CONCEPTUAL FRAMEWORK FOR COMPARATIVE ANALYSIS OF INTEGRATED WATER RESOURCES MANAGEMENTS IN ANDEAN REGION: —A PROPOSAL & CASE STUDY—

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(JAPAN-CGIAR Fellowship Program 2007-2008)
WHO IS SHINJI FUKUDA???

- Japanese
- Ecological modelling (fish habitat, paddy environment, agriculture)
- Tropical Agriculture (Vietnam, Laos, Thailand, etc)
- JAPAN-CGIAR Fellowship Program 2007-2008 (two months in CONDESAN/CIP-Lima)
 CONTENTS

A) Self-introduction
B) Introduction (background, objective)
C) Methods (conceptual framework)
D) Application (a case study)
E) Discussions (merit & demerit)
F) Future Perspectives
ANDEAN SYSTEM OF BASINS

Challenge Program for Water & Food:
International, multi-dimensional, research-for-development initiatives
1st Phase: 2003-2008
- La Miel
- Fuquene
- El Angel
- Ambato
- Altomayo
- Jequetepeque
- Tunari
OBJECTIVES

● Developing conceptual framework
  ➔ *Comparison between basins*
    - Evaluation of past project
      ✓ *How much have we achieved?*
    - For the future directions
      ✓ *How far will we go?*
  
  ➔ *Clarification of key factors for the success*
  ➔ *Sharing experiences between basins*
**How?**

- Existing methodology
  - Water Poverty Index (e.g., Sullivan, 2003)
    - (Access, Resources, Capacity, Use, Environment)
  - Require specific surveys...time consuming...

**What are the tools for?**

- Seeking a future direction (decision-making)
- How to negotiate among stakeholders
- How stakeholders can get closer
- Share image of the past, present, and future

**Should be simple & generally acceptable**
THE PRESENT APPROACH

- **Main components**
  1. Biophysical environment \((BP)\)
  2. Agriculture \((AGR)\)
  3. Socio-economics \((SE)\)
  4. Ecosystems \((ECO)\)

- Index in the range of \([0, 1]\)

- **Integrating components**

\[
\text{Basin Index} = I_{BP} \times I_{AGR} \times I_{SE} \times I_{ECO} \quad (1)
\]

\[
\text{Basin Index} = \left( I_{BP} \times I_{AGR} \times I_{SE} \times I_{ECO} \right)^{\frac{1}{4}} \quad (2)
\]
## BASIC CONCEPT

### Past status

<table>
<thead>
<tr>
<th>Component</th>
<th>10 yrs ago</th>
<th>5 yrs ago</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biophysics</td>
<td></td>
<td></td>
<td>▼</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>↑</td>
<td></td>
</tr>
<tr>
<td>Socio-economics</td>
<td>▼</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystem</td>
<td></td>
<td></td>
<td>▼</td>
</tr>
<tr>
<td>TOTAL</td>
<td>▼</td>
<td></td>
<td>○ or ×</td>
</tr>
</tbody>
</table>

### Future Goals

<table>
<thead>
<tr>
<th></th>
<th>5 yrs later</th>
<th>10 yrs later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biophysics</td>
<td>↑</td>
<td>○ (?)</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td>○ (?)</td>
</tr>
<tr>
<td>Socio-economics</td>
<td>↑</td>
<td>○ (?)</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>↑</td>
<td>○ (?)</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>○ (?)</td>
</tr>
</tbody>
</table>
COMPONENT 1 (BIOPHYSICAL ENV.)

- Potential Water Availability
  - Ratio of months with sufficient PWA
    - Precipitation
    - Evapotranspiration

  \[
  \text{Wetness Index} = \frac{\text{Precipitation (mm)}}{\text{Potential ET (mm)}}
  \]

- Access to water
  - Ratio of population with the access

- Access to irrigation
  - Ratio of area with irrigation
COMPONENT 2 (AGRICULTURE)

● Water Productivity
  ➔ Agricultural yields per water resources
  ■ Land use
  ■ Cropping pattern
  ■ Farming system

● Crop Suitability Index
  ■ Potato, beans, peas, wheat, barley, etc
  ➔ Crop-specific indices (climate, altitude, etc)
**PWA-based approach**

\[
Water \, Productivity = \frac{\text{Crop production (ton/year)}}{WI} \\
I_{\text{AGR}} = \frac{(WP_{\text{Goal}} - WP_i)}{WP_{\text{Goal}}}
\]

![Graph showing the relationship between Water Productivity and Score](image)
Crop suitability-based approach (FAO, 2007)

- Soil, Slope, Air temperature.
- Cropping pattern, growing season, etc.
- GIS software is necessary...
CROP SUITABILITY EXAMPLE

The use of knowledge

Source: Hijmans (2001)
CROP SUITABILITY OUTPUT


White Potatoes

Maize
COMPONENT 3 (SOCIO-ECONOMICS)

- HDI (Human Development Index)
- HPI (Human Poverty Index)
- Community-level, District-level, Country-level

♣ Additional information
- Income sources (agriculture, industry, others)
- Education (% enrolment, literacy rate, etc)
- Infrastructure (water & sanitation)
- Labour force

✓ GDI (Gender-related Development Index)
INDEX BASED ON HDI & HPI

(0 ≤ HPI ≤ 1)

(0 ≤ HPI ≤ 100)

\[ I_{SE} = \left\{ \text{HDI} \times \left(1 - \frac{\text{HPI}}{100}\right) \right\}^{\frac{1}{2}} \]
COMPONENT 4 (ECOSYSTEM)

- How to index?
  - Habitat suitability approach
  - Species composition
  - Expert knowledge-based approach

- Strongly dependent on each basin

For instance,
  - Fuquene: Paramo (high land), Lake (low land)
  - Mojanda: Paramo including lakes (high land)
FUQUENE

- Paramo is affected by potato production
- Lake receives waste water (dom. & agr.)
MOJANDA

● Paramo provides water to all the people
### ECOSYSTEM INDEX

1. \[ I_{ECO,1} = \frac{\text{Actual Area of Paramo}}{\text{Potential Area of Paramo}} \]

2. \[ I_{ECO,2} = \frac{\text{Actual number of species}}{\text{Previously reported number of species}} \]

3. The “**length of fallow period**” can be used as an indicator for “**ecological status of paramo**.”

   Paramo recovers after 4 or 5 yrs fallow  
   (Sarmiento, 2002)
THE PRESENT APPROACH

- Main components
  ① Biophysical environment (BP)
  ② Agriculture (AGR)
  ③ Socio-economics (SE)
  ④ Ecosystems (ECO)
  - Index in the range of [0, 1]

- Integrating components

\[
\text{Basin Index} = I_{BP} \times I_{AGR} \times I_{SE} \times I_{ECO} \quad (1)
\]

\[
\text{Basin Index} = \left( I_{BP} \times I_{AGR} \times I_{SE} \times I_{ECO} \right)^{\frac{1}{4}} \quad (2)
\]
PRODUCT OR GEOMETRIC MEAN

(1) Product

EXAMPLE

IF: A is bad
THEN: Totally bad

(2) Geometric

IF: A is bad, but B is Good
THEN: Totally acceptable (compensatory)
HOW IT WORKS???

Sorry!!!
I could not prepare enough data
(community-level data at any basins)

→ An example using country-base data
(Colombia, Ecuador, Peru, Bolivia, Chile)

- Assuming each country as towns in the basin...

✓ No agricultural & ecosystem analyses

→ Can be done by using GIS software
# APPLICATION RESULTS (TOTAL)

<table>
<thead>
<tr>
<th>Component</th>
<th>Past status</th>
<th>Future Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biophysics</td>
<td>0.42</td>
<td>0.45</td>
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<tr>
<td>Agriculture*</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>Socio-economics</td>
<td>0.818</td>
<td>0.832</td>
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<tr>
<td>Ecosystem*</td>
<td>1.00</td>
<td>0.90</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.724</td>
<td>0.721</td>
</tr>
<tr>
<td>Community</td>
<td>PWA</td>
<td>Irrigation</td>
</tr>
<tr>
<td>-----------</td>
<td>-----</td>
<td>------------</td>
</tr>
<tr>
<td>Colombia</td>
<td>0.50</td>
<td>0.20</td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.50</td>
<td>0.29</td>
</tr>
<tr>
<td>Peru</td>
<td>0.25</td>
<td>0.28</td>
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<tr>
<td>Bolivia</td>
<td>0.33</td>
<td>0.04</td>
</tr>
<tr>
<td>Chile</td>
<td>0.17</td>
<td>0.83</td>
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<tr>
<td><strong>ALL</strong></td>
<td>0.35</td>
<td>0.33</td>
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</table>
**SOCIO-ECONOMICS RESULT (2005)**

<table>
<thead>
<tr>
<th>Community</th>
<th>Life</th>
<th>Education</th>
<th>GDP</th>
<th>HDI</th>
<th>1-HPI/100</th>
<th>TOTAL</th>
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</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>0.788</td>
<td>0.869</td>
<td>0.716</td>
<td>0.791</td>
<td>0.921</td>
<td>0.854</td>
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<tr>
<td>Ecuador</td>
<td>0.828</td>
<td>0.858</td>
<td>0.629</td>
<td>0.773</td>
<td>0.913</td>
<td>0.840</td>
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<tr>
<td>Peru</td>
<td>0.761</td>
<td>0.872</td>
<td>0.684</td>
<td>0.772</td>
<td>0.884</td>
<td>0.826</td>
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<tr>
<td>Bolivia</td>
<td>0.662</td>
<td>0.865</td>
<td>0.557</td>
<td>0.695</td>
<td>0.864</td>
<td>0.775</td>
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<tr>
<td>Chile</td>
<td>0.889</td>
<td>0.914</td>
<td>0.799</td>
<td>0.867</td>
<td>0.963</td>
<td>0.914</td>
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<tr>
<td><strong>ALL</strong></td>
<td>0.786</td>
<td>0.876</td>
<td>0.677</td>
<td>0.780</td>
<td>0.909</td>
<td>0.842</td>
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DISCUSSIONS

A Framework with general viewpoints

● Evaluation of Past & Present status
  ■ What is the achievement?
  ■ How much was it degraded?
  ■ Gaps between basins, communities, upstream & downstream regions, etc.

● Future Direction
  ■ Which sectors or communities should be strengthen?
  ■ What is the breakthrough?
  ➔ Specific analyses (e.g., SWAT, GT, etc)
DISCUSSIONS (CONTD.)

● Problem?
  - Availability of community-level data
  - Accuracy of measurement
  - Uncertainty (e.g. lack of capacity assess)
  - Acceptability among stakeholders

● Strength?
  - Generality across the basins
  - High accessibility to the data required
  - Easy to continue
FUTURE PERSPECTIVES

What shall we do?
- Further accumulation of data and information (monitoring)
- Sharing experience & knowledge
  - Understanding of historical changes (quantitative & qualitative)
  - Evaluation of traditional agriculture (systems, techniques, varieties, etc)
### Gráfico Histórico

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<tr>
<td><strong>Forest &amp; Paramos</strong></td>
<td><img src="image" alt="Forest" /></td>
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<tr>
<td><strong>Water issue: Availability &amp; Quality</strong></td>
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<tbody>
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<td><strong>Status of Lake</strong></td>
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<td><img src="image" alt="Lake" /></td>
<td><img src="image" alt="Lake" /></td>
<td><img src="image" alt="Lake" /></td>
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</tbody>
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Source: GTZ, CONDESAN, CAR (2004)
There would be a question...

Higher Income (export?)

Higher productivity

Tolerance to harsh environments (frost, temp., etc)

Technological innovations

Why potatoes?

Question???

• Where we can cultivate and where we cannot?
• What is the best practice?
→ Multi-disciplinary framework!!!