidence** → **B.** Create policy options & scenarios to solve the identified nexus problems



Understand the complexity of WEF Nexus system



Source: Endo & Yamada

Clarify natural & social WEF nexus systems to improve scenarios in Beppu

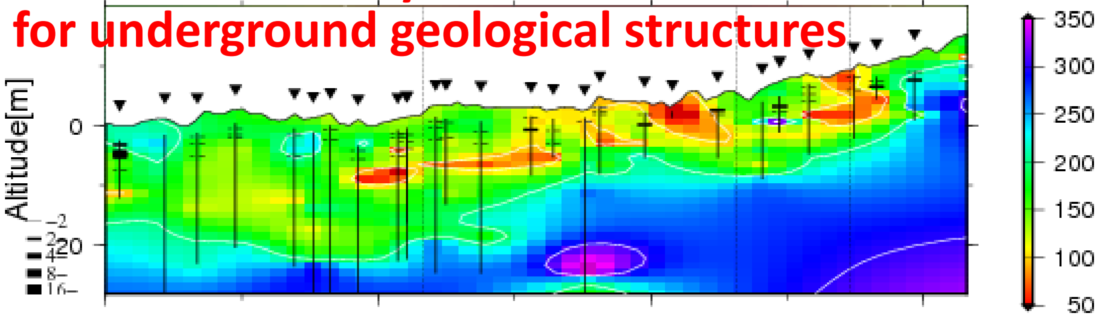
Water-Energy nexus

A. Understand the complexity of WEF Nexus system

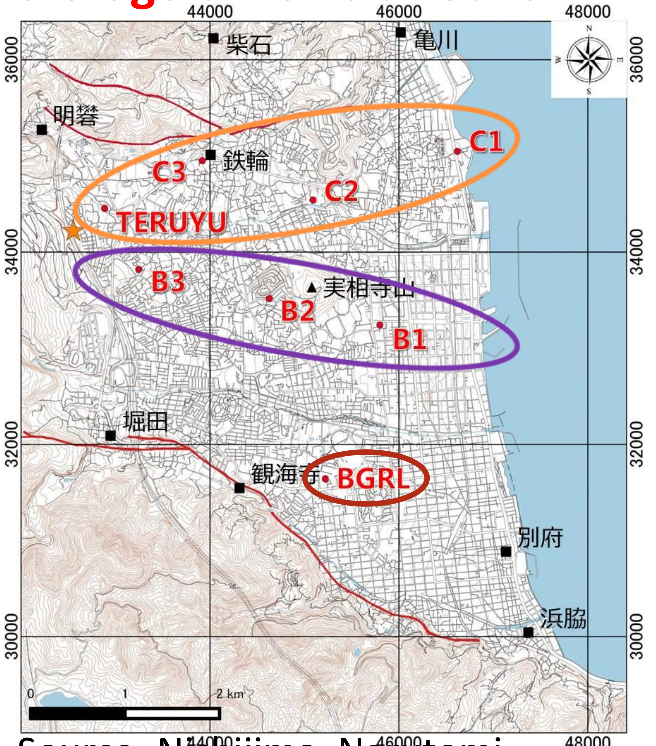
A.1 Analyze underground environmental system

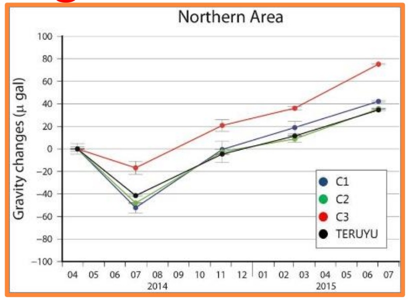
Microtremor array measurements for underground geological structures

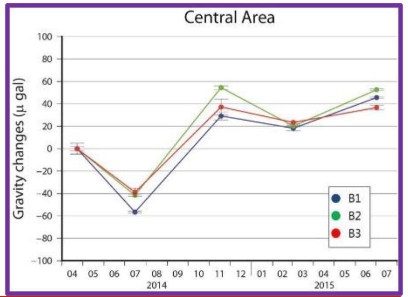
Source: Miyashita

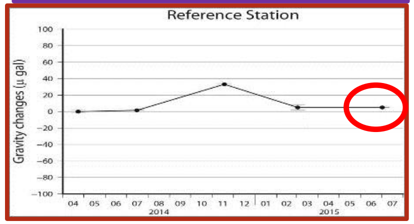


Gravity basement structures for groundwater storage & flows direction





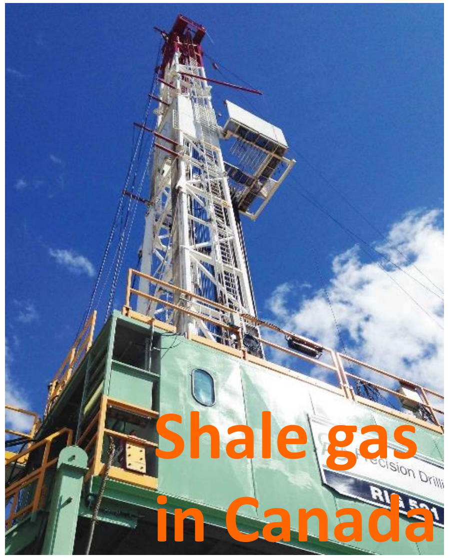




Source: Nishijima, Narutomi

A.2 Analyze effective potential energy production using water

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



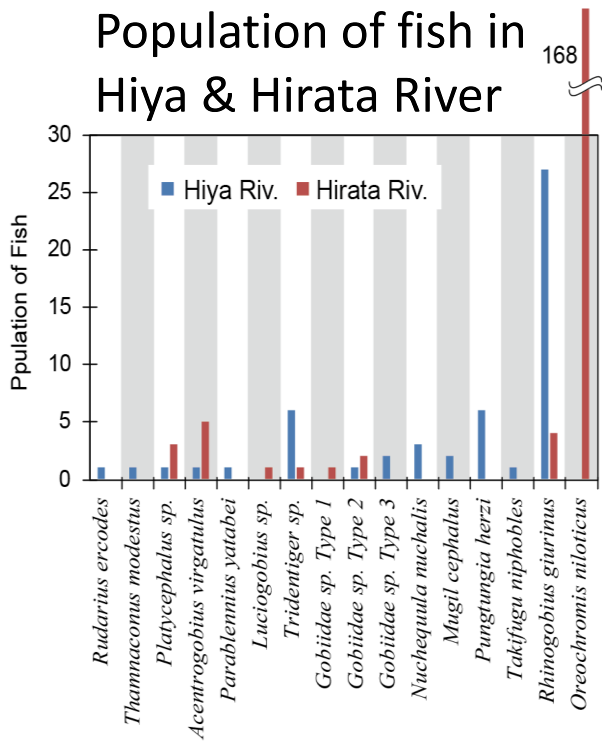
0.0164 kcal/kg-water

66,000 kcal/kg-water

16.3 kcal/kg-water

Source: Fujii & Yamada

A.3.1 Examine the changes in river ecosystems caused by the changes in heat environment



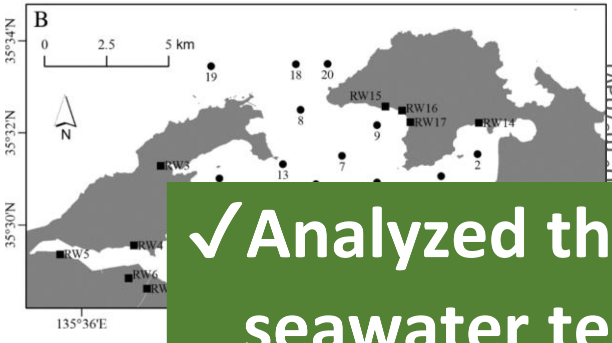
Hot spring drainage creates a more suitable habitat for Nile Tilapia in Hirata river

Hirata riv. Nile Tilapia (*Oreochromis niloticus*)

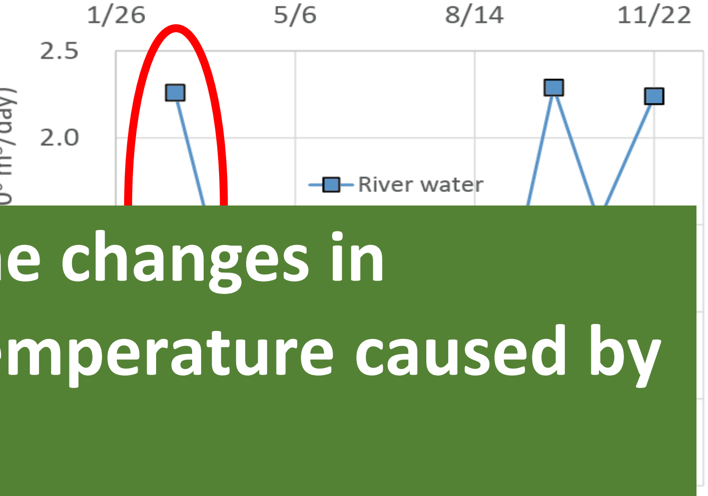
Hiya riv. Barcheek Goby (*Rhinogobius giurinus*)

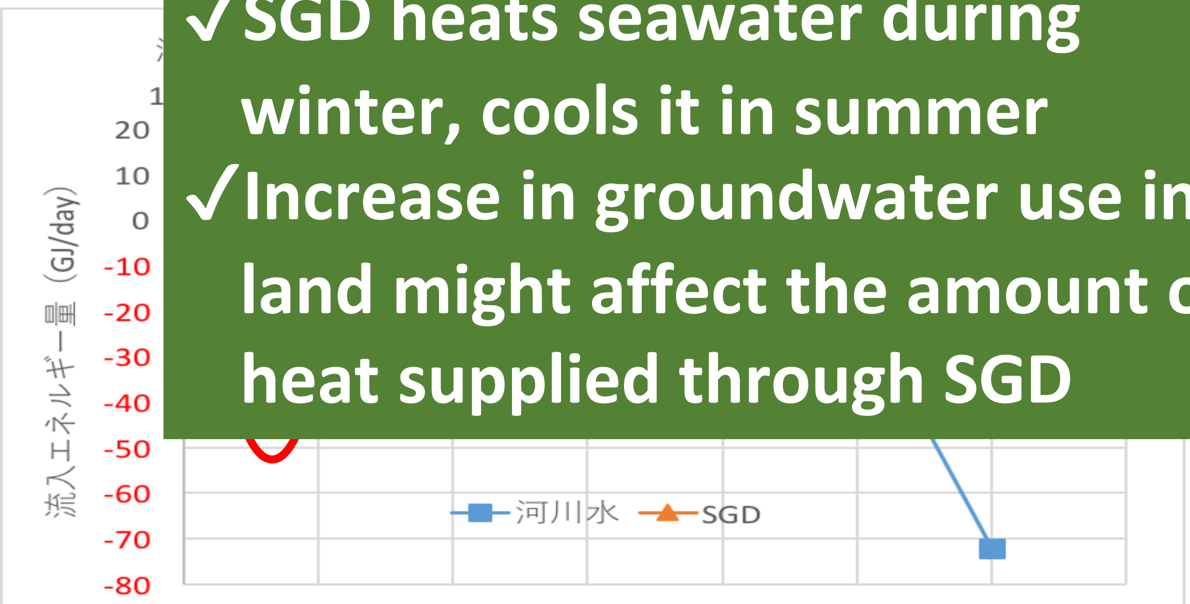
Source: Yamada

A.3.2 Examine the changes in coastal ecosystems caused by SGD



Source: S





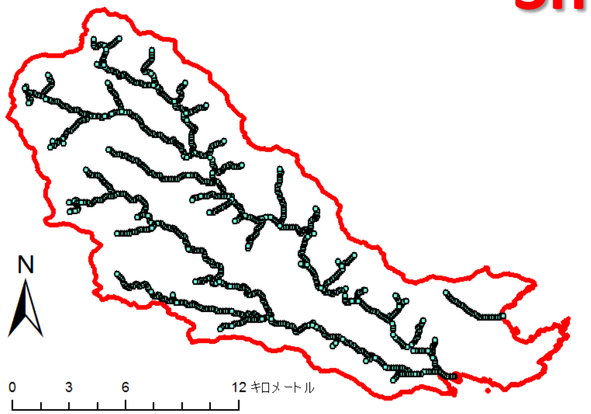
- ✓Analyzed the changes in seawater temperature caused by SGD
- ✓SGD heats seawater during winter, cools it in summer
- ✓Increase in groundwater use in land might affect the amount of heat supplied through SGD

Water-Energy nexus

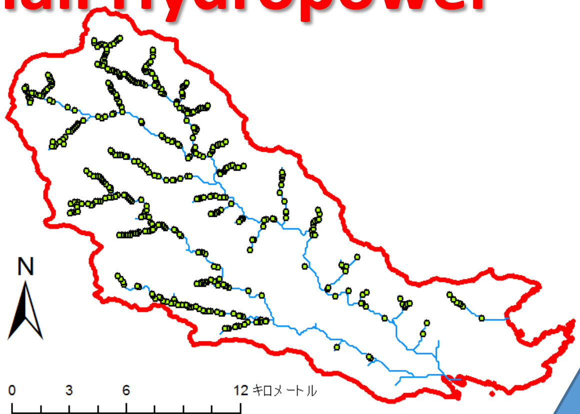
A. Understand the complexity of WEF nexus system

A.4 Diversify renewable energy sources

Small Hydropower

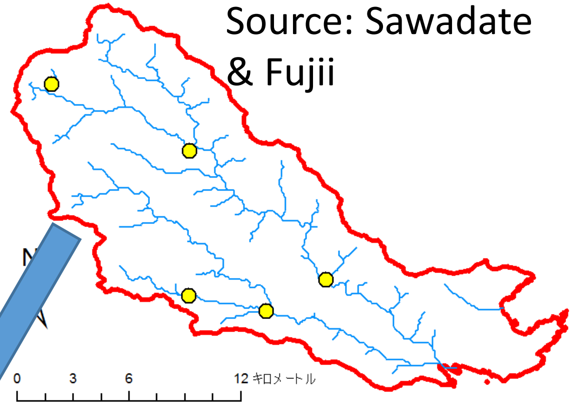


(a) All the potential



(b) Excluding points where natural head is <10m

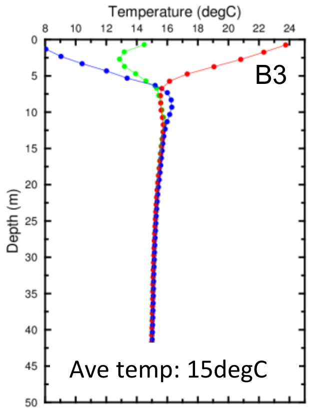
Source: Sawadate & Fujii



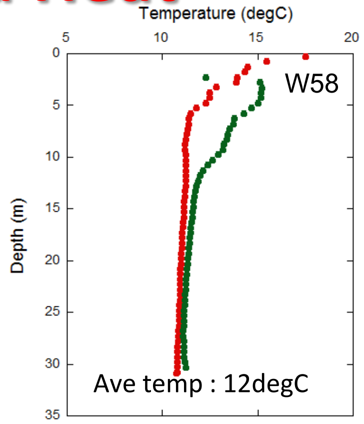
(c) Excluding points without electric lines and with conflicts with salmon and brisling

- Potential electricity generated by 5 small hydropowers is **2,171 MWh**
- Social conditions and conflicts with riverine ecosystem such as salmon

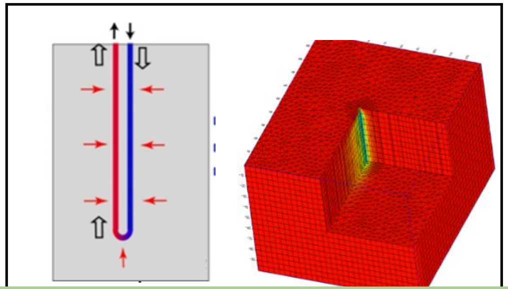
Ground Heat



Obama



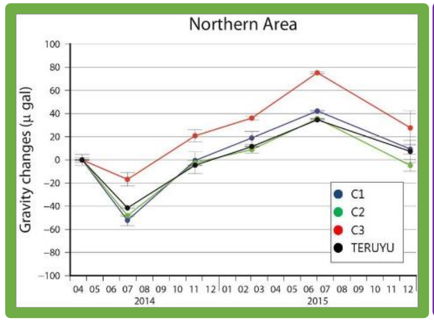
Otuchi

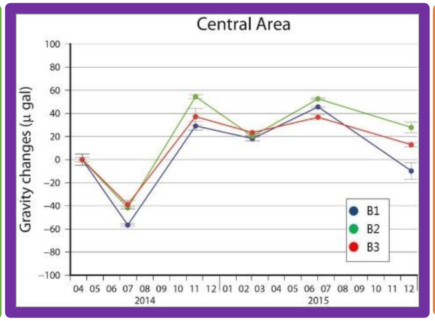


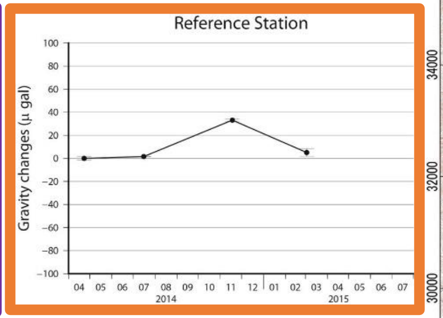
- Soil temperature in Obama is higher than in Otsuchi
- Ground warming
- Utilize the energy from ground heat for application of heat pump

Geothermal

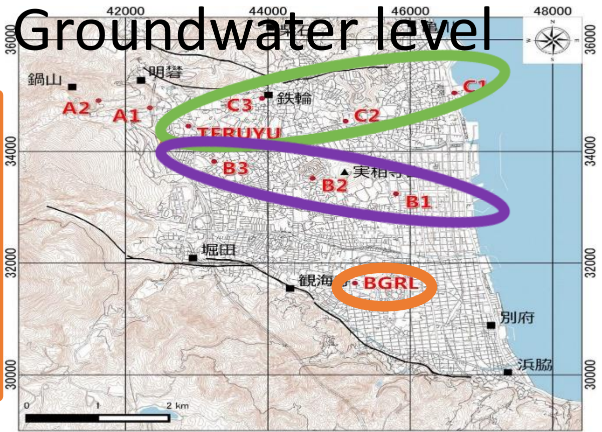
Source: Nishijima







Groundwater level

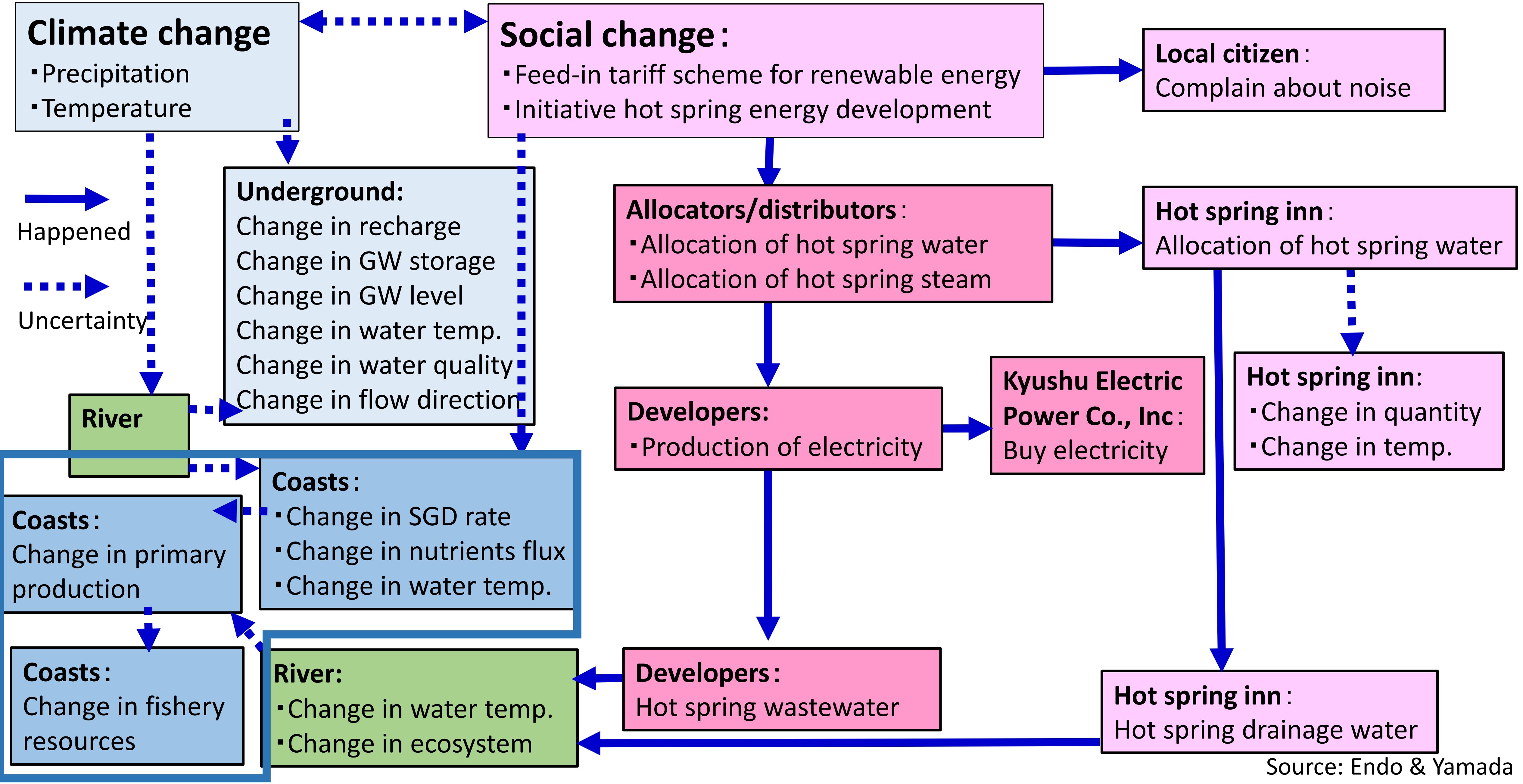


A.5 cascade use of water for food & energy

Full cascade uses of hot spring water and hot spring drainage water in different temperature & quality profiles

Temperature	Quality (chemical components)	Quality profiles	Cascade use
100°C	Hot spring water	Steam	-Hot spring energy development: W-E -Cooking: W-E-F
80°C	ditto	Heat energy Water	??⇐Agriculture productions: W-E-F
60°C	ditto	Heat energy	-Heat pump for heating room: W-E -Grow berry (testing): W-E-F
40°C	ditto	Heat energy Water	Spa: W-E
35°C	Hot spring drainage water (chemical components)	Heat energy	?? ⇐Agriculture productions: W-E-F

Policies and/or regulations for sustainable use of hot spring water and wastewater management should be addressed



G3 *Clarify natural & social WEF nexus systems to improve scenarios in Beppu*

Water-Food nexus

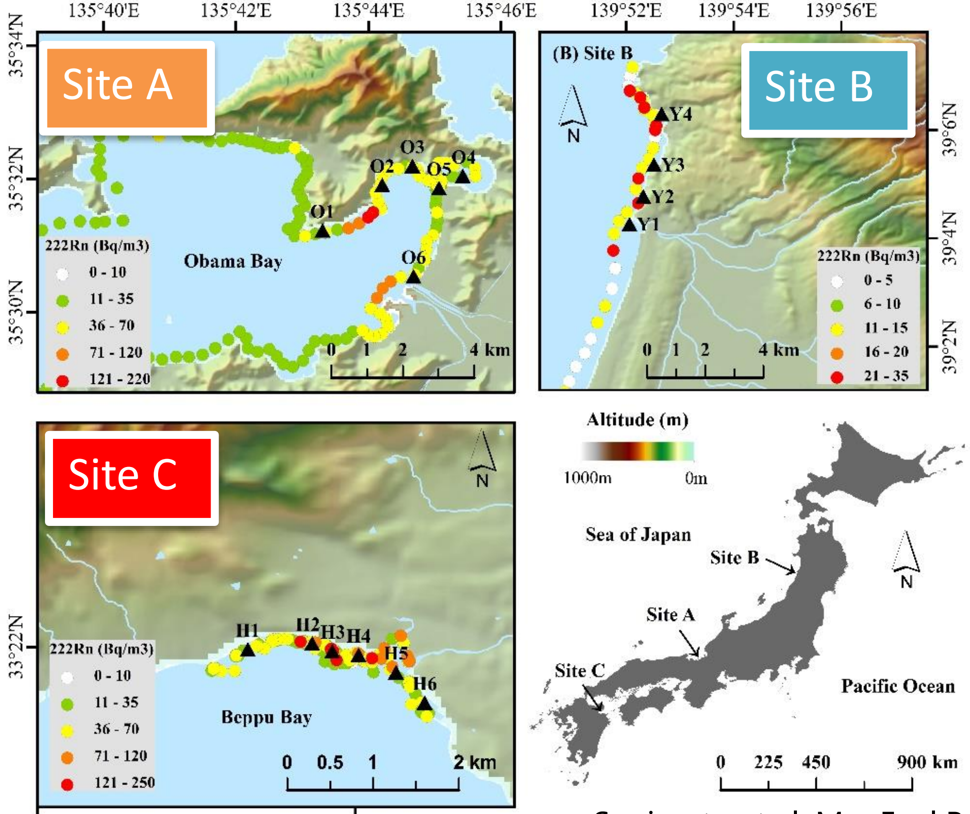
A. Understand the complexity of WEFN system

A.4 Examine the interlinkages between groundwater and fishery production

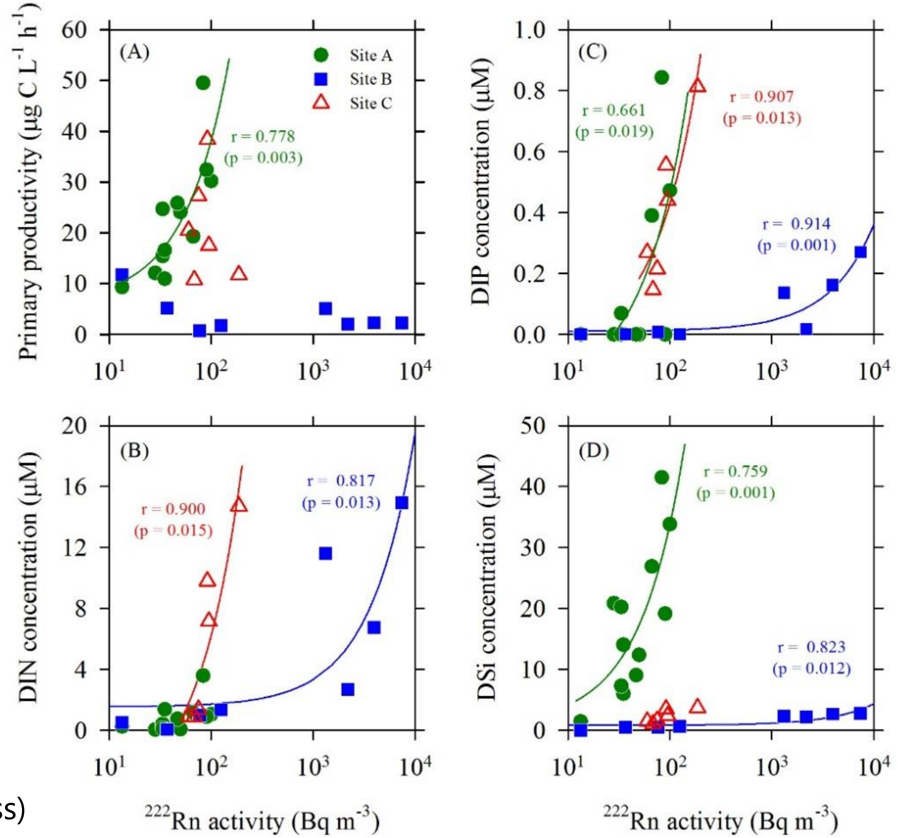
1. Change in SGD rate → 2. Change in nutrients flux → 3. Change in primary production → 4. Change in fishery resources

222Rn surveys to visualize SGD impacts

in situ incubation for phytoplankton primary productivity



Sugimoto et al. Mar Ecol Prog Ser (in press)



Site A: Obama
Site B: Yuza
Site C: Hiji

Positive correlations between Phytoplankton primary productivity and SGD (Radon concentration)

Water-Food nexus

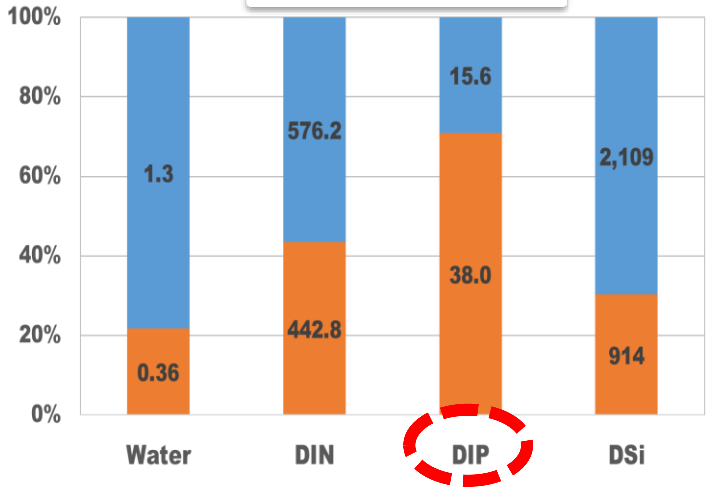
A. Understand the complexity of WEFN system

A.4 Examine the interlinkages between groundwater and fishery production

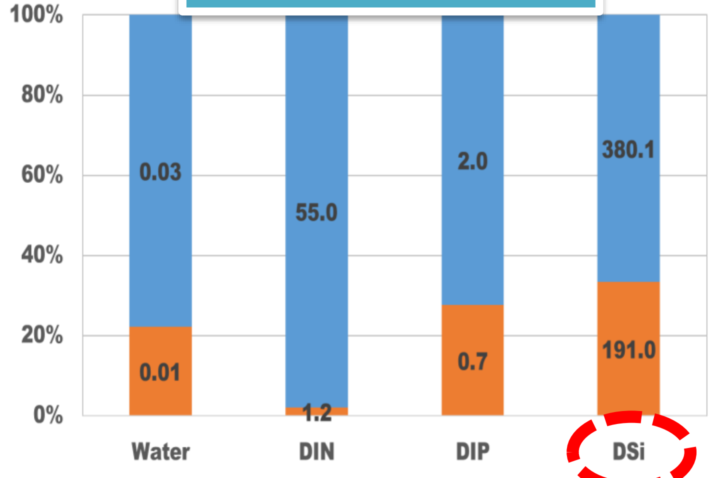
1. Change in SGD rate → 2. Change in nutrients flux → 3. Change in primary production → 4. Change in fishery resources

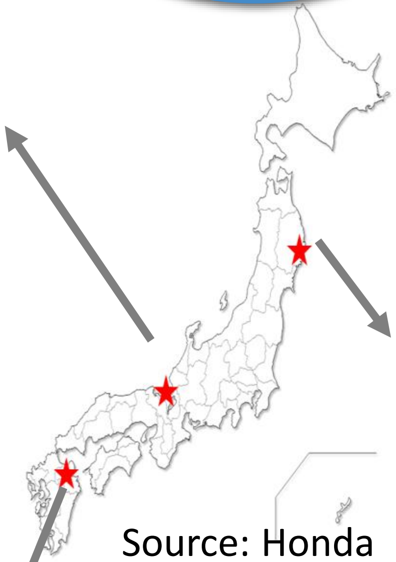
River water vs **Ground water**

Obama Bay



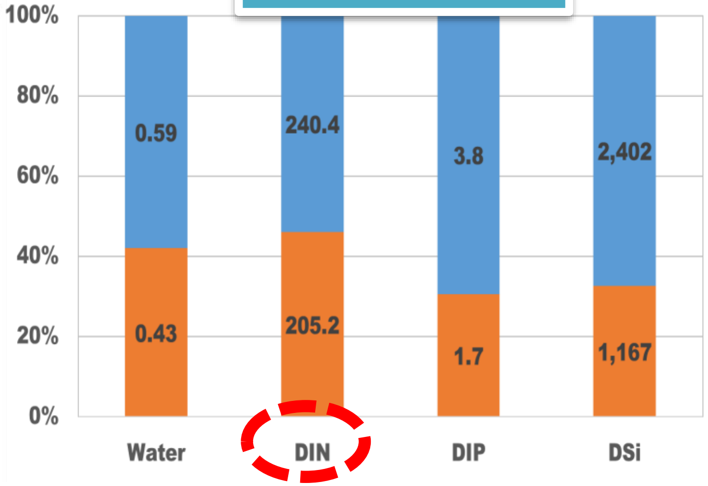
Beppu Bay（Hiji）



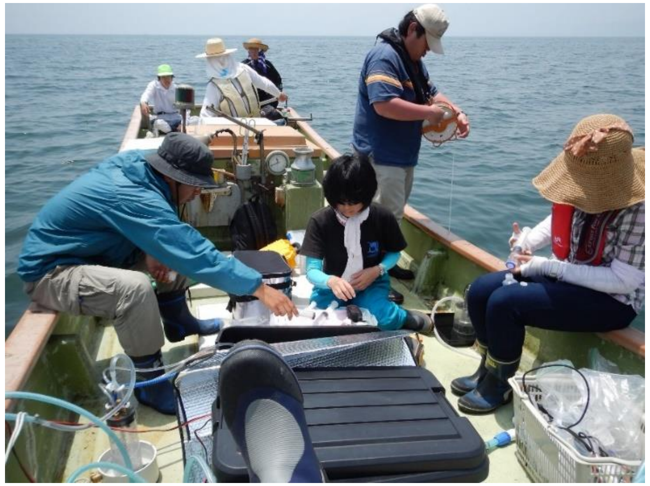


Source: Honda

Otsuchi Bay



Obama – DIP (65%)
Otsuchi – DIN (46%)
Hiji – DSi (33%)



nutrients supplied from the SGD would have a high contribution to primary production

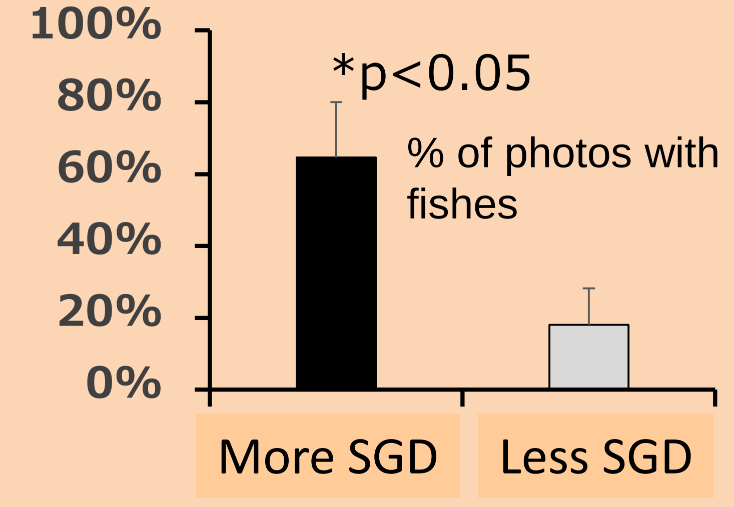
Water-Food nexus

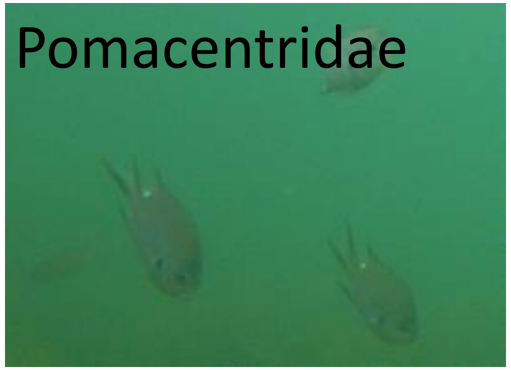
A. Understand the complexity of WEFN system

1. Change in SGD rate → 2. Change in nutrients flux → 3. Change in primary production → 4. Change in fishery resources

SGD– fish community (Hiji)

Underwater cameras
4 replications at each site
Every 1 min. for 3 hours





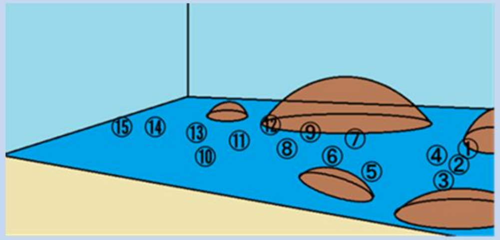
More fishes were recorded nearby SGD

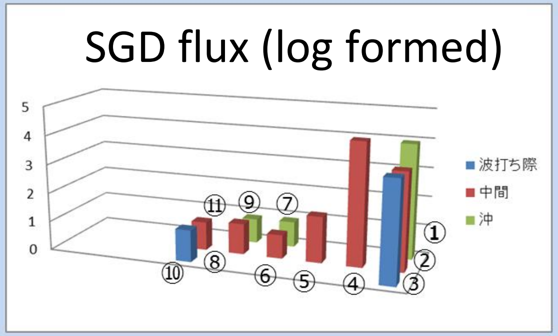
Source: Shoji

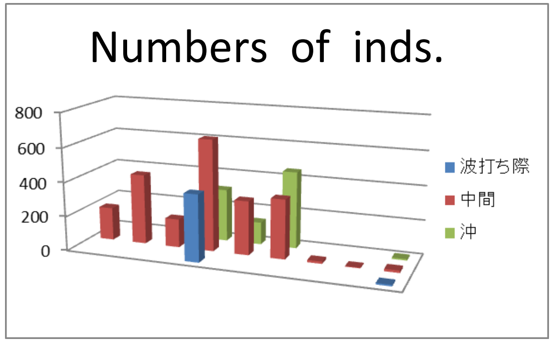
SGD – meiobenthos community: at a smaller spatial scale (Yuza)

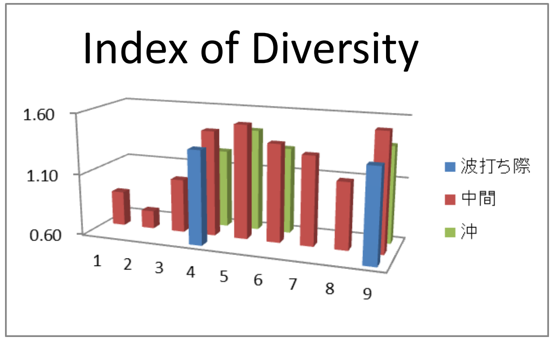
Source: Tominaga

地図に対応した立体図

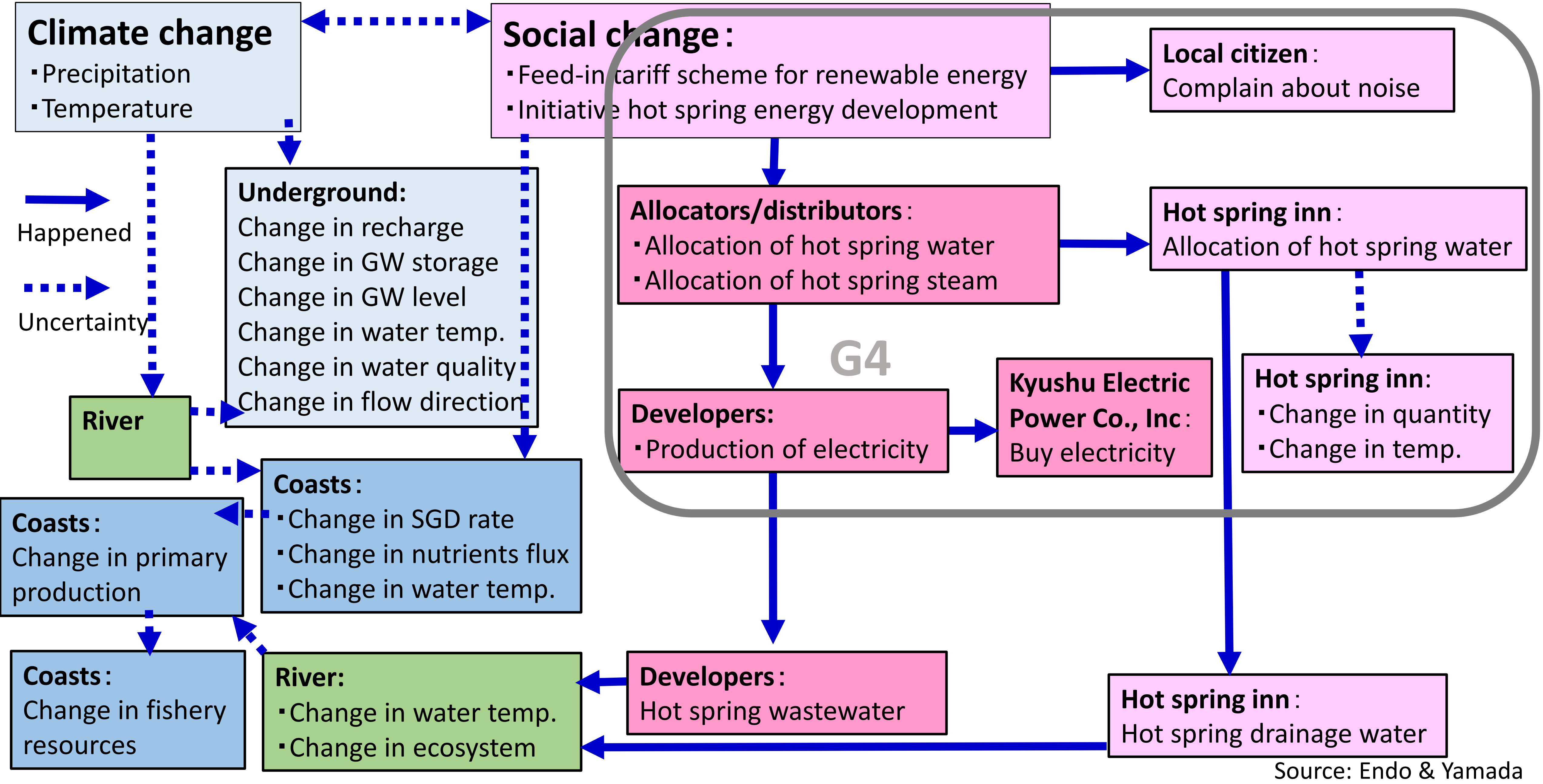








Max value : Low SGD and Low Fresh water rate area



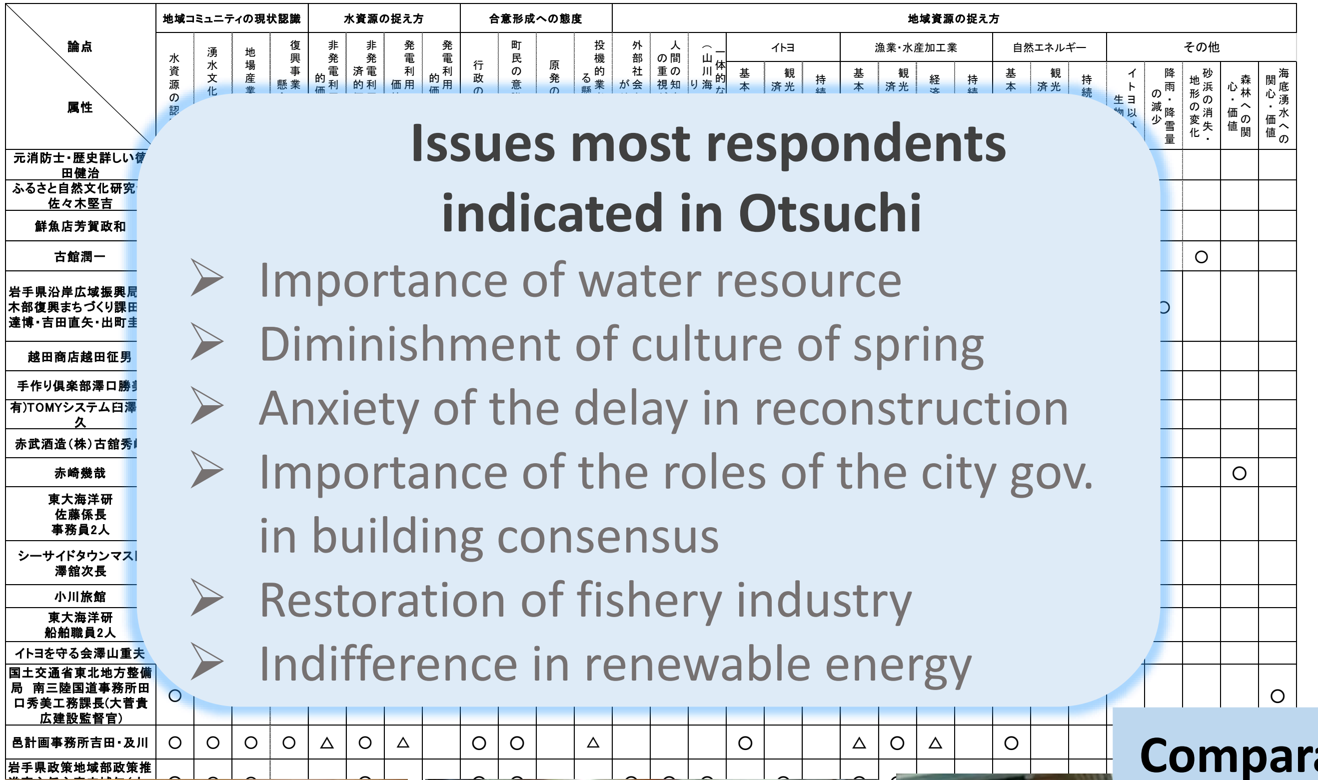
Clarify natural & social WEF nexus systems to improve scenarios in Beppu

Stakeholder analysis

B. Create policy options & scenarios to solve the identified nexus problems

B.1 Identify WEF nexus SHs and their interests at SH Meeting/individual interview as site-specific case study

Source: Baba

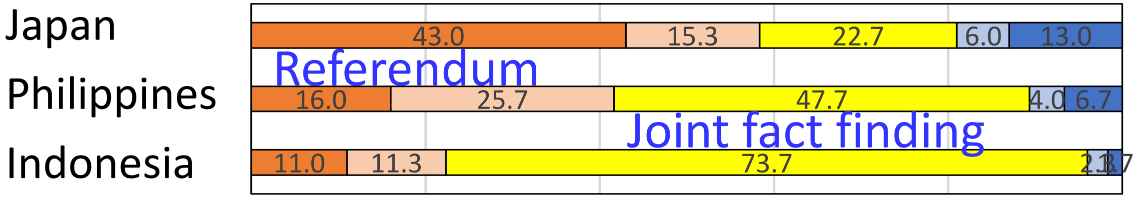


Issues most respondents indicated in Otsuchi

- ➢ Importance of water resource
- ➢ Diminishment of culture of spring
- ➢ Anxiety of the delay in reconstruction
- ➢ Importance of the roles of the city gov. in building consensus
- ➢ Restoration of fishery industry
- ➢ Indifference in renewable energy

Comparative study

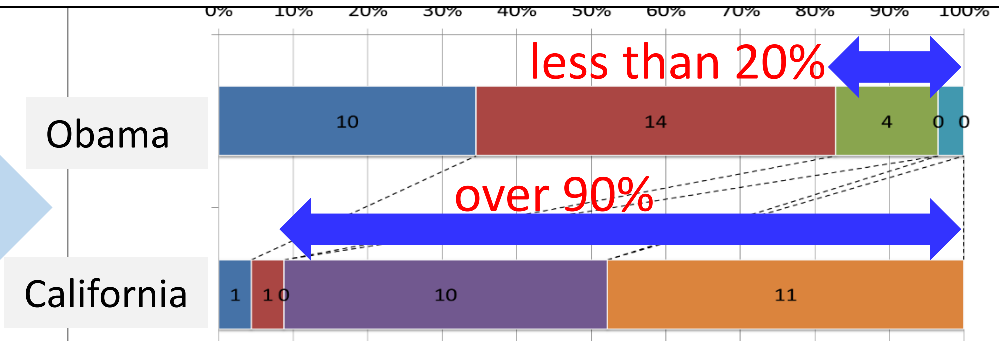
B.2 Identify differences in public attitudes toward energy production at a regional scale



Online survey focusing on general public

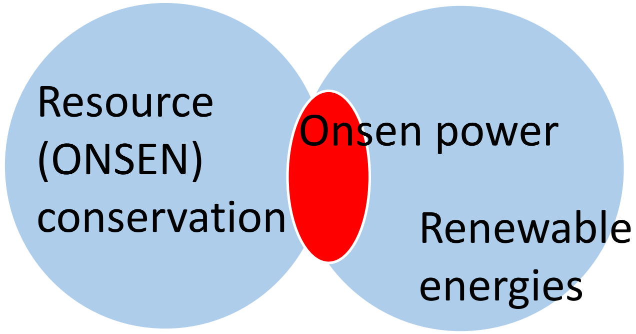
✔Japan: Referendum

✔Philippines & Indonesia: Joint fact finding



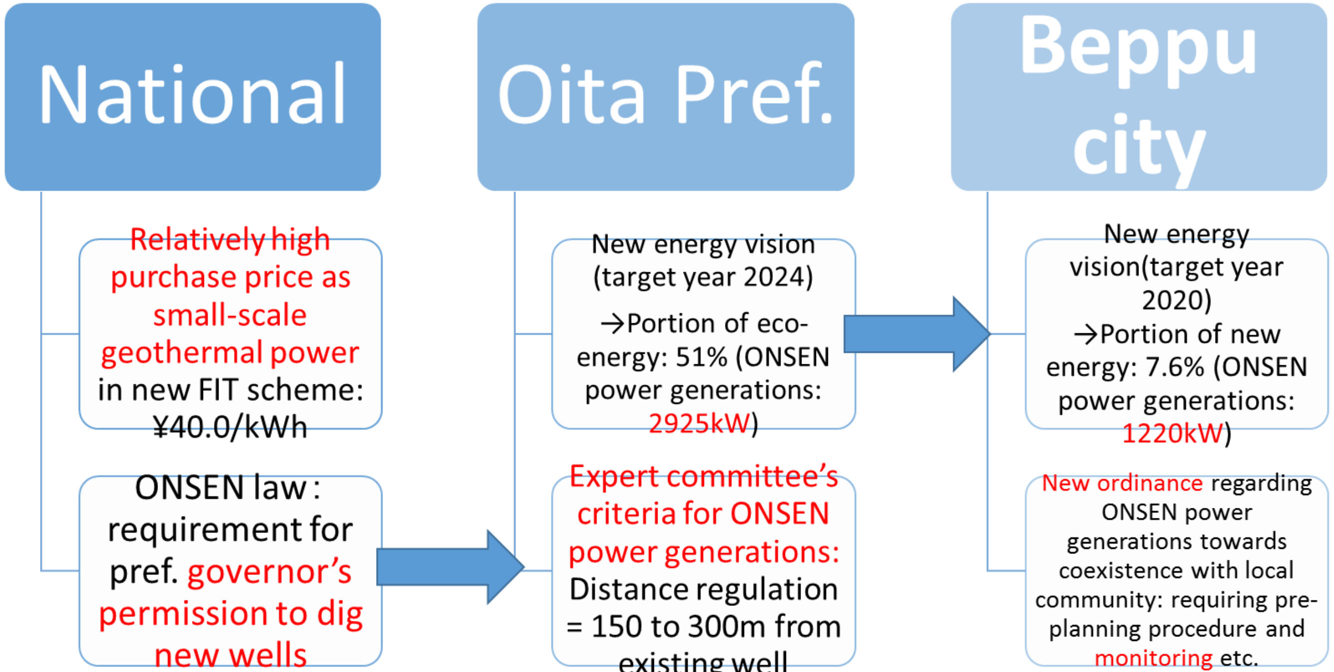
✔California: Join groundwater-related activities more than once per month

B.2 Build governance for coexistence between hot spring energy development & conservation



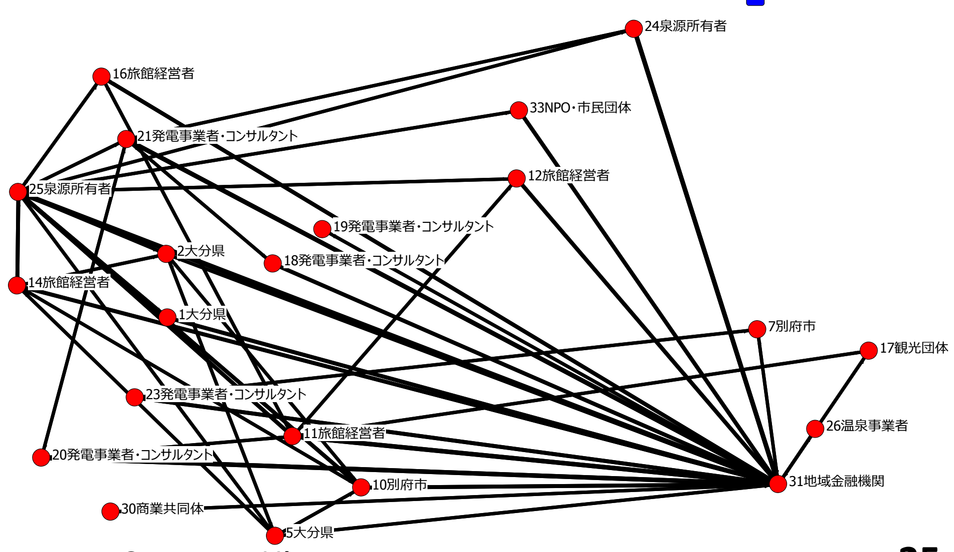
Source : Masuhara

- ✓3 levels of government have their own targets to install more renewable energies without coordination
- ✓Beppu city has no legal authority based on Onsen law



B.3 Visualize social network of hot spring SHs

Social network among SHs (owners of hot springs, onsen inn managers, power generation businesses, local banks, and consultants) who shared same interests is established



Source : Kimura

B.4 Scenario planning

Stakeholder analysis (FY2013)

Interviewing and identifying interests of stakeholders such as local officials, farmer, distributors, plant nursery

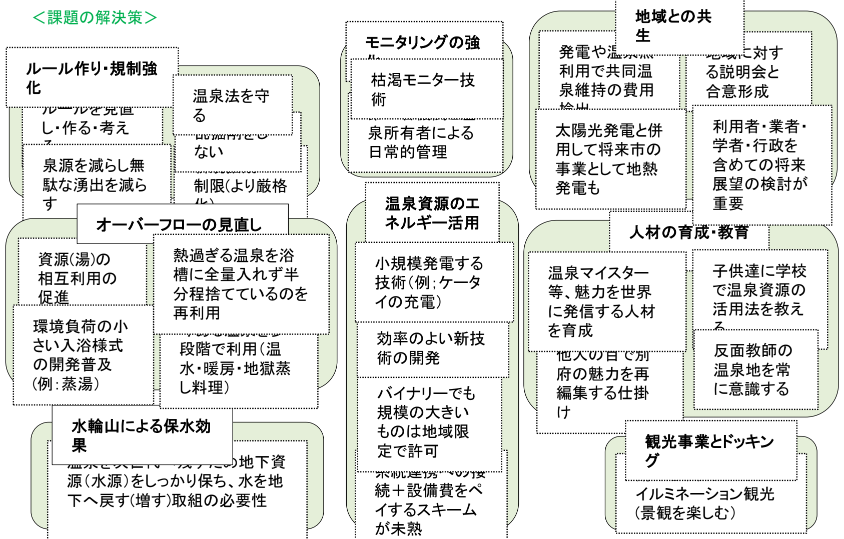
Stakeholder meeting (FY2014-15)

Sharing the results of stakeholder analysis and discussion

(Collecting local knowledge)

	Interests to climate change	Negative effects of climate change				Positive effects of climate change
		disease and pest	Sunburned	Bird and animal damage	Freezing injury	
Local official	△	○	○	○	―	○
Farmer	○	△	○	○	―	△
栽培技術員	○	○	○	○	○	△
流通	○	○	○	―	○	―
種苗	○	―	○	―	○	△
農業資材	×	○	―	―	―	△

Results of SH analysis and discussion



Scenario development (FY2016-17)

Making future scenarios by experts using Delphi method

(Collecting expert knowledge)

Scenario workshop (FY2017)

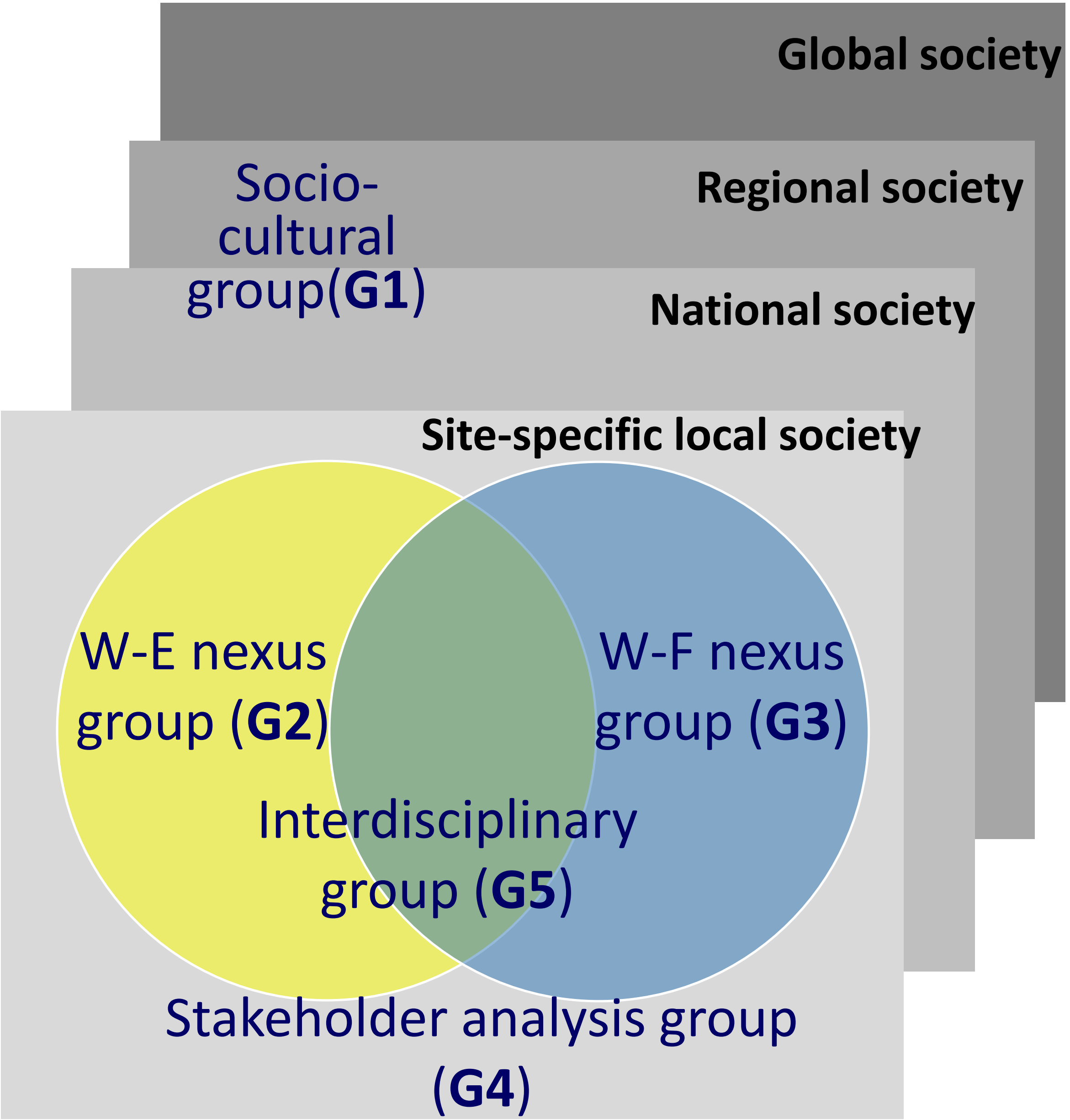
Providing scenarios and development of action plans by collaboration of stakeholders, general public and experts

(Integration of local knowledge and expert knowledge)

Interdisciplinary research

-Methods of the water-energy-food nexus

The structure of RIHN WEFN project



G1:

Jurisprudence/Anthropology/International relations /Sociology/Geography

G2:

Hydrology/Hydrogeology/Hydrometeorology/Geology/Geomorphology/Hot spring studies/ Geothermic/Limnology

G3:

Biology/Environmental science/Bioecology/Fisheries sciences

G4:

Public administration/Environmental policy studies/Social engineering

G5:

Environmental studies/Environmental economics/Fisheries economics/Computer science/ Policy studies

Interdisciplinary team with missions:

1. To identify research problems with local experts

2. To determine the methods and/or create new "discipline-free methods"

-synthesizing and harmonizing team-based production, collected from individual scientists in different disciplines from each team in order to assess human environmental security

-developing these approaches to incorporate non-scientific/non-disciplinary views on the analysis

Goup5 is developing methods following nexus in project each site

	Otsuchi			Obama			Beppu			Laguna de Bay		
	W	E	F	W	E	F	W	E	F	W	E	F
for W		—	—		P	—		—	—		—	—
for E	H		—	Gr		—	H/G/Gr		—	H		—
for F	F	—		F	P		F	—		F/A	—	

Source: Endo, Burnette, Orencio, Kumazawa, Wada, Ishii, Tsurita, Taniguchi 2015

H: micro-hydropower
F: fishery production
P: pumping
G: geothermal energy
Gr: ground heat exchanger system
A: agriculture production

Water-energy-food methodology and taxonomy

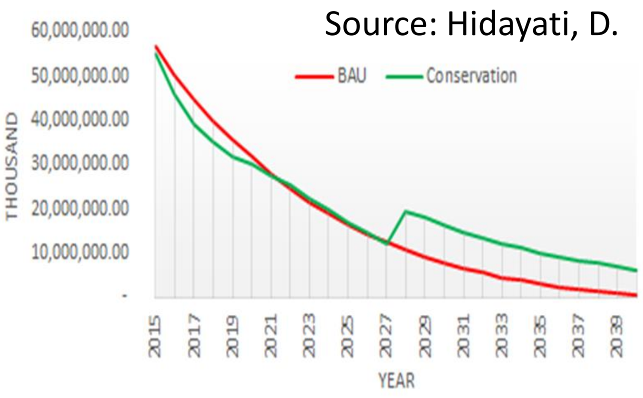
Type of Data		Functions / Methods	Interdisciplinary research approaches				Trans-disciplinary research approaches
Primary	Secondary		Unification	Visualization	Evaluation	Simulation	
Qualitative methods							
✓	✓	Questionnaire Surveys	✓	✓	✓	—	✓
—	—	Ontology Engineering	✓	✓	✓	✓	✓
✓	✓	Integrated Maps	✓	✓	✓	✓	✓
Quantitative methods							
✓	—	Physical Models	✓	✓	✓	✓	✓
✓	✓	Benefit-Cost Analysis	✓	✓	✓	—	✓
✓	✓	Integrated Indices	✓	✓	✓	✓	✓
✓	✓	Optimization Management Models	✓	✓	✓	✓	✓

Source: Endo, A., Orencio, P., Kumazawa, T. and Burnett, K. 2015

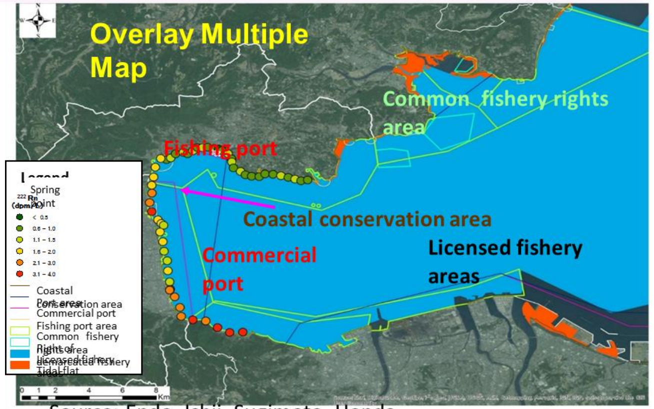
B.5 Develop integrated methods for ID & TD

Type of Data		Functions / Methods	Interdisciplinary research approac		
Primary	Secondary		Unification	Visualization	Evaluation
Qualitative methods					
✓	✓	Questionnaire Surveys	✓	✓	✓
—	—	Ontology Engineering	✓	✓	✓
✓	✓	Integrated Maps	✓	✓	✓
Quantitative methods					
✓	—	Physical Models	✓	✓	✓
✓	✓	Benefit-Cost Analysis	✓	✓	✓
✓	✓	Integrated Indices	✓	✓	✓
✓	✓	Optimization Management Models	✓	✓	✓

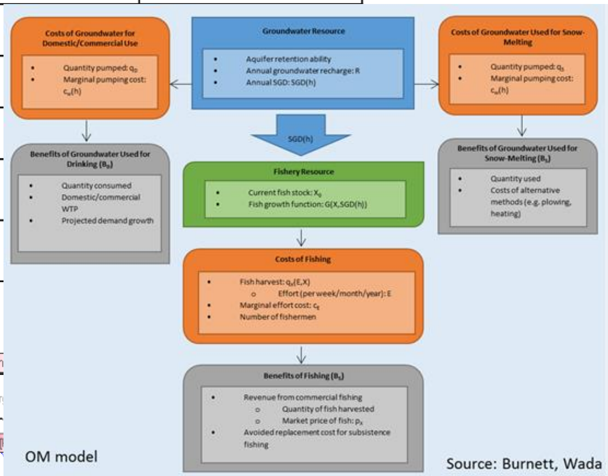
Source: Endo et al 2015



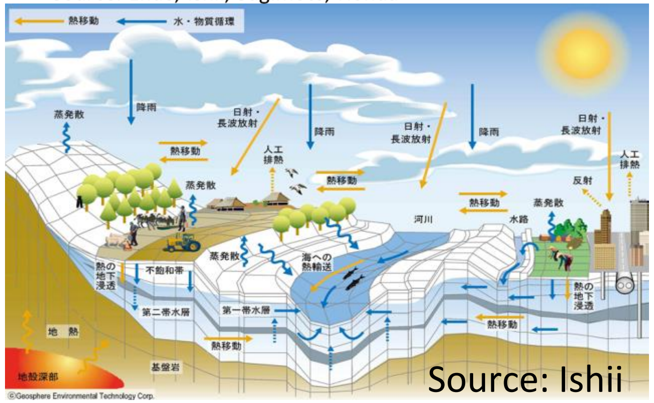
Source: Hidayati, D.



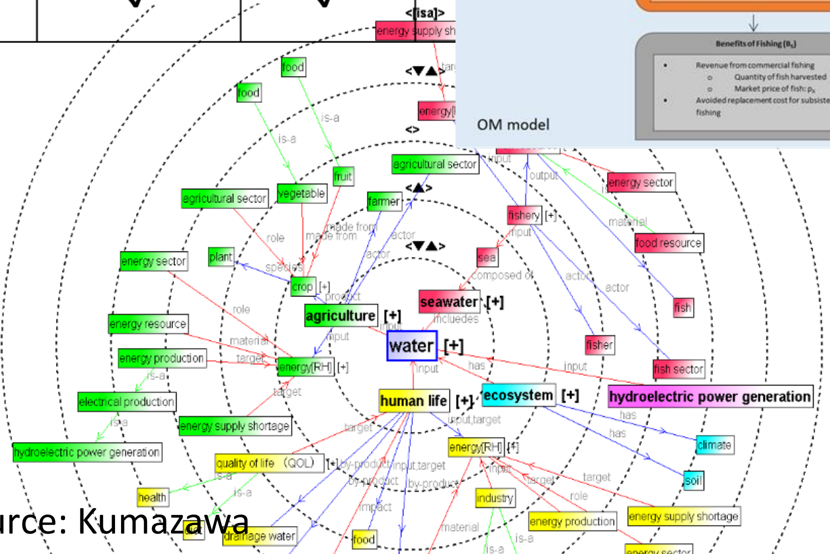
Source: Endo, Ishii, Sugimoto, Honda



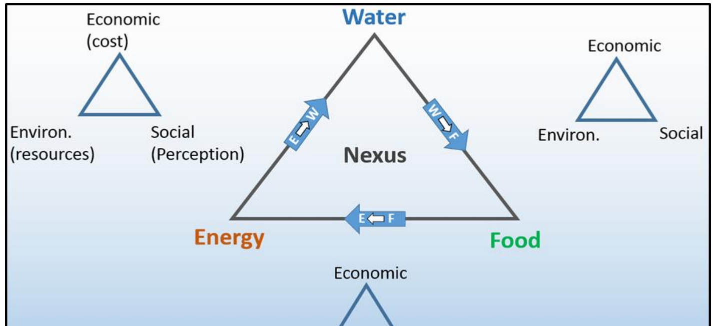
Source: Burnett, Wada



Source: Ishii



Source: Kumazawa



Source: Param et al

Interdisciplinary

B. Create policy options & scenarios to solve the identified nexus problems

B.4 Develop integrated methods for ID & TD

System design

Scenarios

Policy planning stage

Integrated index: incorporate and integrate each result with different disciplines, then evaluate trade-offs to maximize human environmental security

Ontology engineering: assess whether the policy/plan would cover all disciplines and sectors

Physical model: creating and providing policy options working with social scientists

BCA & Optimization management model: creating and providing policy options

Developing stage

Integrated map: provide an opportunity to share knowledge showing actual conditions at a spatial scale among stakeholders

Initial stage

Physical model: understanding the complexity of water-energy food nexus system

BCA & Optimization management model: clarifying trade-offs

Ontology engineering: designing the project to build a list of common concepts of term; the linkages of each term among stakeholders included researchers and practitioners

Questionnaire survey: collecting information to analyze WEF interlinkages when few data exist; then, it would help to identify the key issues

Pros and cons for nexus study: Qualitative methods for ID and TD

Methods	Pros	Cons
Questionnaire survey	-incorporating the local people's general outlook -collecting information to analyze WEF interlinkages when few data exist -identifying the key issues	-site-specific -limited spatial & temporal applications
Ontology	-designing the project to build a list of common conceptual terms; the linkages of each term among stakeholders included researchers and practitioners -designing and visualizing nexus system to understand the linkage, and tradeoffs relationship	
Integrated map	clarifying the dimensions where conflicts of interest emerge among stakeholders at a spatial scale	

Pros and cons of for nexus study: Quantitative methods for ID and TD

Methods	Pros	Cons
CBA	-clarifying trade-offs -creating and providing policy options	-site-specific -limited spatial & temporal applications
Physical model	to understand WEF nexus systems; if it were developed to clarify interlinkages between physical conditions of WEF	the results of integrated model simulation without social and local knowledge may lead people to misconstrue the model's results if the numbers from simulations are unrealistic for political, economic and other reasons
Integrated index	-allowing the data to be normalized for direct comparison with other results at different project locations -discipline-free-method	-site-specific -limited spatial & temporal applications
Optimization management model	-clarifying trade-offs -creating and providing policy options	

Designing and visualizing WEF Nexus system map

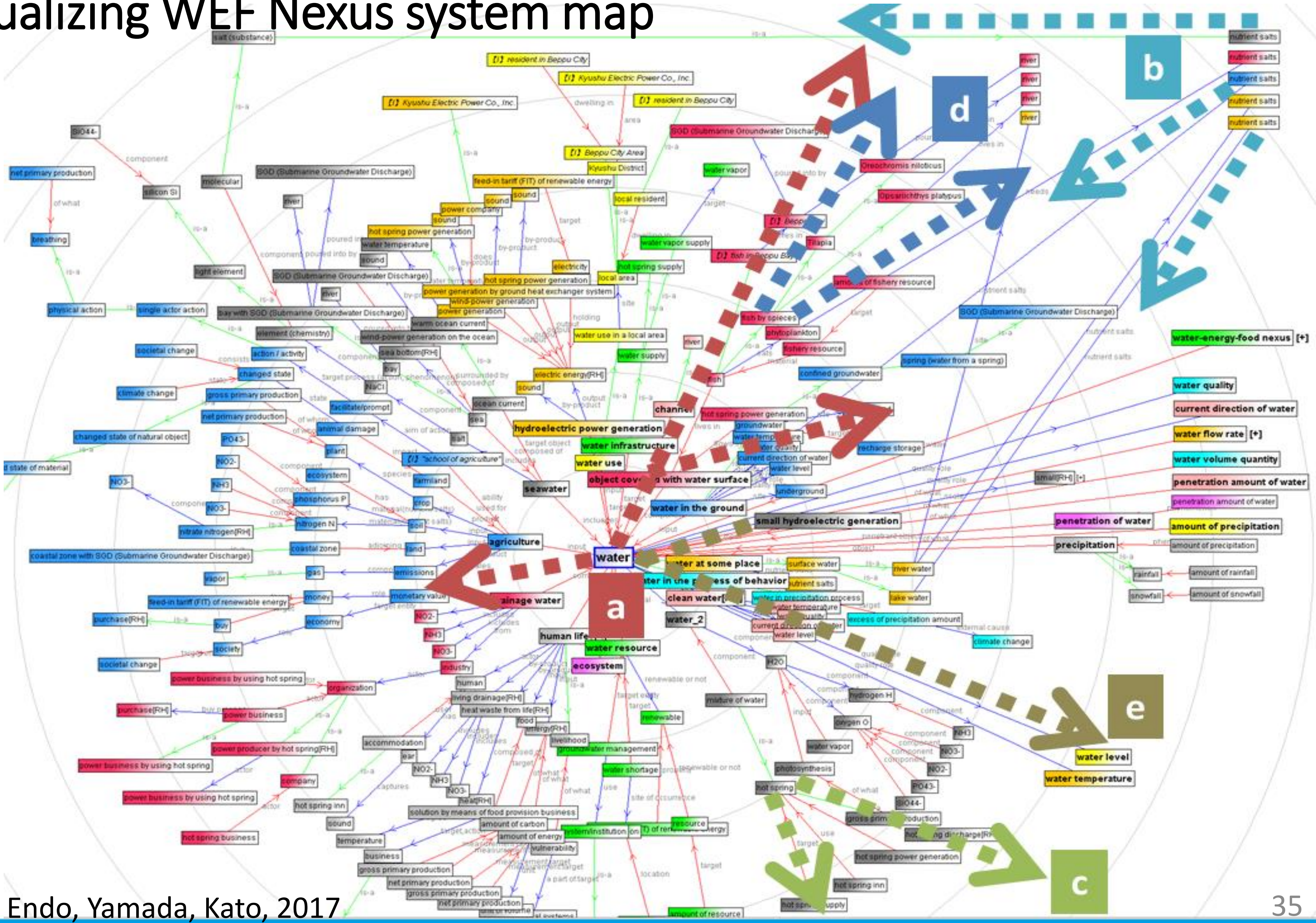


Figure : Kumazawa, Endo, Yamada, Kato, 2017

Designing and visualizing WEF Nexus system map

◻Objective of designing and visualizing a WEF Nexus system

To identify the interrelationships between WEF resources and to understand the subsequent complexity of WEF nexus systems holistically, taking an interdisciplinary approach

◻Hypothesis

the chains of changes in linkages between WEF resources affect the WEF nexus system holistically, temporally, and spatially

◻Challenges

- Clarify the linkages between events
- Identify the tradeoffs between resources/synergies
- Contribute to **scenario planning**

Designing and visualizing WEF Nexus system

(Robinson, 1990)

Scenario planning

✔ **Forecasting scenario planning**

1) problem setting
2) constructing casual networks to represent the targeted system
3) describing scenario storylines
4) describing details, including parameterization and quantification

✔ **Backcasting scenario planning**

1) determining the purpose of scenario building
2) specifying goals; constraints, and targets
3) describing the present system
4) specifying exogenous valuables
5) undertaking scenario analysis, including developing scenarios
6) undertaking impact analysis, including comparison of scenario results with predetermined goals

Designing and visualizing WEF Nexus system

Process of designing a WEF nexus system

-experts in different disciplines and with the same education level had a series of 8 expert group discussions, based on their knowledge, experiences, and instincts

-integrated, developed, and settled the discussion regarding the selection of methods, the development of the selected methods, and the integration of the developed methods

1) to understand a system from ***object-oriented programming concepts*** based on computer science
2) to identify the interrelationships between WEF and to design and visualize a WEF nexus system holistically for a site-specific case study from Beppu, Ōita Prefecture, Japan, using ***ontology engineering***
3) to discuss the possibility of introducing ***economic tools*** into scenario planning

Designing and visualizing WEF Nexus system: Nexus System Map

a) Tradeoff relationship in water use between food and energy production in the land area and in the marine area
b) Tradeoff relationship in nutrient salt use between the land area and marine area
c) Tradeoff relationship in hot spring water between the hot spring energy development and hot spring resort
d) Tradeoff relationship in water temperature between targeting river ecosystems
e) No tradeoff relationship in water use between small hydroelectric generation (energy production) and fishery resources

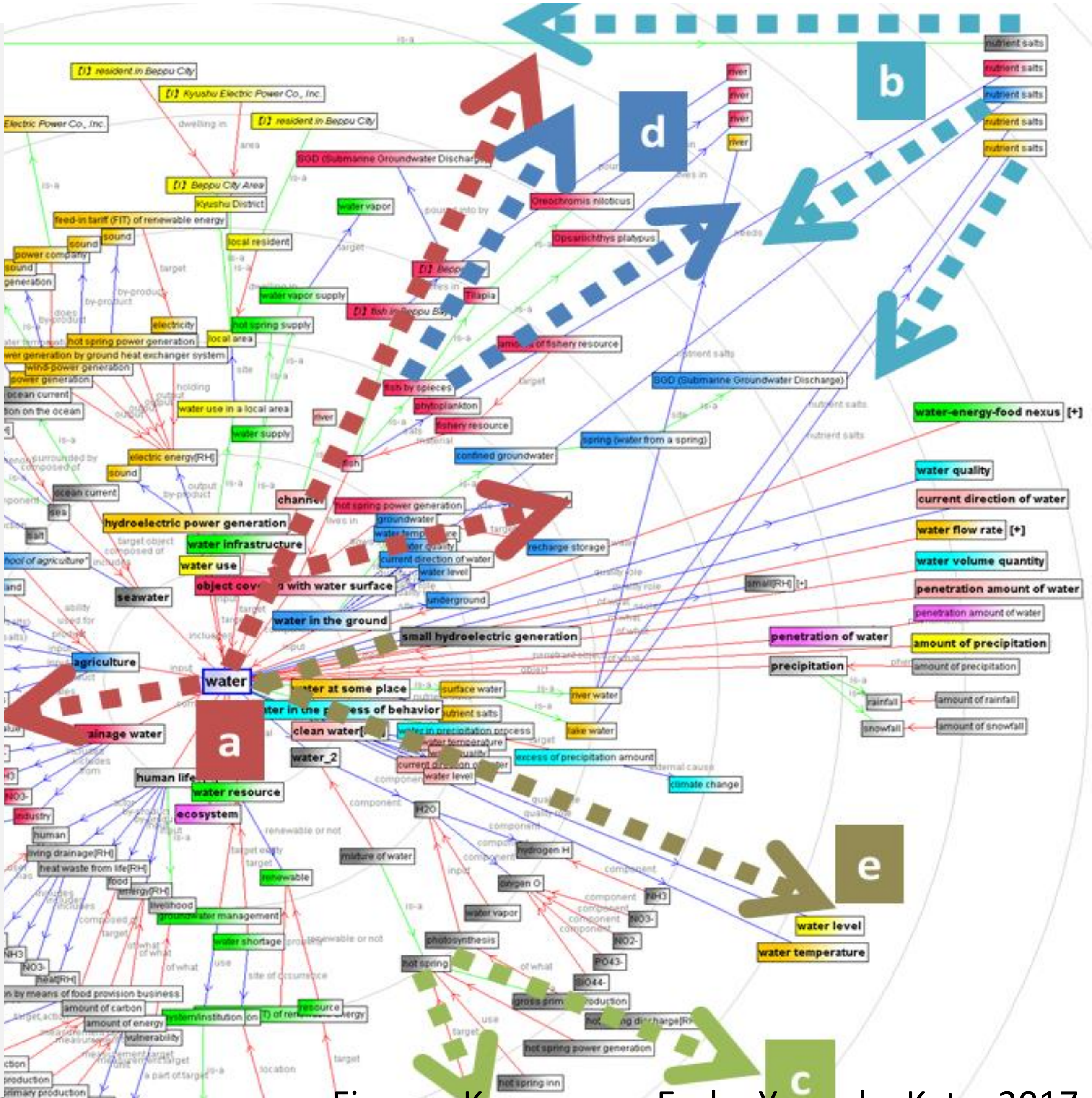


Figure : Kumazawa, Endo, Yamada, Kato, 2017

Co-production activities from Inter & transdisciplinary approach

Co-Production (Van der Hel, S. 2016): New modes of knowledge production

✔Accountability: enhance scientific accountability to society

◆Open local seminar/events co-organised with local governments in Otuchi (2015), in Obama (2016), in Hiji (2015)

◆Achievement to be published

✔Impact: ensure the implementation of scientific knowledge in society

◆Co-working with local governments to formulate local plans on sustainable groundwater use in Obama, Saijo/recovery plan in Otsuchi

✔Humility: include the knowledge, perspectives and experiences of extra-scientific actors in scientific knowledge production

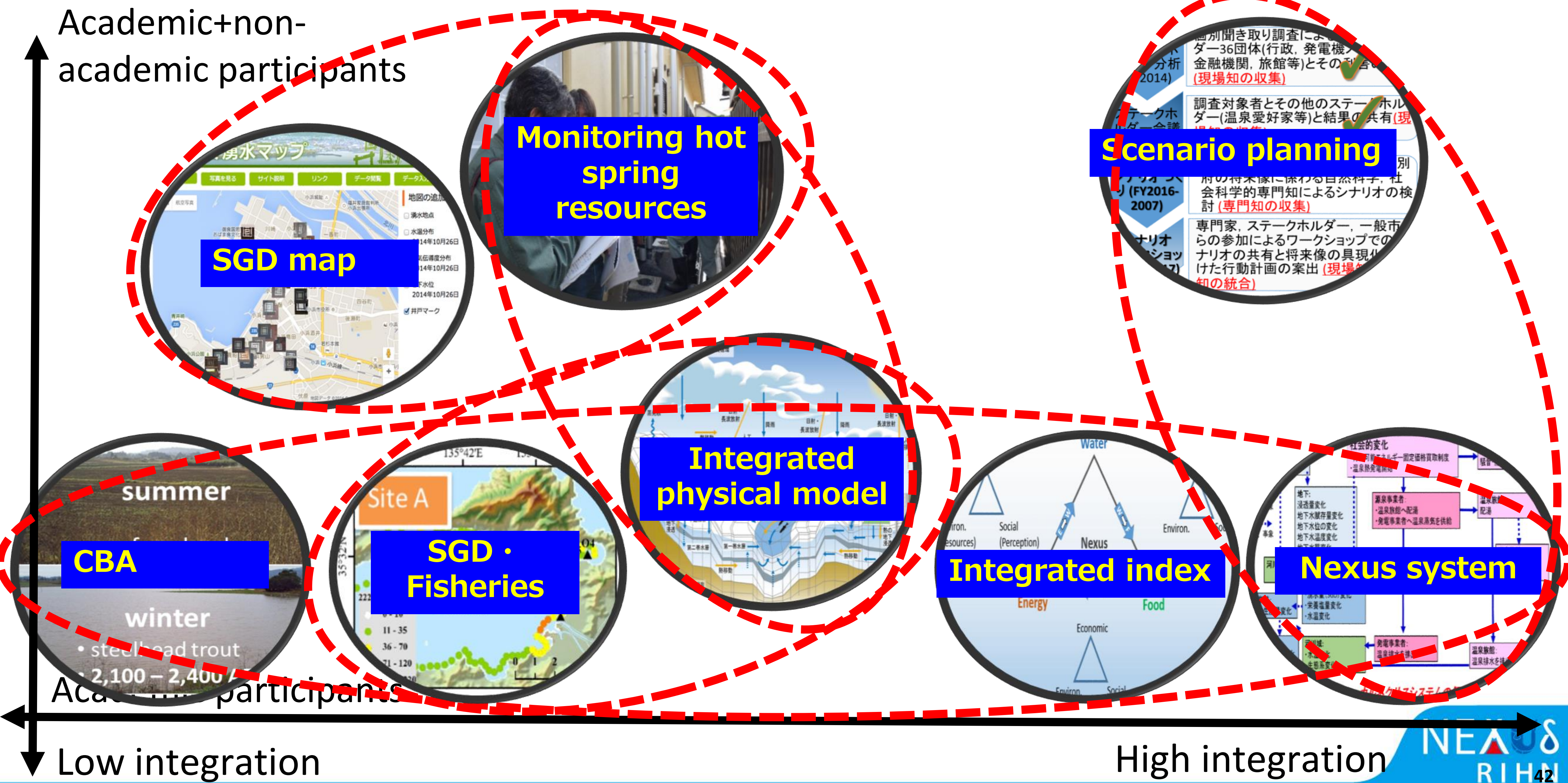
◆Scenario planning working with local stakeholders in Beppu

◆monitoring the temperature of hot spring resources in Beppu

◆Collaborating with private company

◆publicize groundwater information/data/knowledge on the web

Integration and stakeholder involvement (Tress et al. 2005)



Thank you.