Ecosystem-based coastal protection of atoll island countries against sea level rise

“Sustainable ecosystem management” is equal to “Sustainable land management (coastal protection)” against sea level rise in small island countries.

Hajime Kayanne (Univ. Tokyo)

Fongafale Is, Tuvalu
## Distribution of atolls

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of atolls</th>
<th>Population (10 thousand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Ocean</td>
<td>392</td>
<td></td>
</tr>
<tr>
<td>Micronesia</td>
<td>88 Polynesia</td>
<td>107 Melanesia</td>
</tr>
<tr>
<td>SE Asia</td>
<td>114 Australia</td>
<td></td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>41 West</td>
<td>25 Middle East</td>
</tr>
<tr>
<td>Atlantic Ocean</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>N. Caribbean</td>
<td>4 W. Caribbean</td>
<td>15 E. Caribbean</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>482</td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
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<tbody>
<tr>
<td>Pacific Ocean</td>
<td>30 (29)</td>
<td>13.3</td>
</tr>
<tr>
<td>Republic of Micronesia</td>
<td>28 (20)</td>
<td>6.8</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>6 (5)</td>
<td>1.1</td>
</tr>
<tr>
<td>Republic of Kiribati</td>
<td>26 (14)</td>
<td>9.2</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>8 (6)</td>
<td>2</td>
</tr>
<tr>
<td>French Polynesia</td>
<td>79 (43)</td>
<td>24.9</td>
</tr>
<tr>
<td>Republic of Maldives</td>
<td>22 (22)</td>
<td>30.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>87.4</td>
</tr>
</tbody>
</table>
Global threats

Global mean sea level rise

IPCC AR5 (2013)

Nukutoa, Takuu Atoll, PNG

Funafuti Atoll, Tuvalu

Batio, Tarawa Atoll, Kiribati
Ecological process in island formation

Foraminifera sand

Fongafale Is, Funafuti, Tuvalu
Atoll islands are formed by organisms.
Water pollution by sewage effluent

"Bottomless" Septic Tank

Reduced layer 2-3cm below bottom

H₂S

e.coli concentration 25 times higher than Japanese environmental criteria.

Ecosystem deterioration

Fongafale Is, Funafuti, Tuvalu
Almost one million forams in one square meters.

Majuro Atoll, Marshall Is.
Is Tuvalu sinking?

Land use: expansion of residential area to vulnerable low land

Fongafale Is, Funafuti, Tuvalu

Yamano et al. (2007)
Constructions against natural process

Vertical sea walls prevent sand sedimentation at their foots.

Causeways prevent sand transportation

from ocean to lagoon or release to deep ocean through boat channel.
Geo-Ecological process is degraded by local human activities

**Production**
- Ecosystem degradation by seawater pollution
  - Dead corals covered by macro algae
  - Reduced layer 2-3cm below sand

**Transportation**
- Sand drift interrupted by jetties and dredges
  - 2003

**Seimentation**
- Beach erosion by vertical seawalls
  - Vertical seawalls
  - Loss of coastal vegetation

**Erosion**
- Sand drift

Geo-ecological process is degraded by local human activities.
Ecosystem-based coastal protection

Beach nourishments
(not vertical seawalls)

Fongafale Is, Funafuti, Tuvalu

JICA technical cooperation project
(photos by Nippon Koei)
Ideal design of the causeway.
Open-cut to the level of reef flat.
Sewage treatment by bacteria and seawater (Fujita 2016)

Organic matter = 18gBOD/PE/d
$\text{SO}_4^{2-} = 0.4gS/PE/d$
∴ BOD : S = 45 : 1

Immobile carrier of Sulfate-reducing bacteria

$\text{BOD} + \text{SO}_4^{2-} \rightarrow \text{H}_2\text{S} + \text{CO}_2 + \text{H}_2\text{O}$
∴ BOD : S = 1.6 : 1

Soil does not have sufficient $\text{SO}_4^{2-}$ to degrade BOD.

Sea water is used!!

Sepic Tank

Tide

$\text{SO}_4^{2-}=0.9gS/L$
Production

Improvement of coastal environment is required before or in parallel with any ecosystem rehabilitation challenges.

Then we can adopt ecotechnology.

Coral culture and transplantation

Okinotorishima

Foram culture

Tuvalu
Sustainable ecosystem management equals sustainable land management against sea level rise in small island countries.
• Only ecosystem-based management cannot save small islands from rising sea level.
• However, any grey countermeasure works must NOT conflict with, and should enhance natural ecological process which forms the island and coast.
• Combined grey and green technologies are necessary.
• Ecosystem-based management needs understanding by local people and governments, and socio-economical aspects of small island countries.
Adaptive geo-ecosystem

Geo-ecosystem provides many benefits to local social system

= Smooth

Sound geo-ecosystem

High geo-ecological resilience

Traditional island community

Traditional governance
Current social system in Island community

High energy inflow from global economy and international society

= Crushing

Bloated island community

Introduced governance
- Non-adaptive measures
- Seawall/Wastewater treatment/
- Human resource management

Badly-degraded geo-ecosystem

Low geo-ecological resilience
Current social system

In island community, low geo-ecological resilience directly links to the collapse of national land

We proposed several eco-technological measures...BUT
Adaptive social system with high resilience

Enhancing geo-ecological resilience based on traditional governance
Creating new governance system to harmonize all gears (global economy, island community, geo-ecosystem)