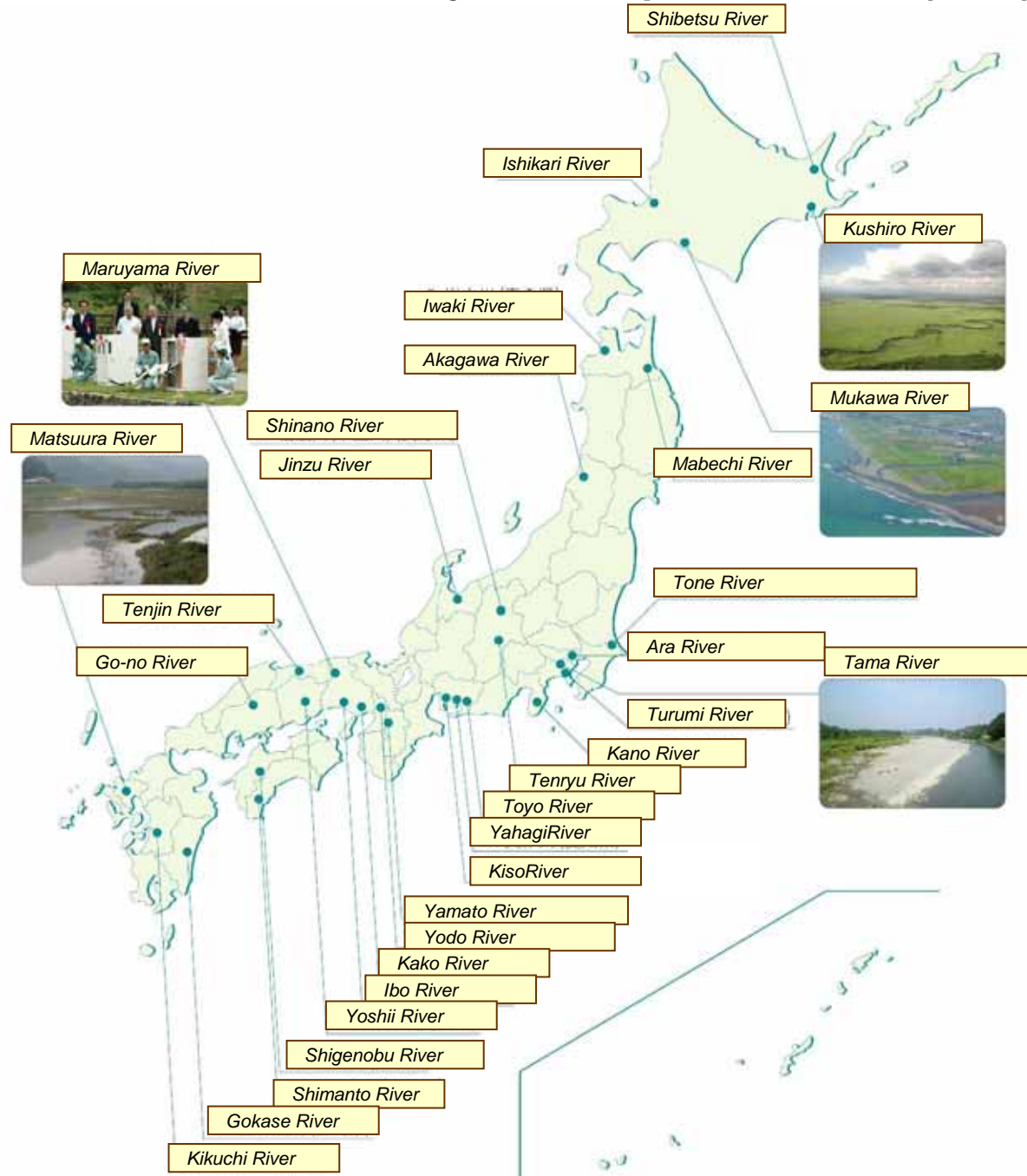# Development of Eco-Compatible River Basin Management toward Nature Restoration
~ Case of Ise bay River Basin ~

Yuji Toda and Tetsuro Tsujimoto

Nagoya University

# Nature Restoration Projects of Japanese Rivers (2006)

- Shibetsu River
- Ishikari River
- Kushiro River
- Maruyama River
- Iwaki River
- Akagawa River
- Mukawa River
- Shinano River
- Matsuura River
- Jinzu River
- Mabechi River
- Tone River
- Tenjin River
- Ara River
- Tama River
- Go-no River
- Turumi River
- Kano River
- Tenryu River
- Toyo River
- YahagiRiver
- KisoRiver
- Yamato River
- Yodo River
- Kako River
- Ibo River
- Yoshii River
- Shigenobu River
- Shimanto River
- Gokase River
- Kikuchi River

ARRN
Asian River
Restoration Network

Restoration of Riparian Wetland by Flood Plain Excavation (Matsuura River)

Re-meandering (Kushiro River)

Restoration of Tidal Mud Flats (Mu River)

干潟試験地(面積約1.0ha)

人工干潟拡幅後(面積約2.7ha)
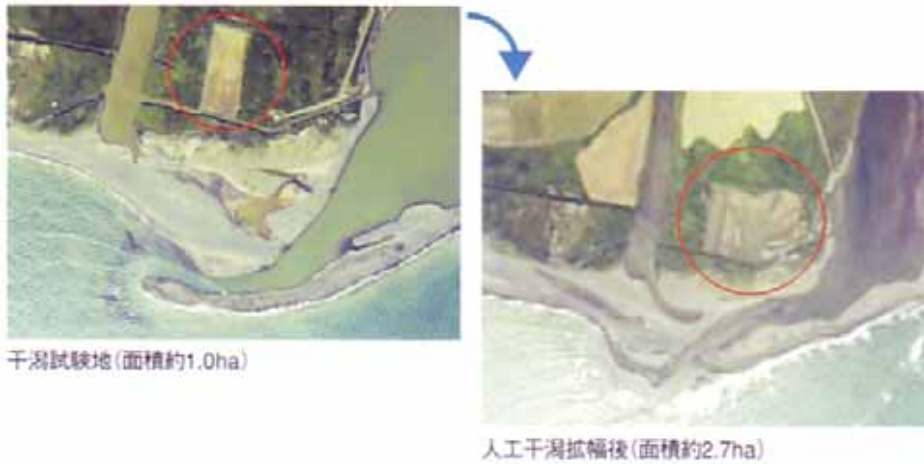
Restoration of Sediment Continuity along River

(Image: from Pamphlet of Nature Restoration: Ministry of Land, Infrastructure, Transport and Tourism, JAPAN)

Mountainous Area

Restoration of Forest (Mt. Kunugi)

Preservation of Grassland (Mt. Aso)

Agricultural Area

Reduction of Chemical Fertilizer

Coastal Area

Preservation of Tidal Mad Flats (Sanban-se)

(Image: from Pamphlet of Nature Restoration: Ministry of the Environment, JAPAN)

Each Project has own Objective

Each project might somewhat contribute the sustainability of our society,

  but

- How can we measure the contribution of each project to sustainability?

- How can we design the eco-compatible and sustainable society?

Today␣s my talk:

  Introduction of a Joint research project of Ise Bay Eco-Compatible River Basin Research Project (from 2006 to 2011)

Nagoya Univ.,

National Inst. For Land and Infrastructure Management,   Pubic Work Research Inst.,

National Inst. For Environmental Studies,

National Inst. Rural Engineering,   National Inst. Fisheries Engineering,   National Inst. Aquaculture

Reconstruction of <u>sustainable society</u>
            "sustainability"
Supported by "<u>Eco-compatible</u>" <u>river basin</u> management

      <u>Ecosystem</u> provide proper "<u>ecosystem service</u>"
                  fossil fuels
      proper scale of national-land management
            significance of "<u>river basin</u>"

Metropolises in Japan are located around a bay
   composed of multiple river basins and sea area= "<u>river basin complex</u>"

Metropolitans in Japan

River basin *is a unit of "Hydrological Cycle" for global surface*
    limited area by "divide"

What happens in "river basin"

Run-off process   Precipitation – River flow – Evapo-transpiration
                      Flow regime   flux network of water

Sediment   fluvial process ---- morphology

Materials, in particular "biophilic elements"
               Non-organic, Organic   Habitat support
                nutrients   bio-mass
                        flux network of various materials
          Energy support (food)

Biological aspect (individual, population, species richness, etc.)

Ecosystem

What is the "Ecosystem"?
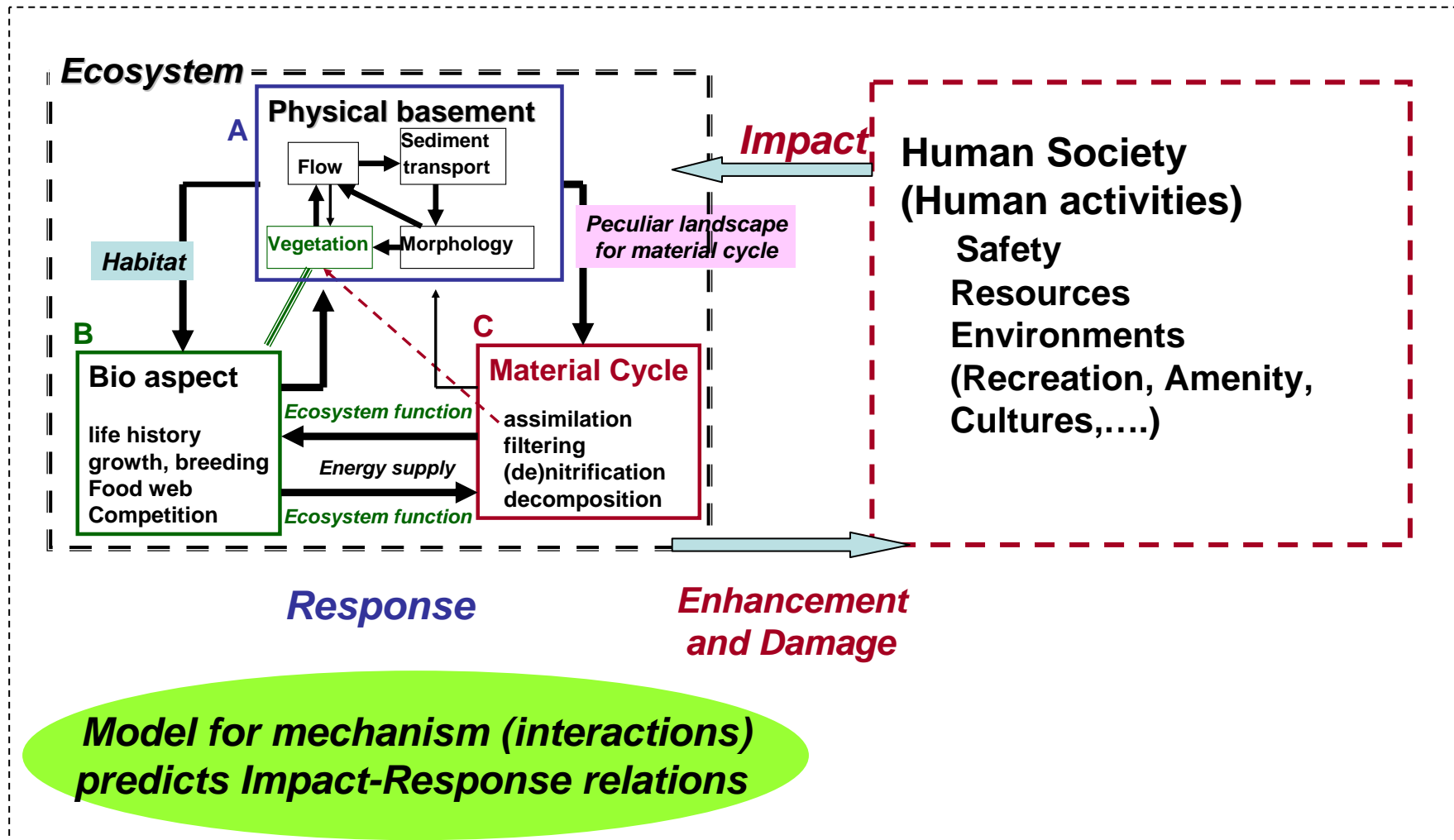
How can we proceed research cooperation?
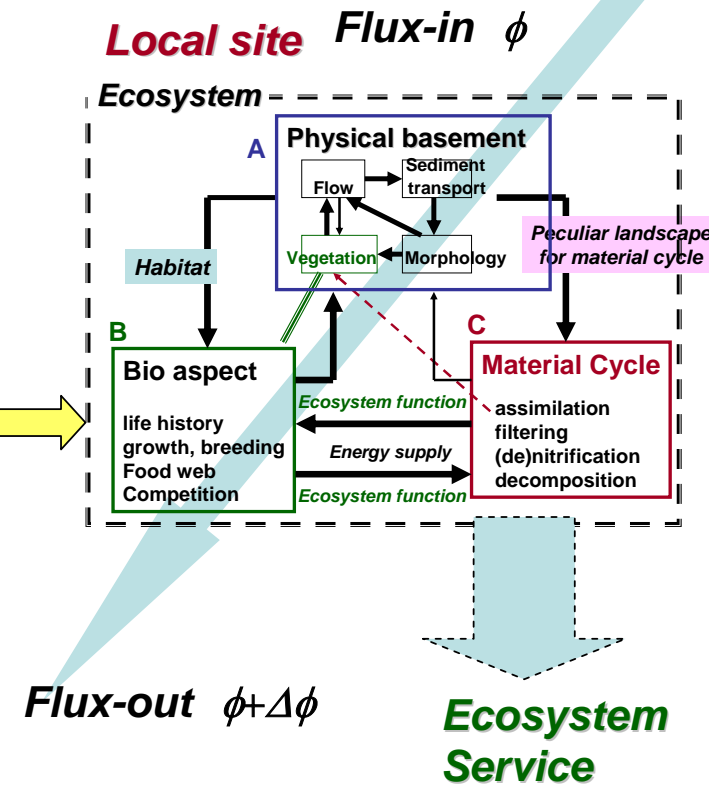
Strategy to Discipline-Cooperation

Ecosystem

A

Physical basement

Flow → Sediment transport → Morphology → Vegetation

Habitat

Peculiar landscape for material cycle

B

Bio aspect

life history
growth, breeding
Food web
Competition

C

Material Cycle

assimilation
filtering
(de)nitrification
decomposition

Ecosystem function

Energy supply

Ecosystem function
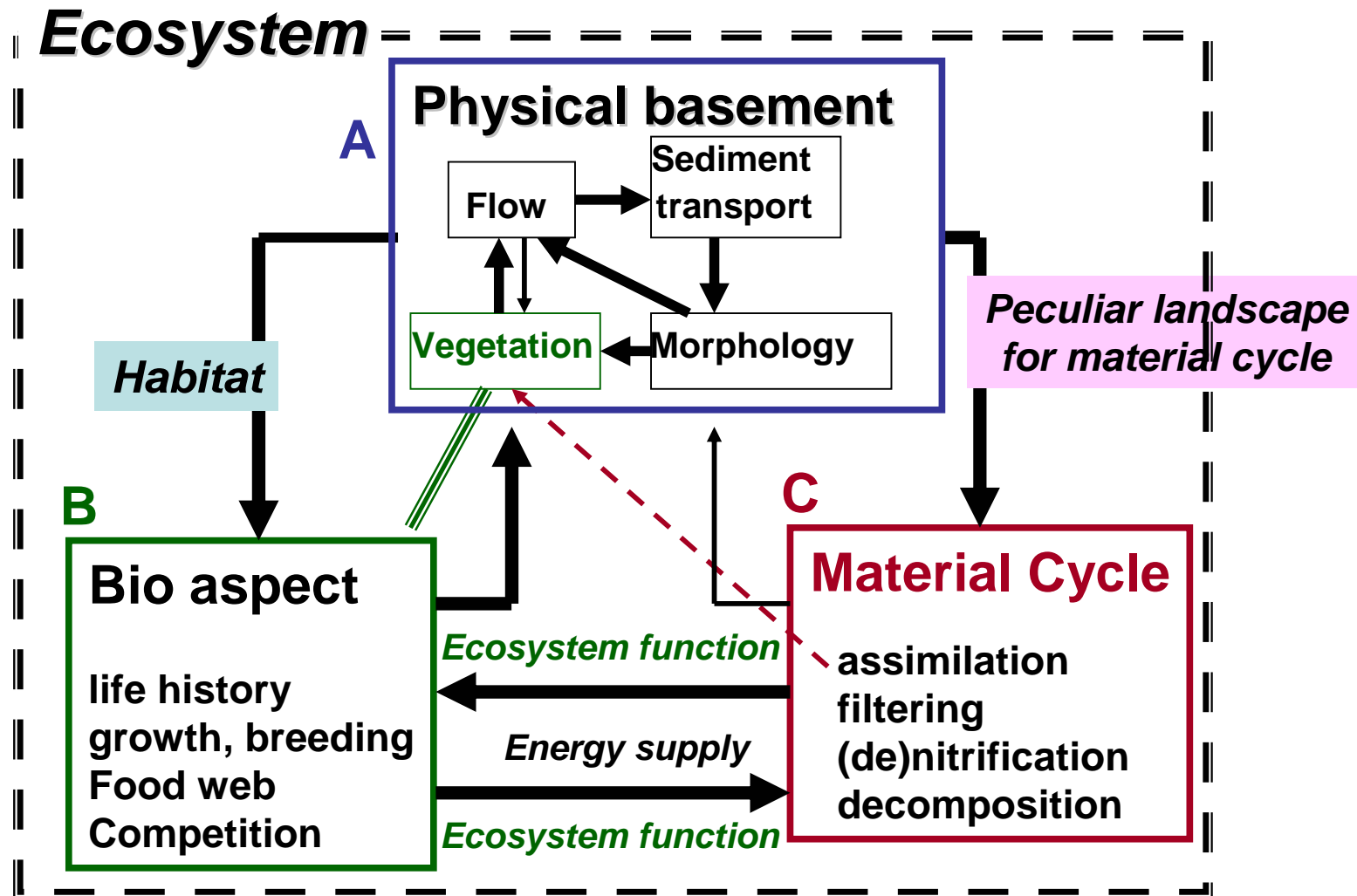
How does the ecosystem respond to human activities?

Homeland development and sustainability
  Human activities

Ecosystem

Physical basement
A

Flow → Sediment transport

Vegetation ← Morphology

Habitat

B

Bio aspect

life history
growth, breeding
Food web
Competition

Ecosystem function

Energy supply

Ecosystem function

C

Material Cycle

assimilation
filtering
(de)nitrification
decomposition

Peculiar landscape for material cycle

Impact

**Human Society
(Human activities)**
  Safety
  Resources
  Environments
  (Recreation, Amenity,
  Cultures,….)

Response

Enhancement and Damage

Model for mechanism (interactions) predicts Impact-Response relations

River basin

Local site *Flux-in* ϕ

Ecosystem

Divide

Natural Flux Networks

A Physical basement
Flow — Sediment transport
Habitat Vegetation ← Morphology
Peculiar landscape for material cycle

River Basin

Landscape "Ecosystem" Ecosystem service

River Network

B Bio aspect
life history growth, breeding Food web Competition
Ecosystem function
Energy supply
Ecosystem function

C Material Cycle
assimilation filtering (de)nitrification decomposition

Artificial Infrastructure Functions

Artificial Flux Network

Coastal Zone

Coast

Flux-out $\phi+\Delta\phi$

Ecosystem Service

River basin is an assembly of networks of various materials
Driven by hydrological cycle.

In a river basin, there are various sites where original ecosystem exist.
It brings "ecosystem service" while the fluxes may change locally but
It propagates within a river basin through the flux network.

In modern age, we added facilities (instead of ecosystem service) and artificial Flux networks (to strengthen).
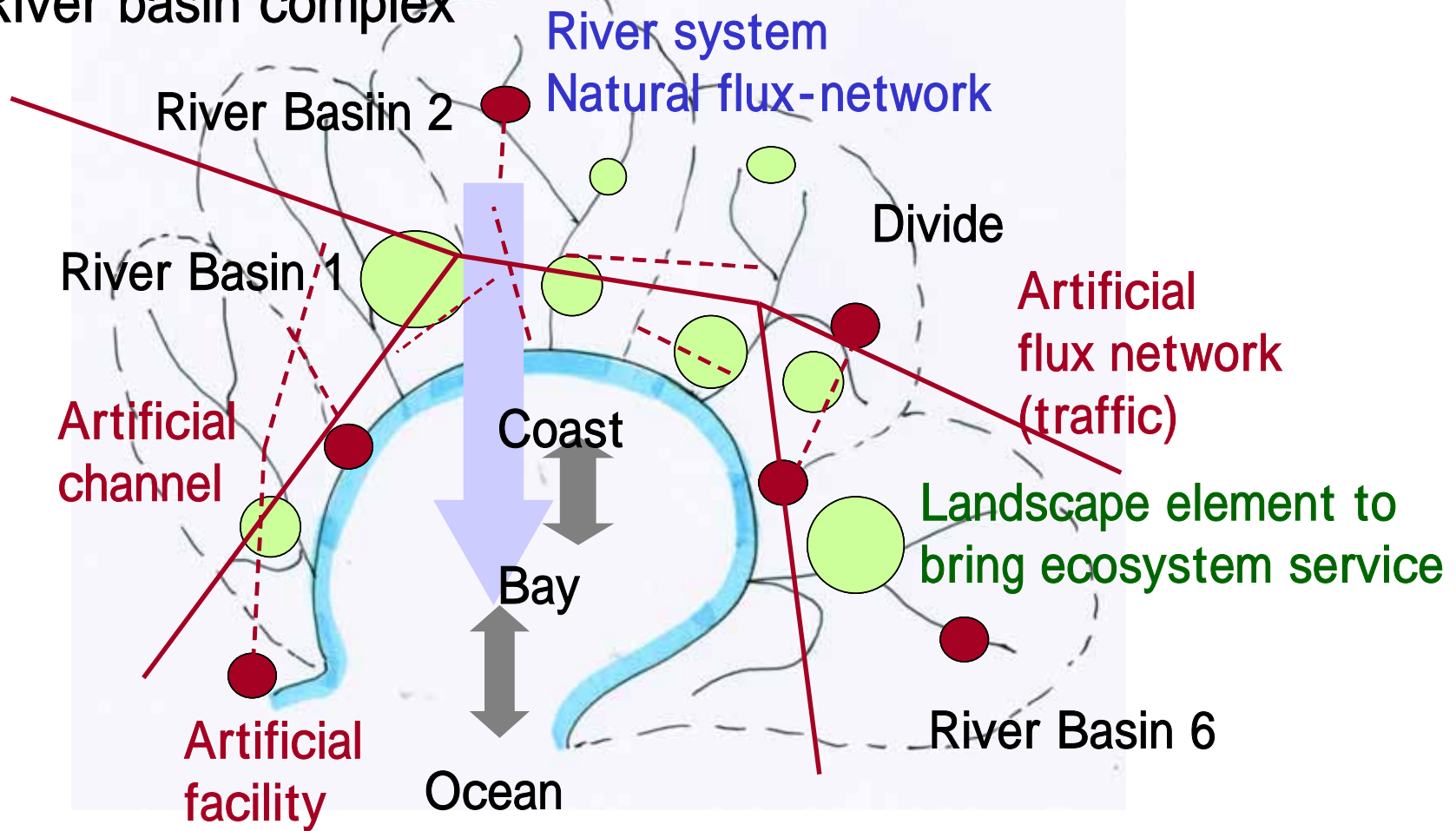
What is
    ASSESSMENT for "eco-compatible" river basin-complex management
and how to do it

Each site ecosystem brings "Ecosystem service" (**ES**) there locally,
and it changes the fluxes (ϕ) there, and it ($\underline{\Delta\phi}$) propagates anywhere
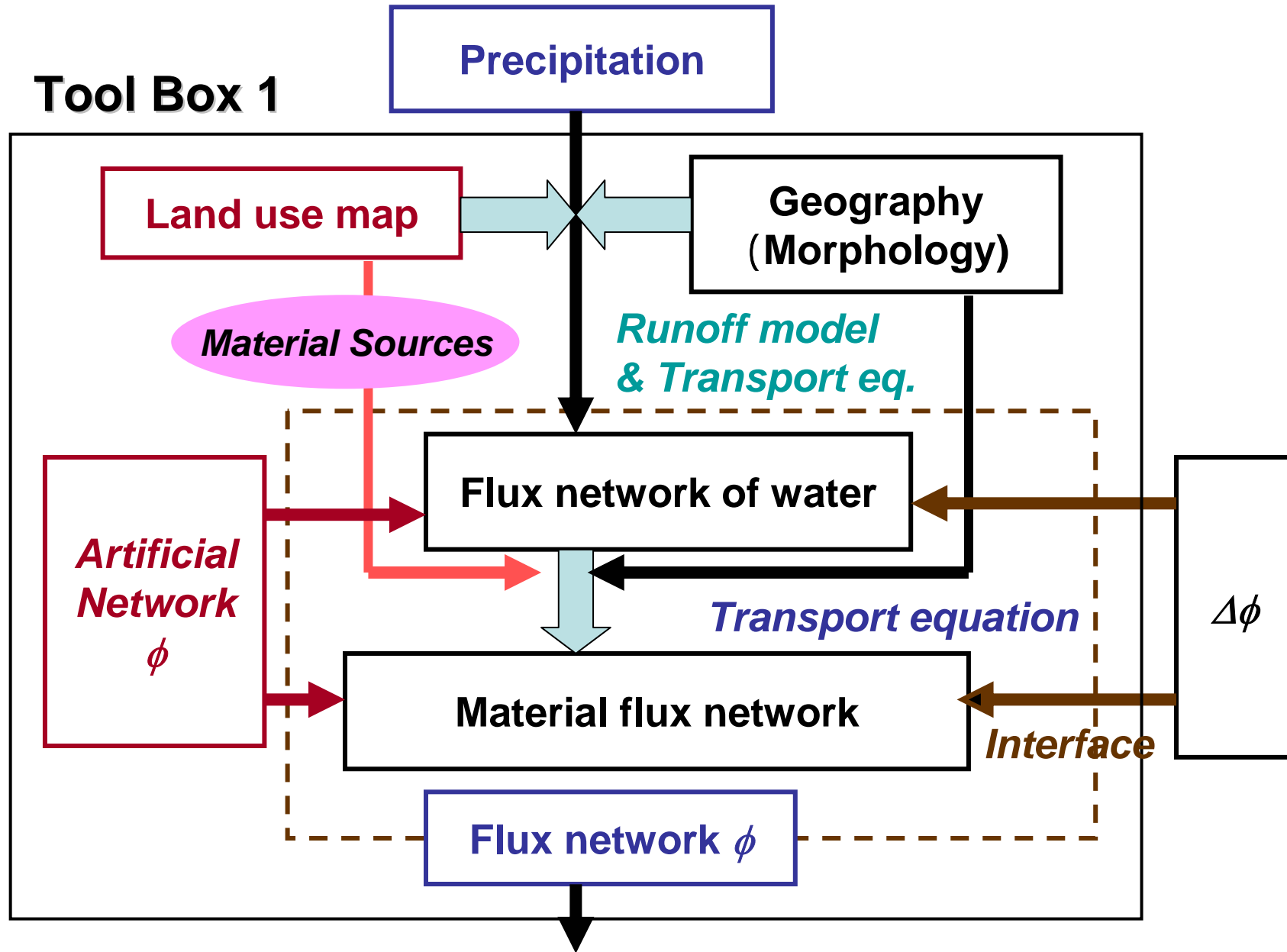inside the river basin.

ES should be evaluated locally for the local value of ϕ (output of flux network).
And, ES appearing locally in a river basin should be integrated.

$\Delta\phi$ imposing locally should be reflected to the flux network calculation, and
Flux network calculation should be updated (Updated ϕ)
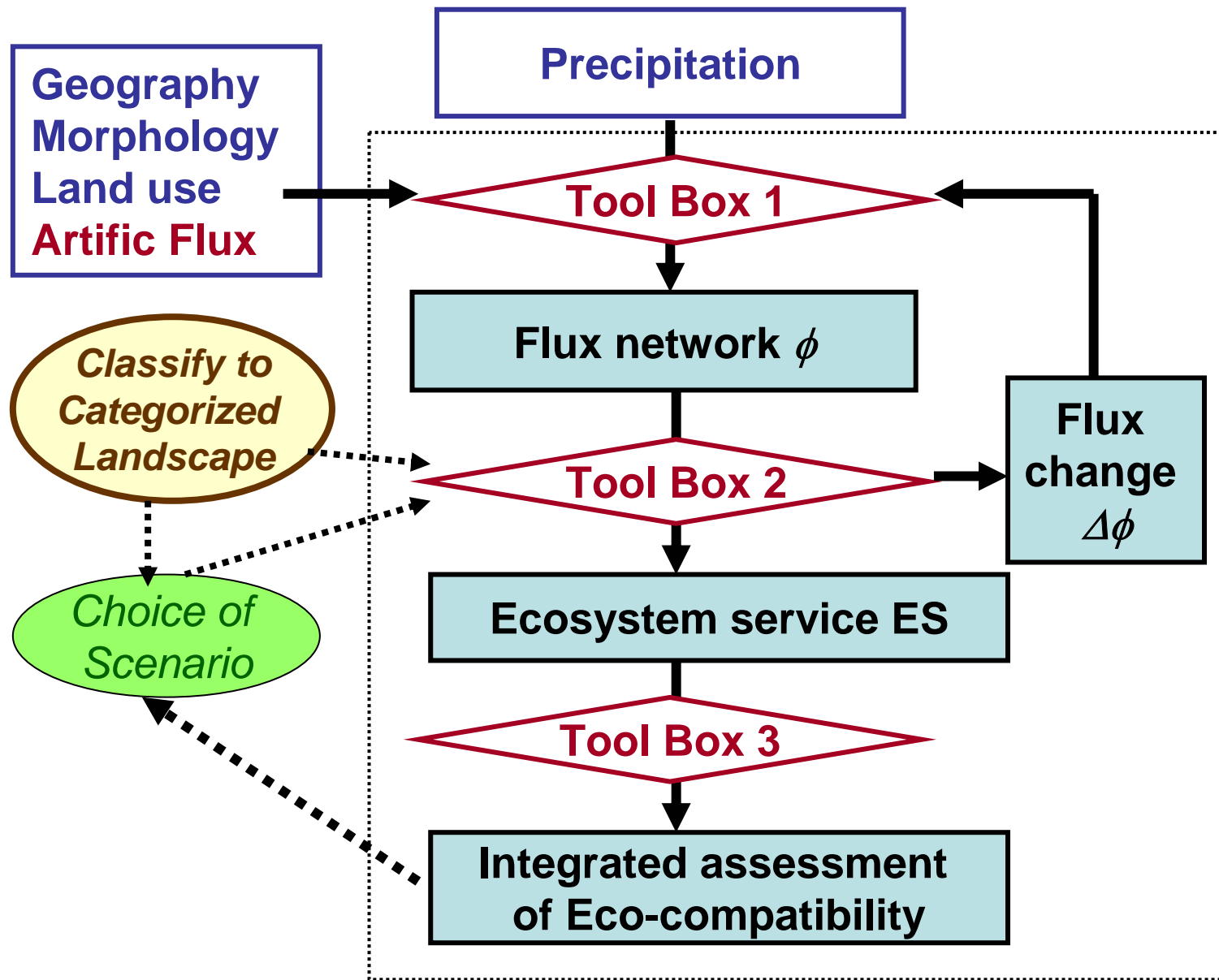
Tool Box 1   Flux Network

Land area: Hydrological Modeling
Sea area: Flow computation
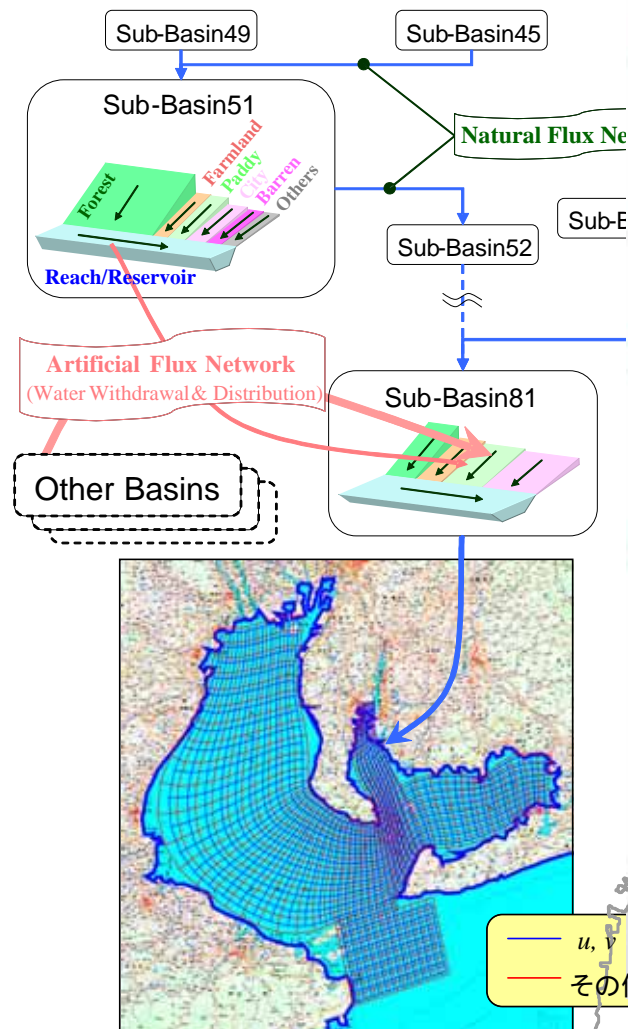
Target Basin: Yahagi river

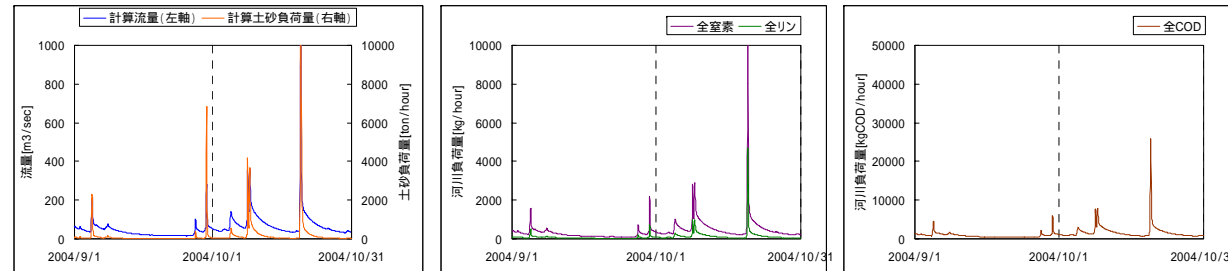Sub-Basin49

Sub-Basin45

Sub-Basin51

Natural Flux Ne

Forest

Farmland
Paddy
City
Barren
Others

Reach/Reservoir

Sub-B

Sub-Basin52

Artificial Flux Network
(Water Withdrawal & Distribution)

Sub-Basin81

Other Basins

Yahagi dam

Meiji Weir

Hosokawa Weir

Otogawa Weir

u, v

Land Use (1997)

- Forest
- Paddy
- Farmland
- City
- Barren
- Others
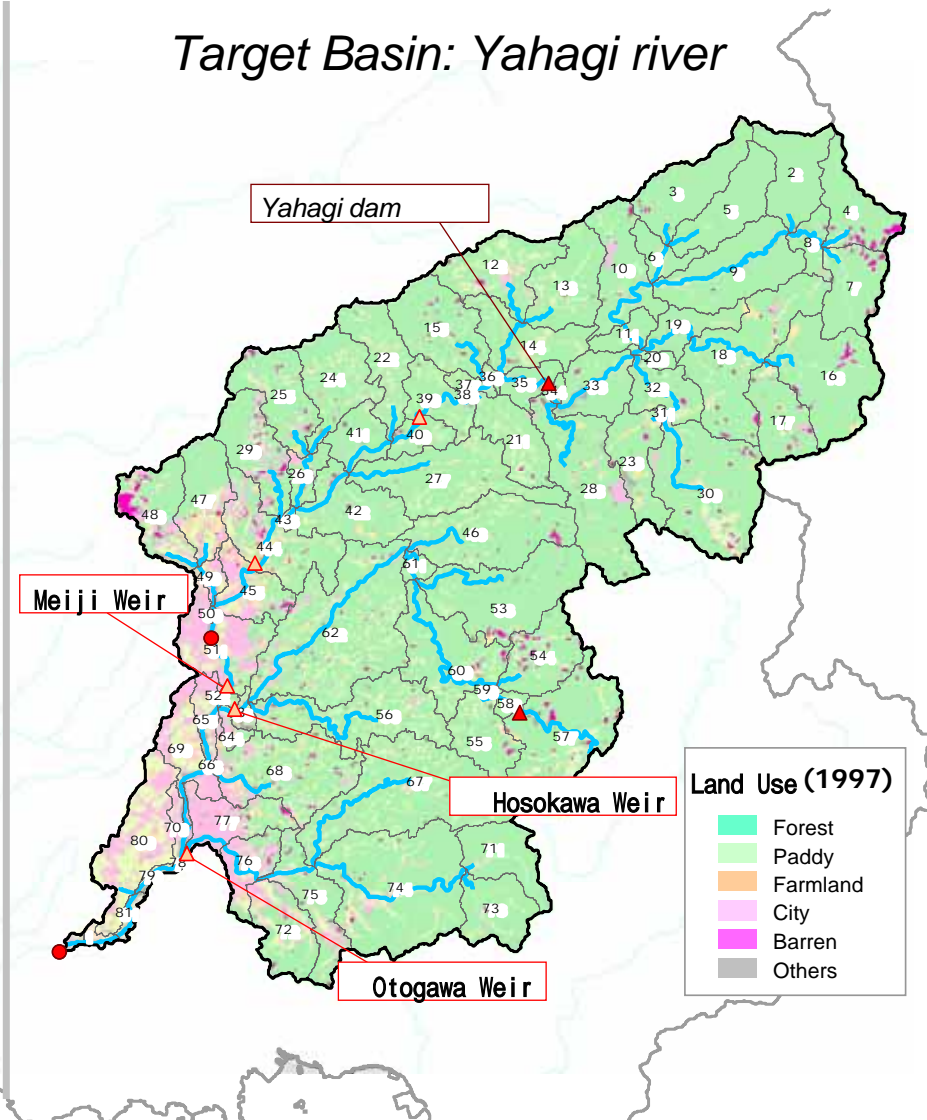
Example of flux computation: Yahagi River Basin

ϕ=*Water* *Sediment* *Nutrients, Organic*

Target Basin
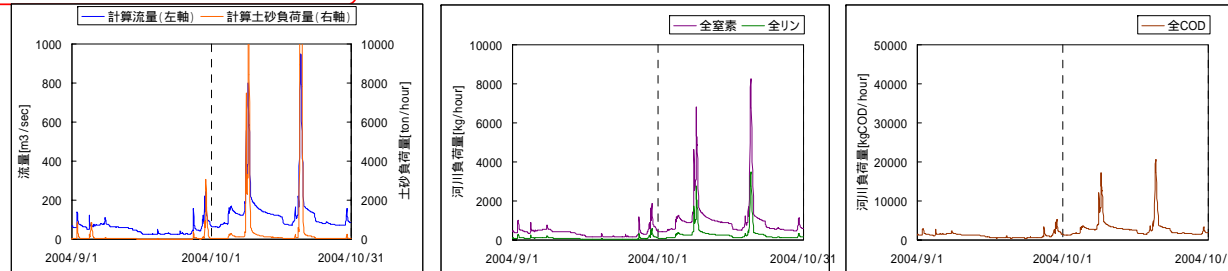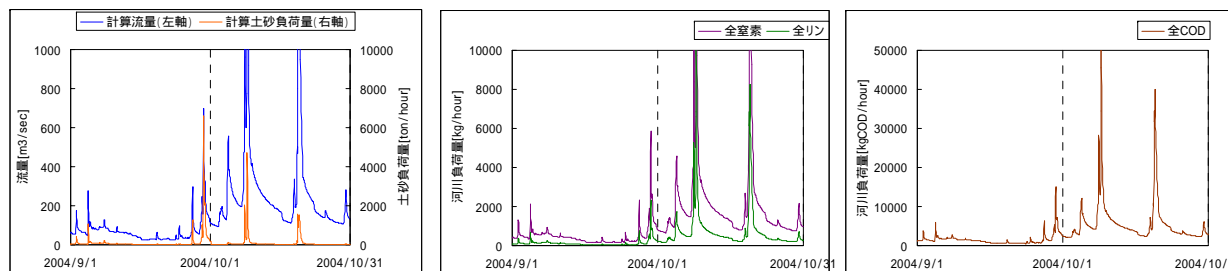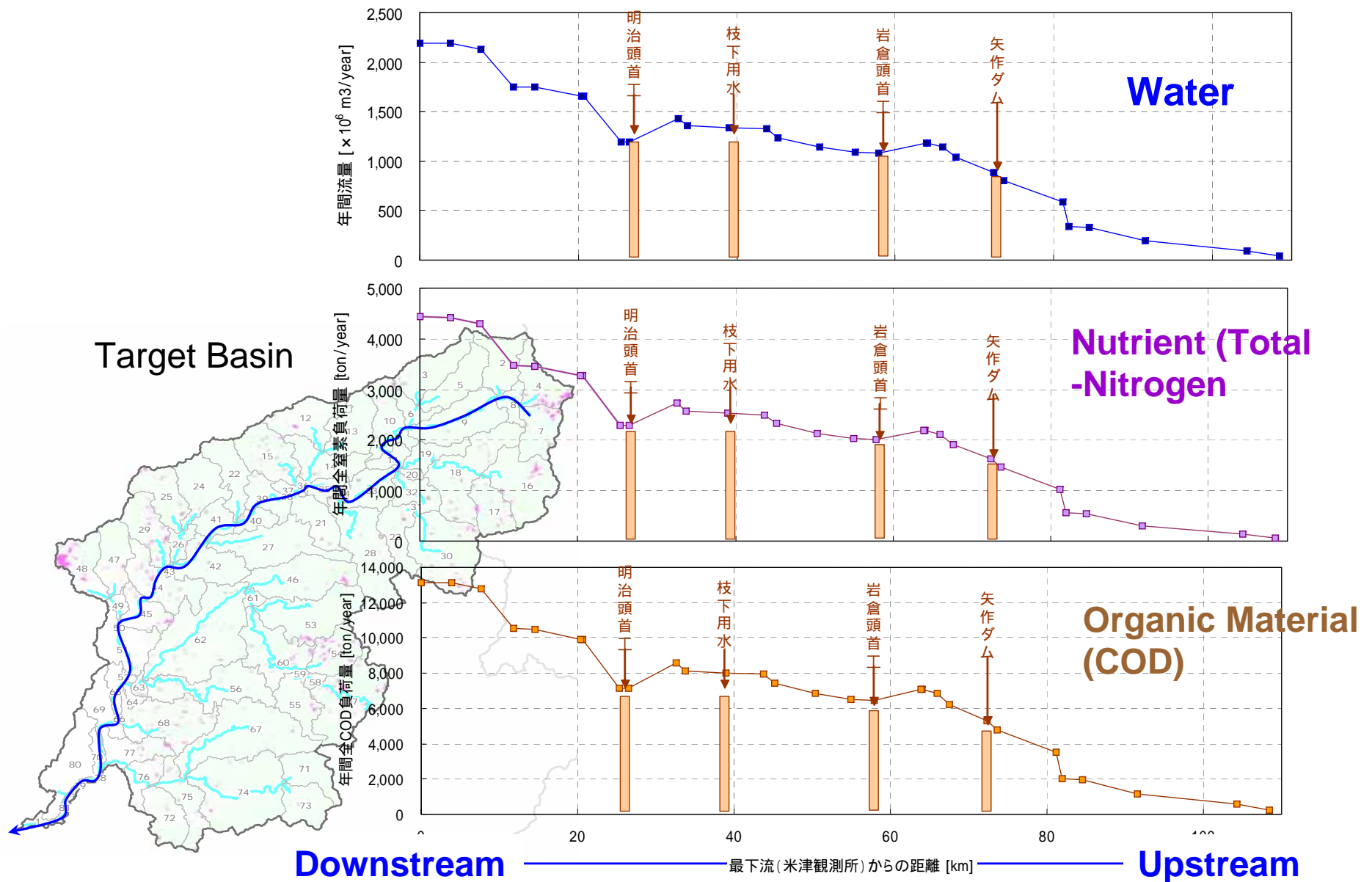

Flux of each location can be evaluated by Tool Box 1

Spatial variation of flux can be also evaluated by Tool Box 1 $\phi(x)$

Target Basin

Water

Nutrient (Total -Nitrogen)

Organic Material (COD)

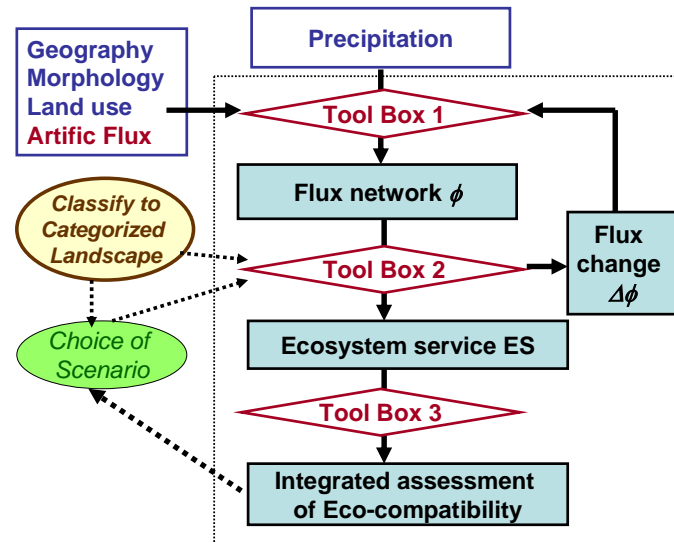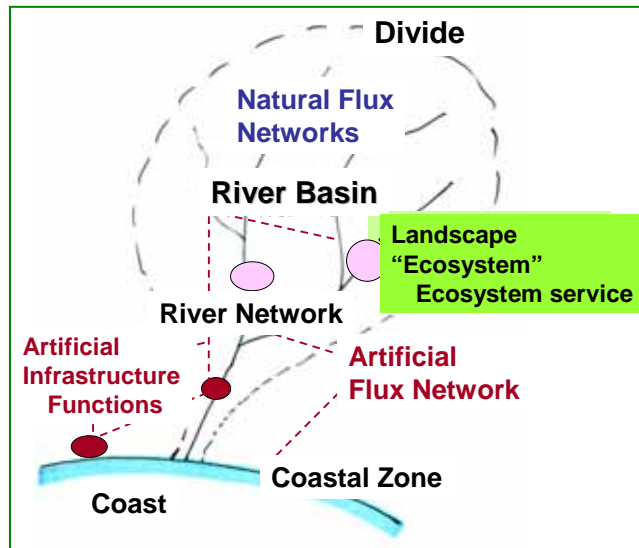Downstream ——————   [km] ——— Upstream

Flux network in the Bay area (Tool Box1)
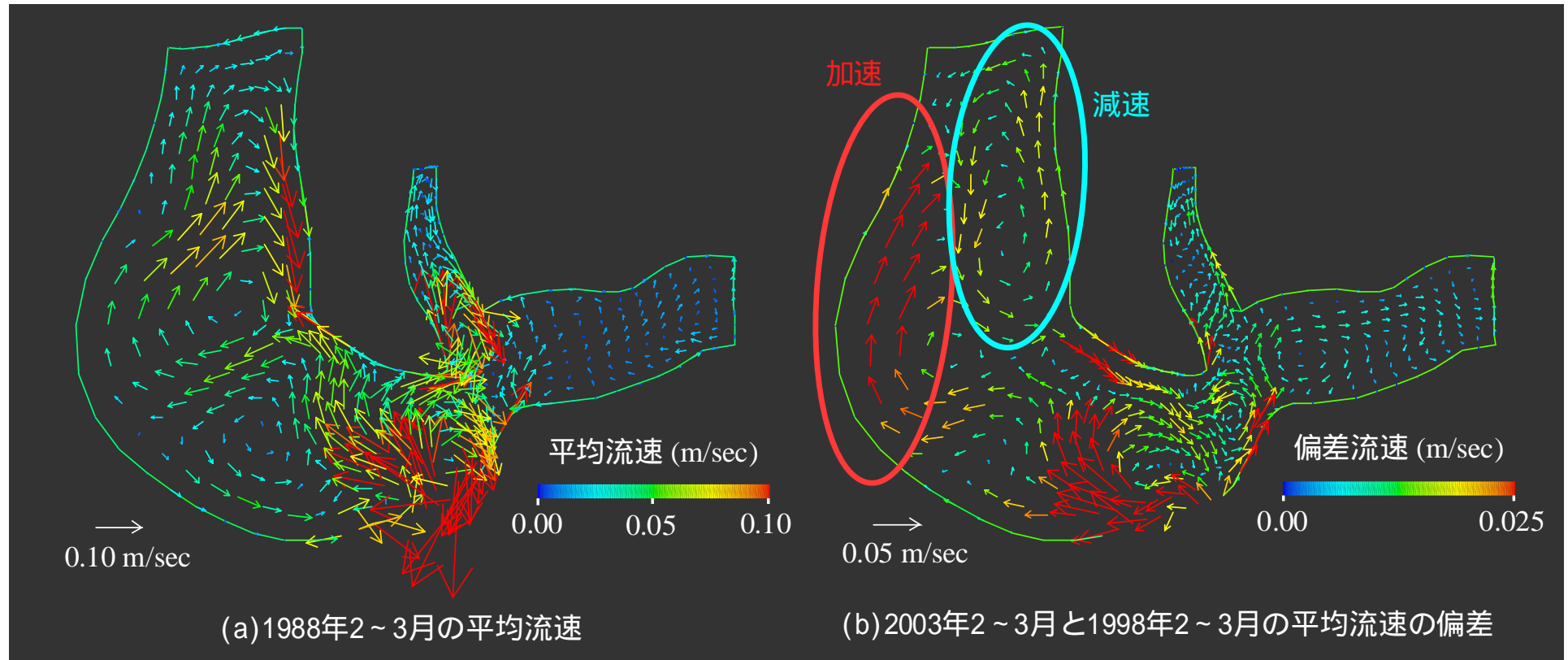
Local evaluation of Ecosystem Service (*ES*) and $\Delta\phi$

= *ToolBox 2*   Based on the mechanism of *"Ecosystem"*

Divide

Natural Flux Networks

River Basin

Landscape "Ecosystem" Ecosystem service

River Network

Artificial Infrastructure Functions

Artificial Flux Network

Coastal Zone

Coast

Geography Morphology Land use Artific Flux

Precipitation

Tool Box 1

Flux network ϕ

Classify to Categorized Landscape

Tool Box 2

Flux change $\Delta\phi$

Choice of Scenario

Ecosystem service ES

Tool Box 3

Integrated assessment of Eco-compatibility

Introduction of the concept **"Categorized landscape"**

In each categorized landscape, the tools (method) to evaluate ES and $\Delta\phi$ are similar.

Ecosystem

Physical basement

A

Flow

Sediment transport

Vegetation ← Morphology

Peculiar landscape for material cycle

Habitat

B

Bio aspect

life history growth, breeding Food web Competition

Ecosystem function

Energy supply

Ecosystem function

C

Material Cycle

assimilation filtering (de)nitrification decomposition
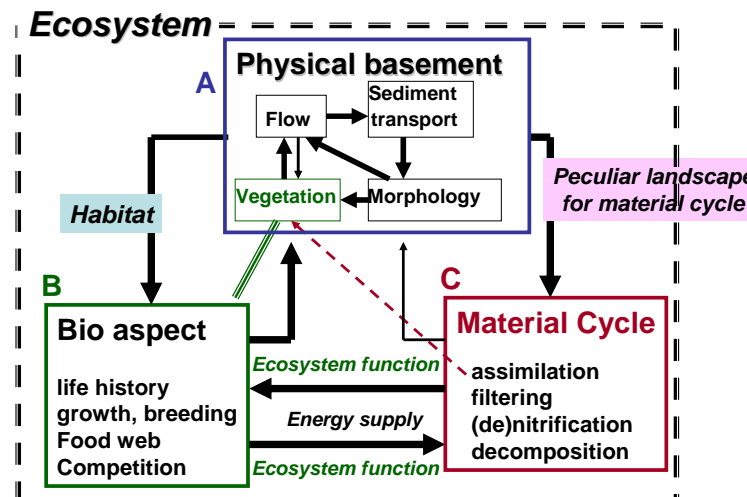
Natural geography × **Artificial Land Use**

A: Mountain and hill area
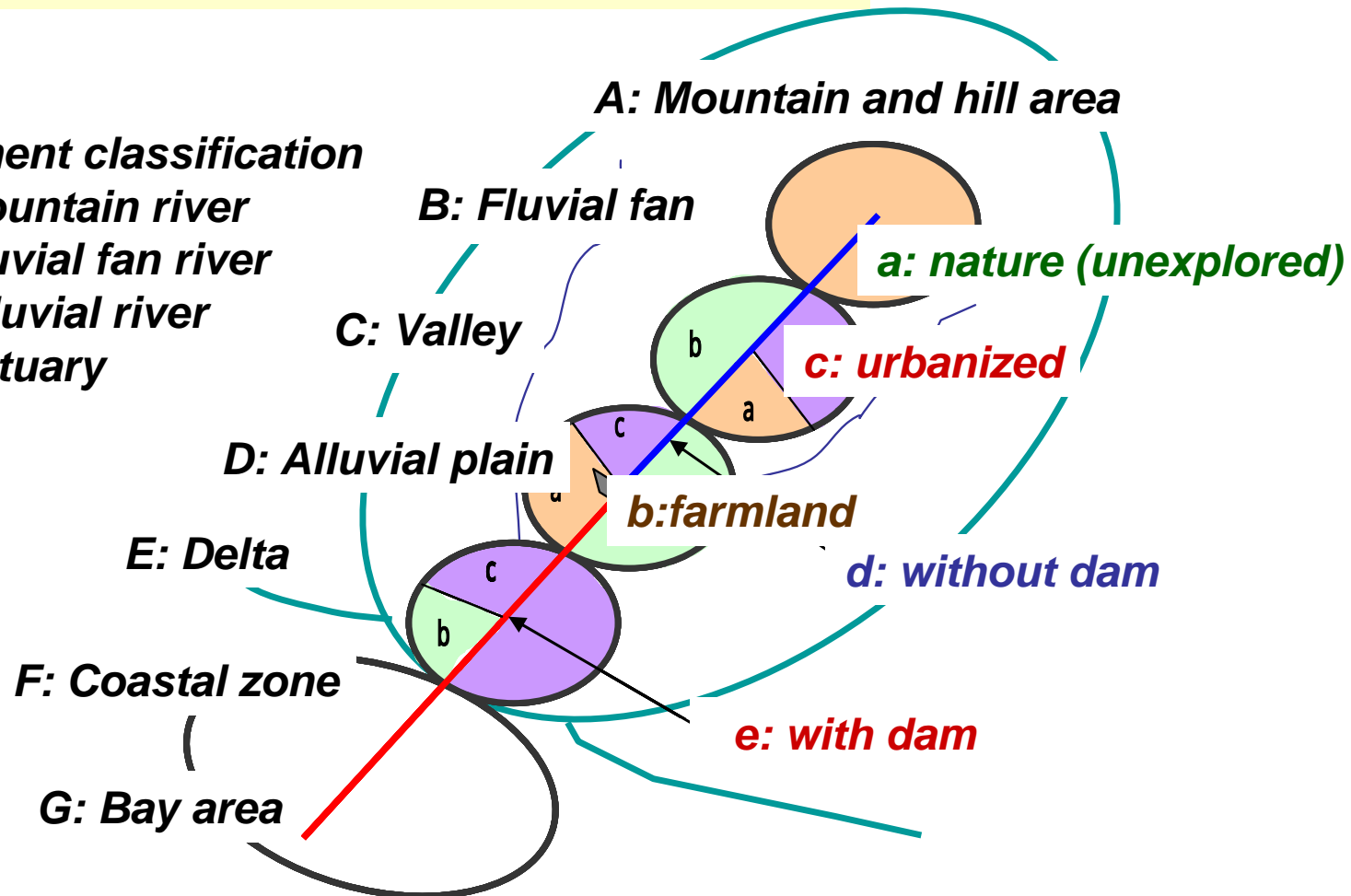
Segment classification
  Mountain river
  Fluvial fan river
  Alluvial river
  Estuary

B: Fluvial fan

C: Valley

D: Alluvial plain

E: Delta

F: Coastal zone

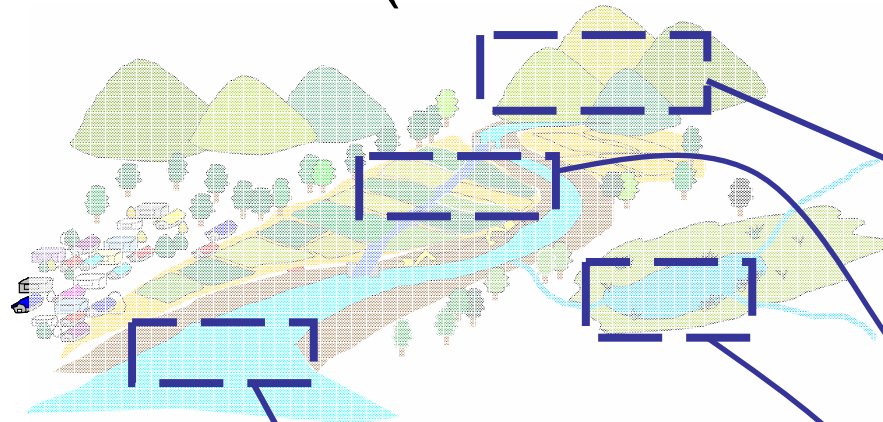G: Bay area

a: nature (unexplored)

c: urbanized

b: farmland

d: without dam

e: with dam
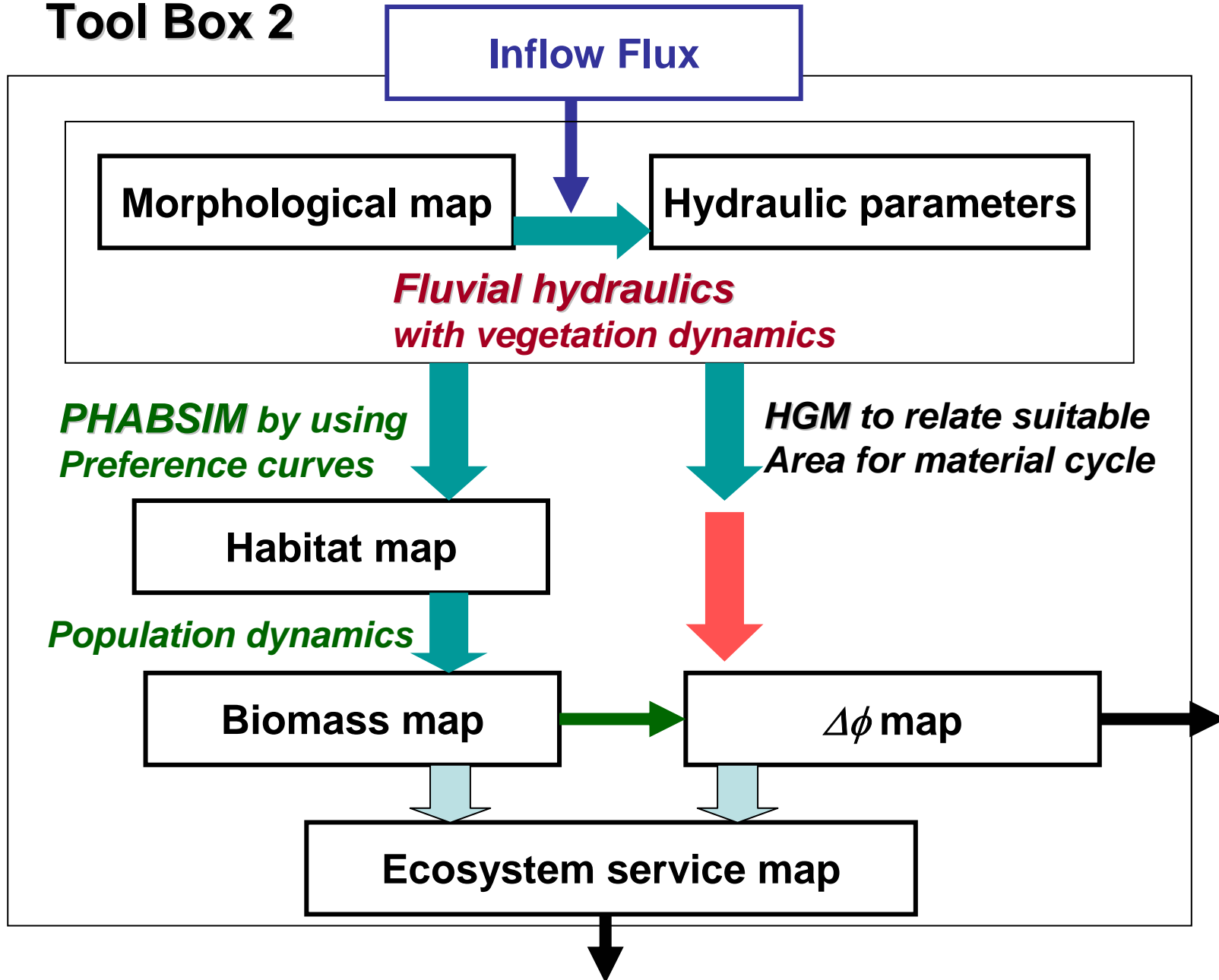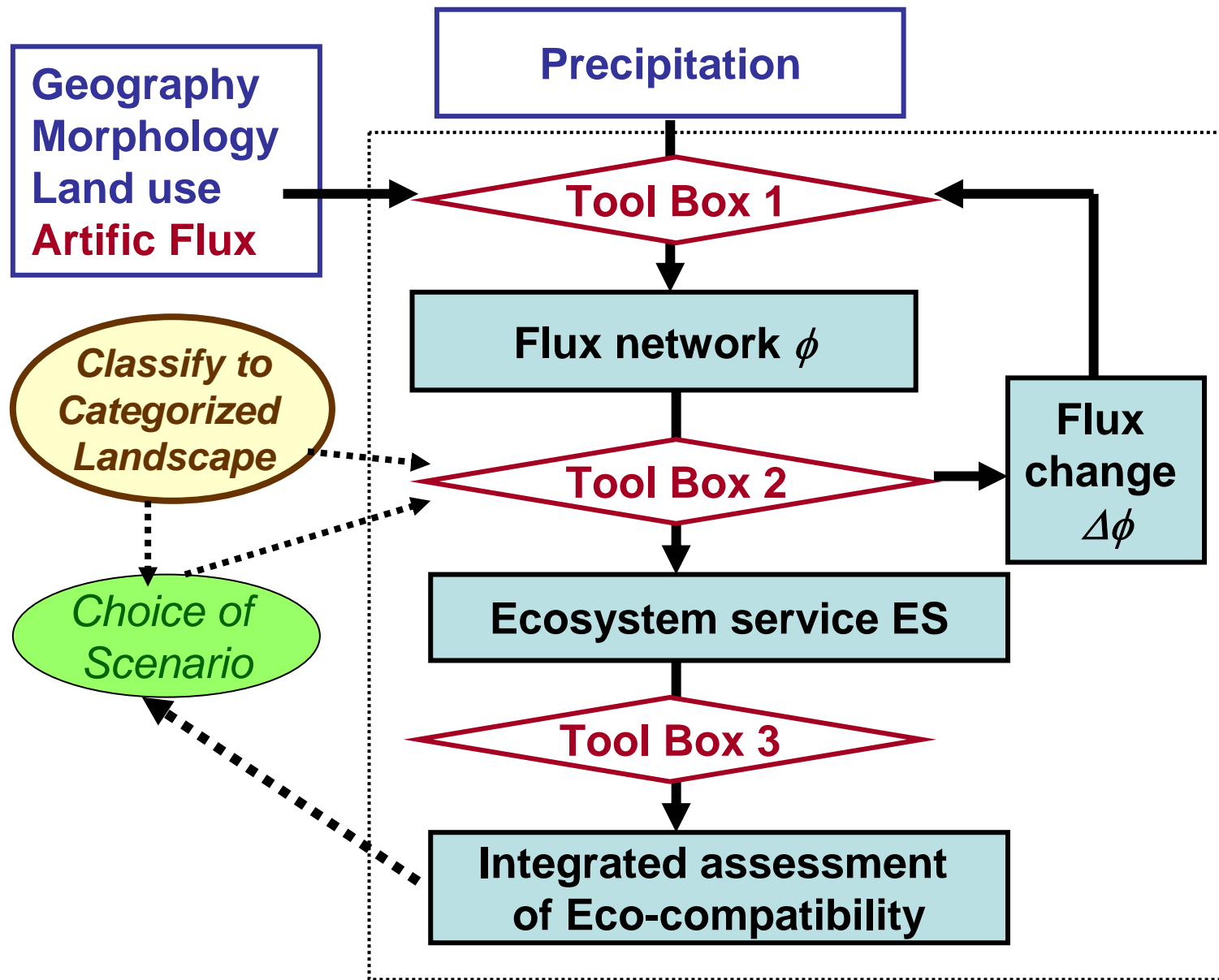
Examples of Tool Box 2
(Evaluation of Ecosystem Services)

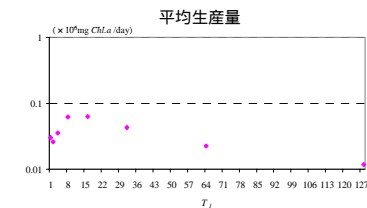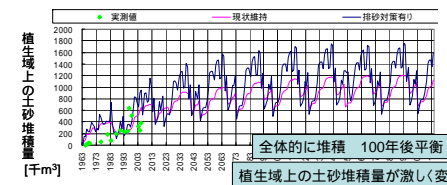**Water Purification (Supporting Services)**

Forest Area

- Development of eco-system model of forest
- Change of nutrient flux by forest management

River

- Development of eco-system model along river
- Evaluation of self-purification of rivers under various river management scenarios.
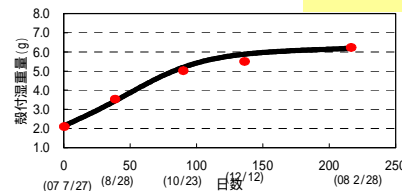
Sg2-1

Sg2-2

Agricultural Area

- Nutrient flux control by agricultural policy

Coastal Area

- Ecosystem model in the Ise bay
- Evaluation of Nutrient removal by the coastal ecosystem

PON

$$\frac{dW_w}{dt} = G_{w\,max}\; f_{gT}\,(T)W_w^{\frac{2}{3}} - r_{w\,max}\; f_{rT}\,(T)W_w$$

$$V = V_f\, f_v\,(T)W_d^{\,q}$$

PON
216   155mg-N

An example of ES evaluation in river

Example of sand bed river

Target Ecosystem

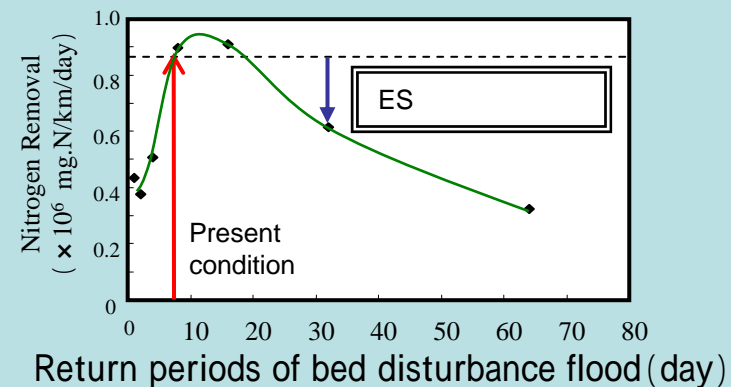**Interaction of Flow and Ecosystems**

After flood → No Biomass

Ordinary water stage → Biomass growth

River bed

Attached algae

Numerical Modeling

Estimation of ES

ES (Org. Pro.)

Present condition

T_I (days)

Biomass (10^6mg.chl.a/km)

ES

Present condition

Nitrogen Removal $\times 10^6$ mg.N/km/day

Return periods of bed disturbance flood day
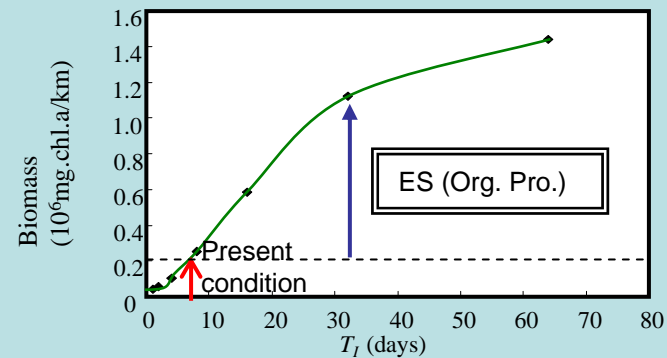
Large ⟷ Small

Disturbance of River Bed

Numerical modeling of Ecosystems of River

Invertebrate

Fish

Attached algae

Bed topography, River discharge

Field measurement

Shallow water equations

Grain diameter

Shear stress τ_*

Critical shear stress τ_{*c}

$\tau_* > \tau_{*c}$

$\tau_* < \tau_{*c}$

Periphyton biomass M
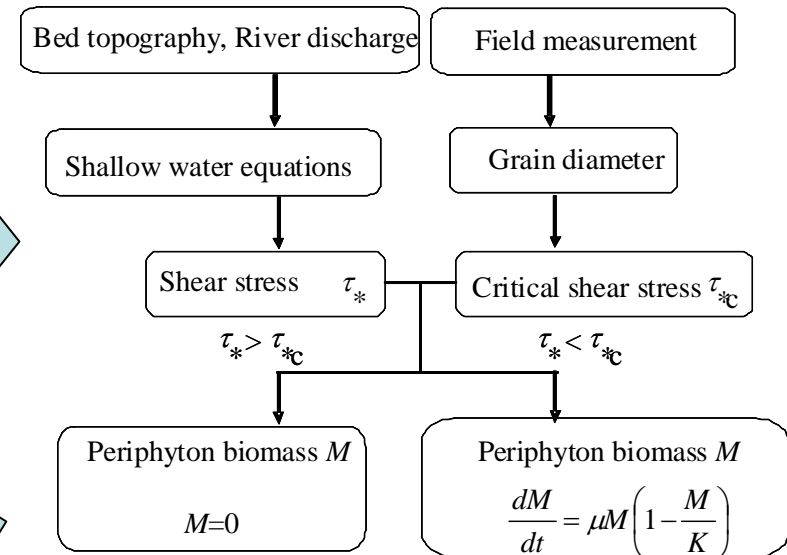
$M=0$

Periphyton biomass M

$$\frac{dM}{dt} = \mu M \left(1 - \frac{M}{K}\right)$$

Distribution of periphyton communities

Periphtyon biomass (mg/m²)

| 0 – 1 |
| 1 – 4 |
| 4 – 8 |
| 9 – 12 |
| 12 – 16 |
| 16 – 20 |
| 20 – 24 |
| 24 – 28 |

Bottom shear stress

| 0 – 0.0005 |
| 0.0005 – 0.001 |
| 0.001 – 0.0015 |
| 0.0015 – 0.002 |
| 0.002 – 0.0025 |
| 0.0025 – 0.003 |
| 0.003 – 0.0005 |
| 0.0035 – 0.004 |
| 0.004 – 0.0045 |
| 0.0045 – 0.005 |

N

flow

flow

flow

0   60   120   240   m

Field Measurement   Numerical Simulation

Integration of Ecosystem Services   Tool Box 3)
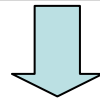
Target: Development of sustainable society

- Bottleneck: energy

- Present situation: dependence on *fossil fuels*
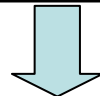
          ----> restoration or enhancement of Ecosystem Services

Tool Box 3

Evaluated Ecosystem Services at Each Categorized Landscape (Tool Box 2)

⬇

Alternative Potential of Fossil Fuels

⬇

Integration over the River Basin

Estimation of Alternative Potential of Fossil Fuels

ES1: Water purification

Amount of fossil fuels being costed to construct and to manage the sanitation facilities

ES2: Carbon Assimilation
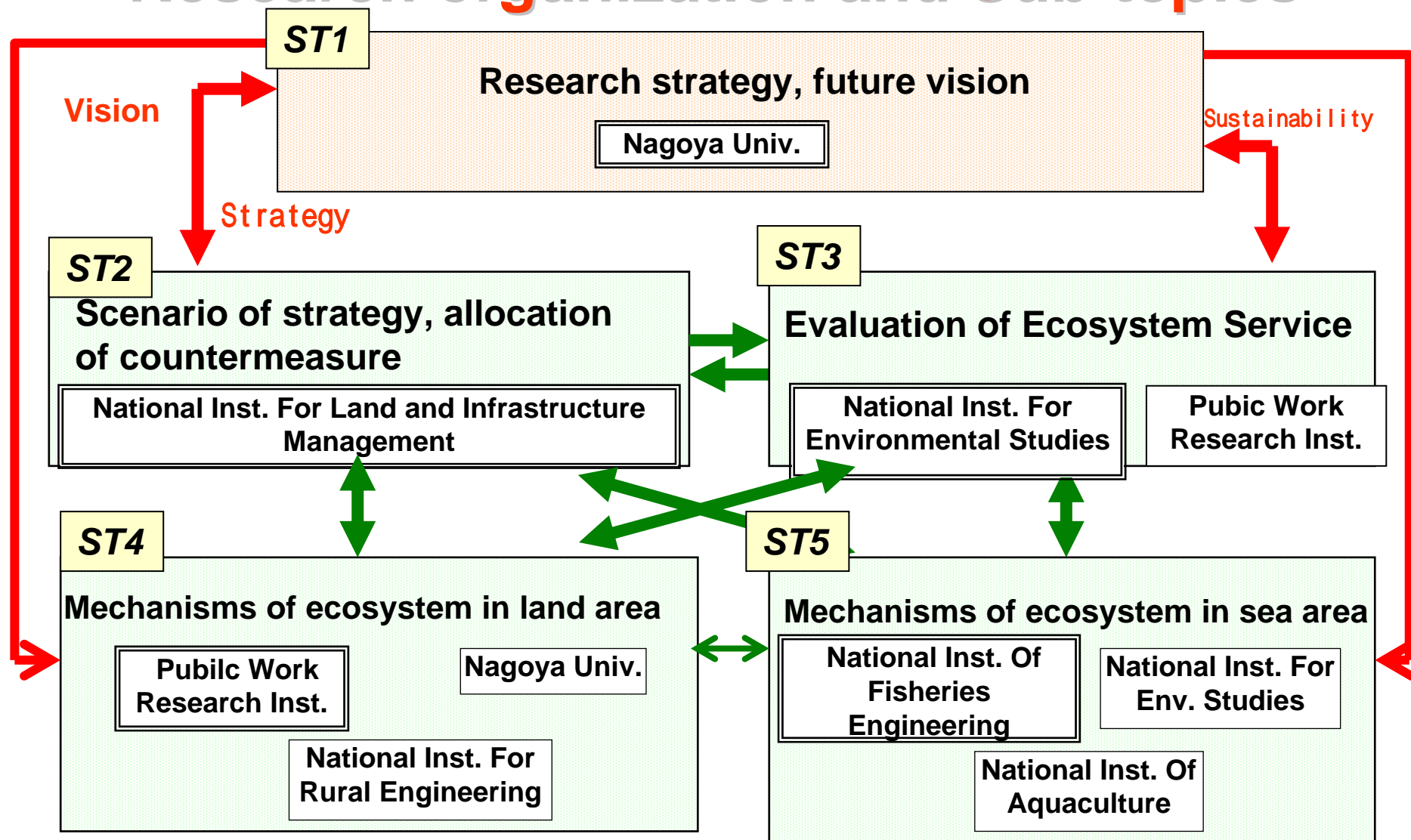
Equivalent amount of fossil fuels in terms of carbon

ES3: Food Production, Material Production

Amount of fossil fuels being costed to import the same amount of food/materials from the outside of the river basin

. . . .

Research organization and Sub-topics

ST1

Research strategy, future vision

Nagoya Univ.

Vision

Sustainability

Strategy

ST2

Scenario of strategy, allocation of countermeasure

National Inst. For Land and Infrastructure Management

ST3

Evaluation of Ecosystem Service

National Inst. For Environmental Studies

Pubic Work Research Inst.

ST4

Mechanisms of ecosystem in land area

Pubilc Work Research Inst.

Nagoya Univ.

National Inst. For Rural Engineering

ST5

Mechanisms of ecosystem in sea area

National Inst. Of Fisheries Engineering

National Inst. For Env. Studies

National Inst. Of Aquaculture

Conclusion

The framework for eco-compatible river basin management is introduced with three tool boxes to support it.

A river-basin complex is considered to be composed of categorized landscapes connected one another by flux network, natural and man made.

Tool Box 1 can describe flux network,
Tool Box 2 can evaluate ecosystem service for each landscape, and
Tool Box 3 is prepared for integrated evaluation through river basin.

Eco-compatibility should be evaluated among various scenarios composed of several programs, and
the framework discussed here will be able to do so reasonably.