Human-Environmental Security in Asia-Pacific Ring of Fire
- Water-Energy-Food Nexus -
RIHN 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 system.
Target areas

- Special issues: 22 papers
- Future Earth NEXUS-Cluster Apr 2016 at RIHN

RIHN initiative

Water use for producing or consuming food or energy on land might affect fisheries production in coastal areas.

SGD: Submarine Groundwater Discharge

Spatial scale

- Global society
- Regional society
- National society
- Site-specific local society

- W-E nexus group (G2)
- W-F nexus group (G3)
- Interdisciplinary group (G5)
- Site-specific stakeholder analysis group (G4)

RIHN initiative

Japan (Obama, Otsuchi, Beppu & others)
US, Canada, Indonesia, the Philippines

Science in/for society group (G1)

Future Earth NEXUS Cluster Apr 2016 at RIHN

Target areas

- 5 countries
- 35 countries

Future Earth NEXUS Cluster Apr 2016 at RIHN

SGD: Submarine Groundwater Discharge

Water use for producing or consuming food or energy on land might affect fisheries production in coastal areas.

SGD: Submarine Groundwater Discharge

W-E nexus group (G2)
W-F nexus group (G3)
Interdisciplinary group (G5)
Site-specific stakeholder analysis group (G4)
Temporal scale

Developing stage

Policy planning stage

Initial stage

**Water-Energy nexus: G2**

A.1 Analyse effective potential energy production using water
A.2 Examine the changes in river ecosystems caused by the changes in heat environment
A.3 Diversify renewable energy sources

**Water-Food nexus: G3**

A.4 Examine the interlinkages between groundwater and fishery production

**Stakeholder analysis: G4**

B.1 Identify WEF nexus SHs and their interests at SH meeting/individual interview
B.2 Clarify differences in public attitudes toward energy production
B.3 Study cultural significance of wells/springs in local communities/households

**Science in/for society: G1**

B.4 Develop integrated methods for ID & TD

**Interdisciplinary: G5**

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

Identify tradeoffs & conflicts

A. Understand the complexity of WEF nexus system

Scientific uncertainty

Scientific evidence

A. Identify tradeoffs & conflicts

B. Create policy options & scenarios to solve the identified nexus problems
A. Understand the complexity of WEF Nexus system

A.1 Analyse effective potential energy production using water

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

Small hydropower in Beppu

Shale gas in Canada

Hot spring drainage water in Beppu

0.0164 kcal/kg-water

66,000 kcal/kg-water

16.3 kcal/kg-water

Population of fish in Hiya & Hirata River

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

Nile Tilapia

(Oreochromis niloticus)

Barcheek Goby

(Rhinogobius giurinus)

Source: Yamada

Source: Fujii & Yamada
A. Understand the complexity of WEF nexus system

A.3 Diversify renewable energy sources

**Small Hydropower**

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

(a) All the potential
(b) Excluding points where natural head is <10m
(c) Excluding points without electric lines and with conflicts with salmon and brisling

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

Source: Nishijima

- Groundwater level

Source: Sawadate & Fujii

- Geothermal

Source: Hamamoto & Miyashita
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

Higher fish abundance was observed at area with more SGD

Source: Shoji

Change in SGD rate
Change in nutrients flux
Change in primary production
Change in fishery resources

A positive correlation between Primary production and Radon concentration (SGD)

Source: Sugimoto

Fish sampling
100 m² Seine net 4 mm mesh

More fishes

Kamaiso (more SGD)
Shonai (less SGD)

Radon Concentration

Fish Number / Area

Fish Weight / Area

Kamaiso
Shonai

More SGD at Kamaiso

More fishes

Fewer fishes

Source: Shoji

Obama Bay

Primary Productivity (mgC L⁻¹ hr⁻¹)

$^{222}$Rn (Bq L⁻¹)

$\rho < 0.01$

$r = 0.76$

June
July
Aug
A. Understand the complexity of WEF nexus system

1. Change in SGD rate

2. Change in nutrients flux

3. Change in primary production

4. Change in fishery resources

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**Water-Food nexus**

- **222Rn (dpm/L)**
- **Hiji coast**

Source: Sugimoto

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**Obama Bay**

- SGD flux: 0.3 % 
  \((0.36 \times 10^6 \text{ m}^3 \text{ day}^{-1})\)

- DIN flux of SGD: 17% 
  \((443 \text{ kg day}^{-1})\)

- DIP flux of SGD: 26% 
  \((38 \text{ kg day}^{-1})\)

DIN via SGD play an important role in biological production

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**Otsuchi Bay**

- SGD flux: 0.2 % 
  \((0.43 \times 10^6 \text{ m}^3 \text{ day}^{-1})\)

- DIN flux of SGD: 6% 
  \((300 \text{ kg day}^{-1})\)

- DIP flux of SGD: 0.2% 
  \((1.7 \text{ kg day}^{-1})\)

DIN via SGD have a substantial contribution on primary production

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**Dissolved Inorganic Phosphorus (umol/L)**

DGP is the main source of DIP

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**Dissolved Inorganic Nitrogen (umol/L)**

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

#### Source: Baba

<table>
<thead>
<tr>
<th>Japan</th>
<th>Philippines</th>
<th>Indonesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.0%</td>
<td>16.0%</td>
<td>11.0%</td>
</tr>
<tr>
<td>15.3%</td>
<td>47.7%</td>
<td>15.3%</td>
</tr>
<tr>
<td>22.7%</td>
<td>73.7%</td>
<td>25.7%</td>
</tr>
<tr>
<td>16.0%</td>
<td>13.0%</td>
<td>11.0%</td>
</tr>
</tbody>
</table>

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

#### 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

- **Japan**: Referendum
- **Philippines & Indonesia**: Joint fact finding

#### Online survey focusing on general public

- **Japan**: Referendum
- **Philippines & Indonesia**: Joint fact finding

#### Stakeholder analysis

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

#### Table: Self-Assessment of SH Meeting

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Not at all</th>
<th>Slightly</th>
<th>Fairly</th>
<th>Very much</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Indifference</td>
<td>5%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Anxiety</td>
<td>5%</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Restoration of fishery industry</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Importance of water resource</td>
<td>10%</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
</tbody>
</table>

#### Graphs:

- **California**: Join groundwater-related activities more than once per month
- **US**: Less than 20%
- **Japan**: Over 90%
B.4 Develop integrated methods for ID & TD

Interdisciplinary

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Function</th>
<th>Interdisciplinary research approaches</th>
<th>Trans-disciplinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td></td>
<td>Unification</td>
<td>Visualization</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Qualitative methods

- ✔ ✔ Questionnaire
- ✔ ✔ Ontology
- ✔ ✔ Integrated Maps

Quantitative methods

- ✔ Physical Models
- ✔ CBA
- ✔ Integrated Indices
- ✔ ✔ OM Models

Costs of Groundwater for Domestic/Commercial Use
- Quantity pumped: \( q_D \)
- Marginal pumping cost: \( c_{w,D} \)
- Aquifer retention ability
- Annual groundwater recharge: \( R \)
- Annual SGD: \( SGD(h) \)

Benefits of Groundwater Used for Drinking (\( B_{D} \))
- Quantity consumed
- Domestic/commercial WTP
- Projected demand growth

Fishery Resource
- Current fish stock: \( X_0 \)
- Fish growth function: \( G(X,SGD(h)) \)

Costs of Fishing
- Fish harvest: \( q_x(E,X) \)
- Effort (per week/month/year): \( E \)
- Marginal effort cost: \( c_{E} \)
- Number of fishermen

Benefits of Fishing (\( B_{S} \))
- Revenue from commercial fishing
- Quantity of fish harvested
- Market price of fish: \( p_x \)
- Avoided replacement cost for subsistence fishing

OM model

Source: Burnett, Wada
<table>
<thead>
<tr>
<th>Methods</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire</td>
<td>-incorporating the local people’s general outlook</td>
<td>-site-specific case studies</td>
</tr>
<tr>
<td>survey</td>
<td>-collecting information to analyze WEF interlinkages when few data exist</td>
<td>-limited spatial &amp; temporal applications</td>
</tr>
<tr>
<td></td>
<td>-to identify the key issues</td>
<td></td>
</tr>
<tr>
<td>Ontology</td>
<td>-designing the project to build a list of common conceptual terms; the linkages of each term among stakeholders included researchers and practitioners</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-assess whether the policy/plan would cover all disciplines including natural sciences, social sciences and the humanities, and sectors such as WEF</td>
<td></td>
</tr>
<tr>
<td>Integrated map</td>
<td>provide an opportunity to share knowledge showing actual conditions at a spatial scale among stakeholders</td>
<td></td>
</tr>
</tbody>
</table>
## Pros and cons of nexus study: Quantitative methods for ID and TD

<table>
<thead>
<tr>
<th>Methods</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCA</td>
<td>- clarifying trade-offs</td>
<td>- site-specific case studies</td>
</tr>
<tr>
<td></td>
<td>- creating and providing policy options</td>
<td>- limited spatial &amp; temporal applications</td>
</tr>
<tr>
<td>Physical model</td>
<td>to understand WEF nexus systems; if it were developed to clarify</td>
<td>the results of integrated model simulation without social and local</td>
</tr>
<tr>
<td></td>
<td>interlinkages between physical conditions of WEF</td>
<td>knowledge may lead people to misconstrue the model’s results if the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>numbers from simulations are unrealistic for political, economic and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>other reasons</td>
</tr>
<tr>
<td>Integrated index</td>
<td>- normalized data to allow for direct comparison with other results</td>
<td>- site-specific</td>
</tr>
<tr>
<td></td>
<td>at different project locations</td>
<td>- limited spatial &amp; temporal applications</td>
</tr>
<tr>
<td></td>
<td>- discipline-free-method</td>
<td></td>
</tr>
<tr>
<td>Optimization management model</td>
<td>- clarifying trade-offs</td>
<td></td>
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<td></td>
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</table>
B. Create policy options & scenarios to solve the identified nexus problems

B.4 Develop integrated methods for ID & TD

**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

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

**Developing stage**

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

**Initial stage**

*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
Climate change:
- Precipitation
- Temperature

Social change:
- Feed-in tariff scheme for renewable energy
- Initiative for hot spring energy development

Local citizen:
- Complain about noise

Hot spring inn:
- Allocation of hot spring water

Kyushu Electric Power Co., Inc:
- Buy electricity

Hot spring inn:
- Change in quantity
- Change in temp.

Developers:
- Production of electricity

Allocators/distributors:
- Allocation of hot spring water
- Allocation of hot spring steam

Hot spring inn:
- Allocation of hot spring drainage water

Developers:
- Hot spring wastewater

Allocators/distributors:
- Allocation of hot spring water
- Allocation of hot spring steam

Underground:
- Change in recharge
- Change in GW storage
- Change in GW level
- Change in water temp.
- Change in water quality
- Change in flow direction

River:
- Change in water temp.
- Change in ecosystem

Coasts:
- Change in primary production

Coasts:
- Change in SGD rate
- Change in nutrients flux
- Change in water temp.

G3

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

Source: Endo & Yamada
Thank you very much.
1. What are the pros and cons using your methods to address the nexus issues (reducing tradeoffs or minimizing conflicts)?

2. What’s new in your methods to address nexus issues, such as developing the functions of existing methods, or developing new methods?

3. When and how can you use your methods effectively to address interdisciplinary and transdisciplinary research approaches (under the project if you are a member of the project)?

4. How can you use your methods to address nexus issues from the perspective of temporal and spatial (from local to global or from global to local, or, local to local) scales?