Creation of Human-Nature Model Based on Watershed Using GIS

- To Aim for the Re-establishment of Positive Inter-Relationships between Humans and Nature in the Urban Context through Watershed Level Evaluations of Functions with "Spaceship Earth" as the Ultimate Model -

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Abstract:

There has been a pressing need to solve the global environmental problems. These problems are supposed to be caused by interaction between growing activities of human being and natural systems. This research aims to analyze Human-Nature System based on natural ecosystems and human ecosystems. For quantitative analysis on accumulation of human activities and the resilience of natural systems, a concept of Watershed Environmental Capacity has been established. For modeling, five indices have been set, CO2 Fixation, Cooling, Food Resources, Water Resources, and Wood Resources. The analyzing unit, which is based on watershed as an ecosystem, includes three different scales to set the hierarchical watershed management model. To do the modeling efficiently, we've integrated scientific knowledge and environmental data accumulated in society by using GIS. Our target is to promote recognition on the raison d'être of nature, human attribute, to contribute to development of environmental planning method and lifestyle.

Keywords:

Human-Nature System Model, River Basin, Watershed, Urban-Nature System, Ecological Planning, Watershed Environmental Capacity, Hierarchical Watershed Management Model, Multi-disciplinary Research, Human Lifestyle, Geographic Information System (GIS)

1. Background and Motivation

In recent years, there has been a pressing need to address various environmental problems such as global warming and other global problems concerning water, food, forest resources as well as regional problems such as the "heat island" effect created in urban areas. These problems are thought to be caused by the interaction between the significantly increasing activities of human beings juxtaposed on natural systems. To even begin to address these rising problems it is essential to create a process that can quantitatively grasp the various interactions between humans and nature in the living environment. This research presented here aims to analyze "The Interactive Human and Nature System" quantitatively from the point of view of natural ecosystems and human ecosystems. (Fig. 1)

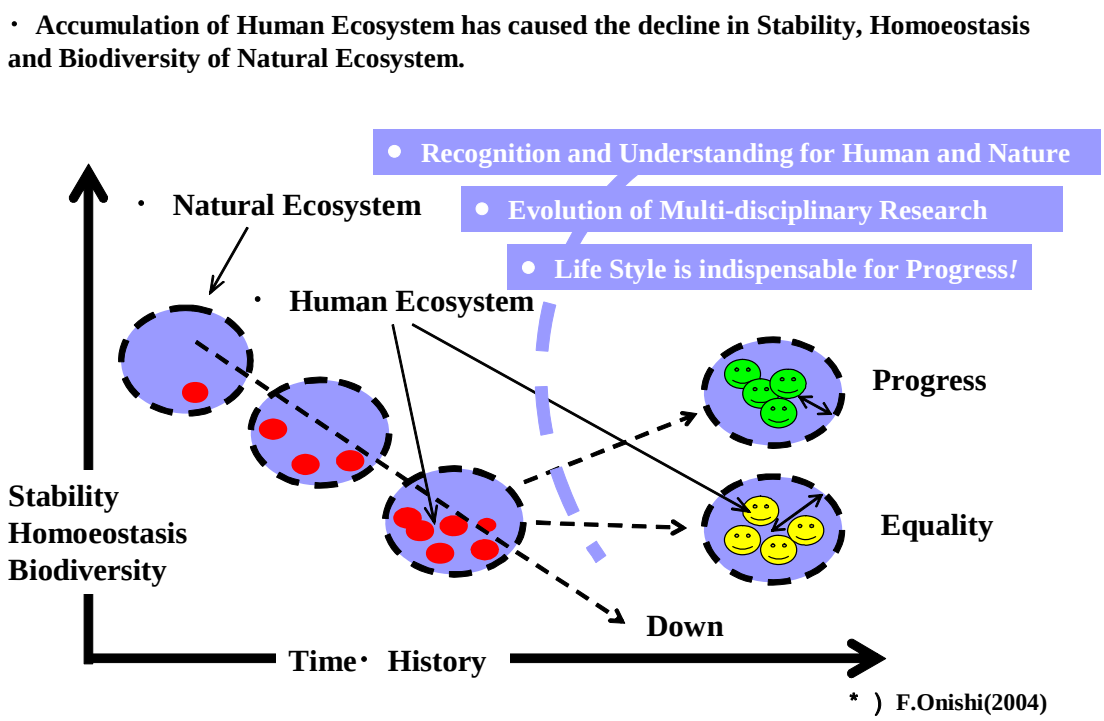


Fig. 1. Interaction between significant growing activities of human being and natural systems

2. Approach

For quantitative analysis on the accumulation of human activities and the resilience of natural systems, a concept of "Watershed Environmental Capacity (WEC)" based on watershed as an ecosystem has been established. For modeling of the pluralistic "Human-Nature System", five indices of WEC have been set including: WEC CO2 Fixation, WEC Cooling capacity, WEC Food Resources, WEC Water Resources, and WEC of Wood Resources. (Fig. 2)

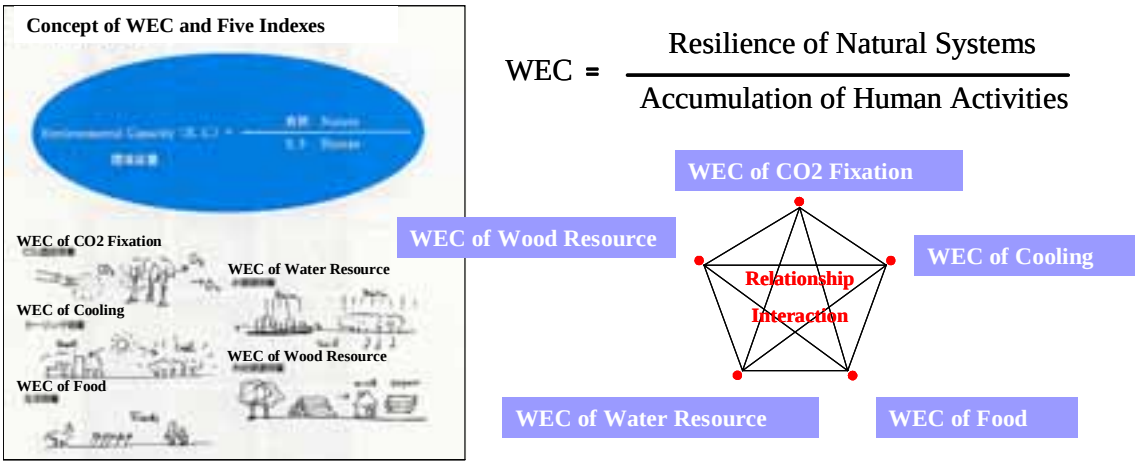


Fig. 2. Concept and Five Indices of Watershed Environmental Capacity (WEC)

The analysis unit, which is based on the watershed as an ecosystem, includes three different scales to characterize a hierarchical river basin management model: the River Basin Unit, the Sub River Basin Unit and the Community Unit. (Fig. 5, 6) To do the modeling efficiently and to build upon the Digital National Land Information, a quantitative analysis database system based on numerical modeling and geographic information system (GIS) based visualizations have been developed. (Fig. 4, 7, 8)To grasp the geographic extent and temporal status of conditions in Japan, a quantitative analysis has been conducted in the three major Metropolitan areas of the Country including: Tokyo, Osaka, and Nagoya including their surrounding regions. (Fig. 3)

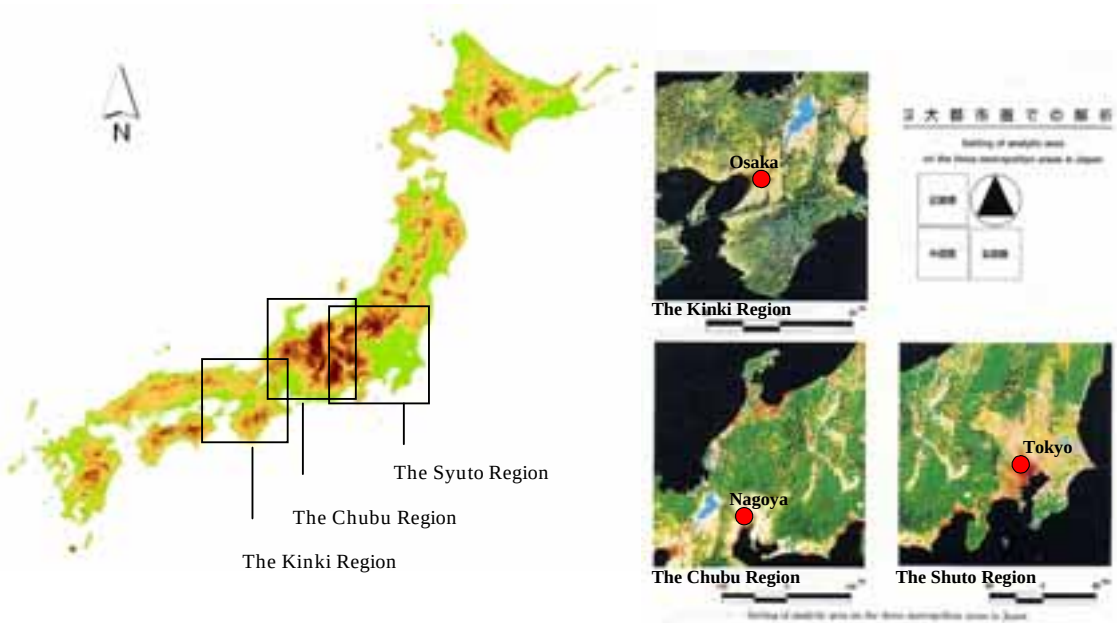


Fig. 3. Analyzing area in Japan

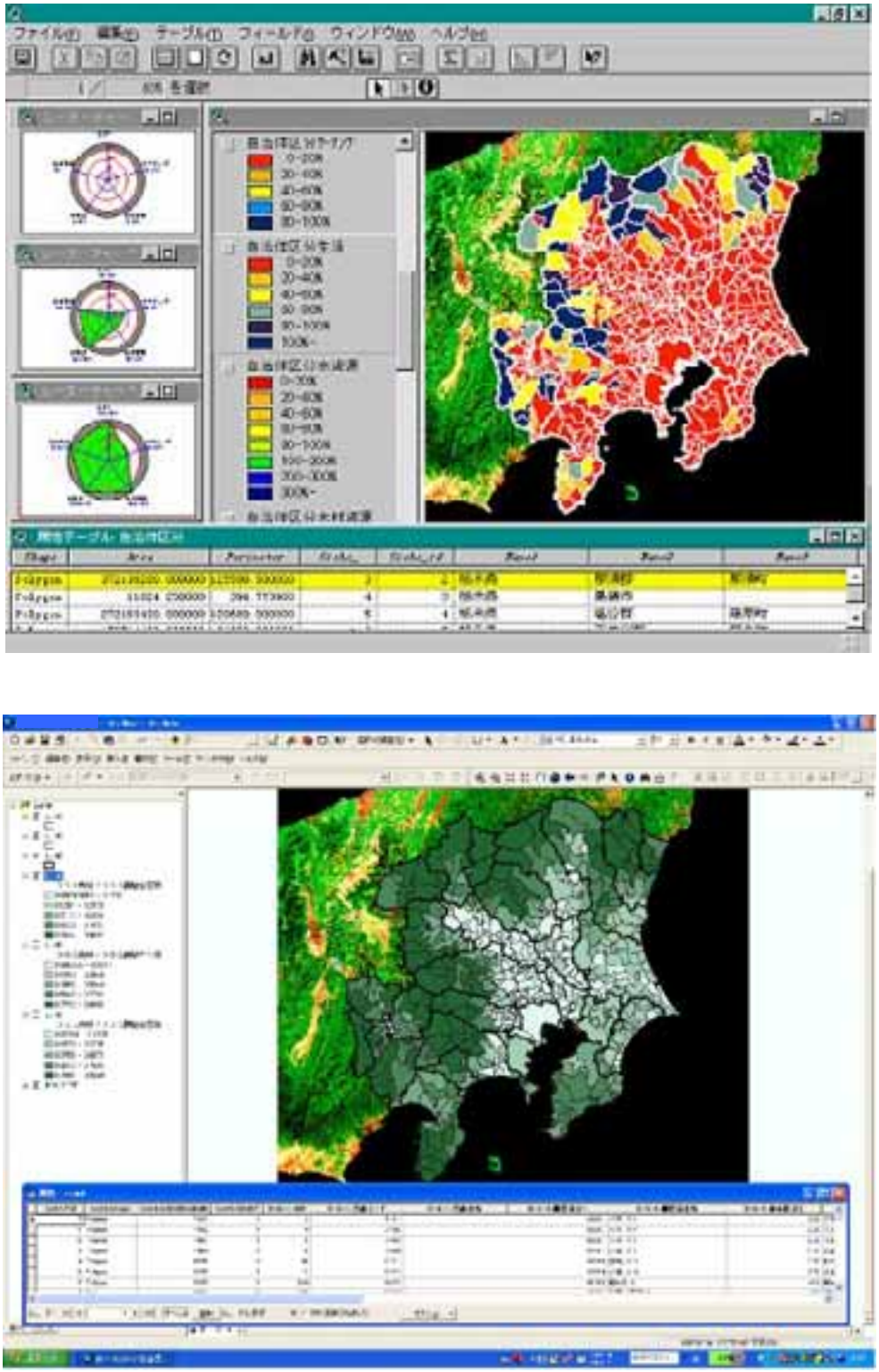


Fig.4. Analysis system by using ArcGIS Desktop 9.1 and ArcView3.0a

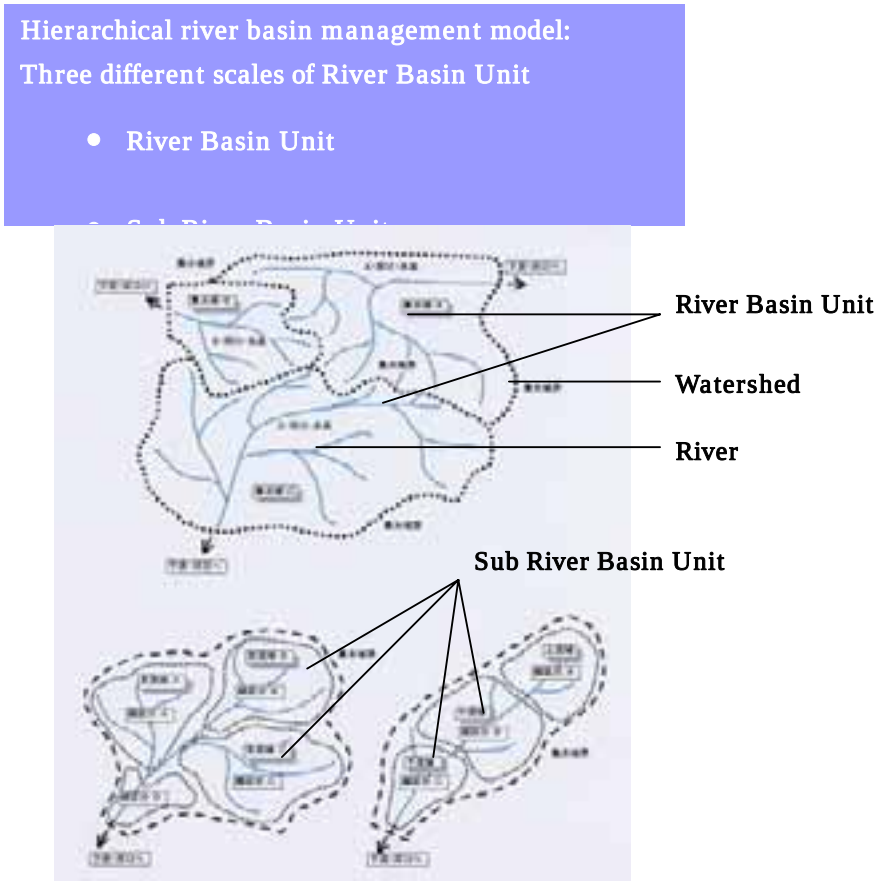


Fig. 5. General idea of hierarchical river basin management model:

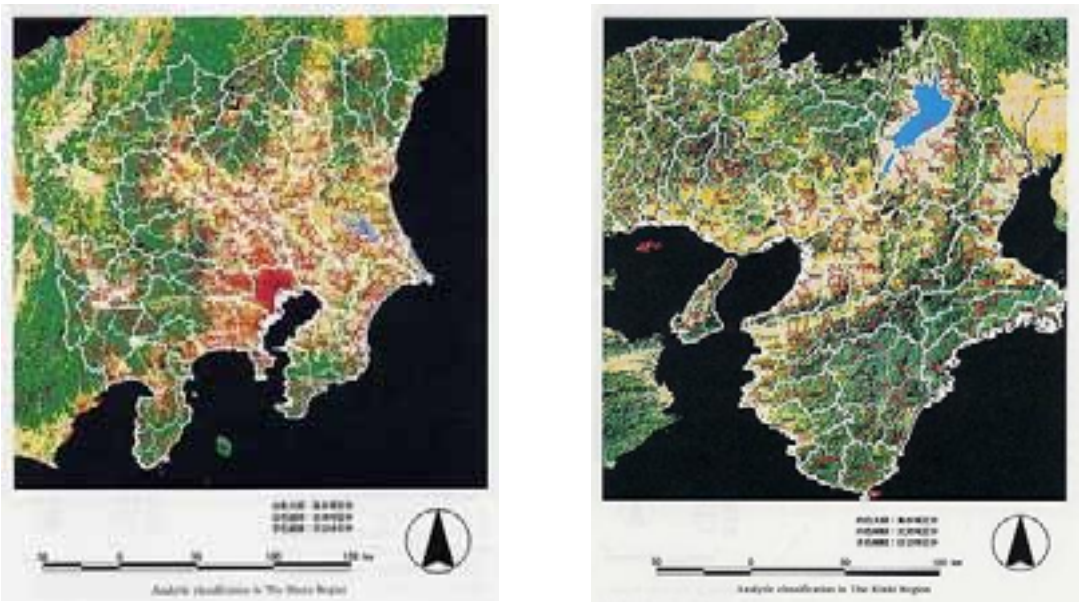


Fig. 6. Hierarchical analysis unit of Syuto (Tokyo) region and Kinki (Osaka) region

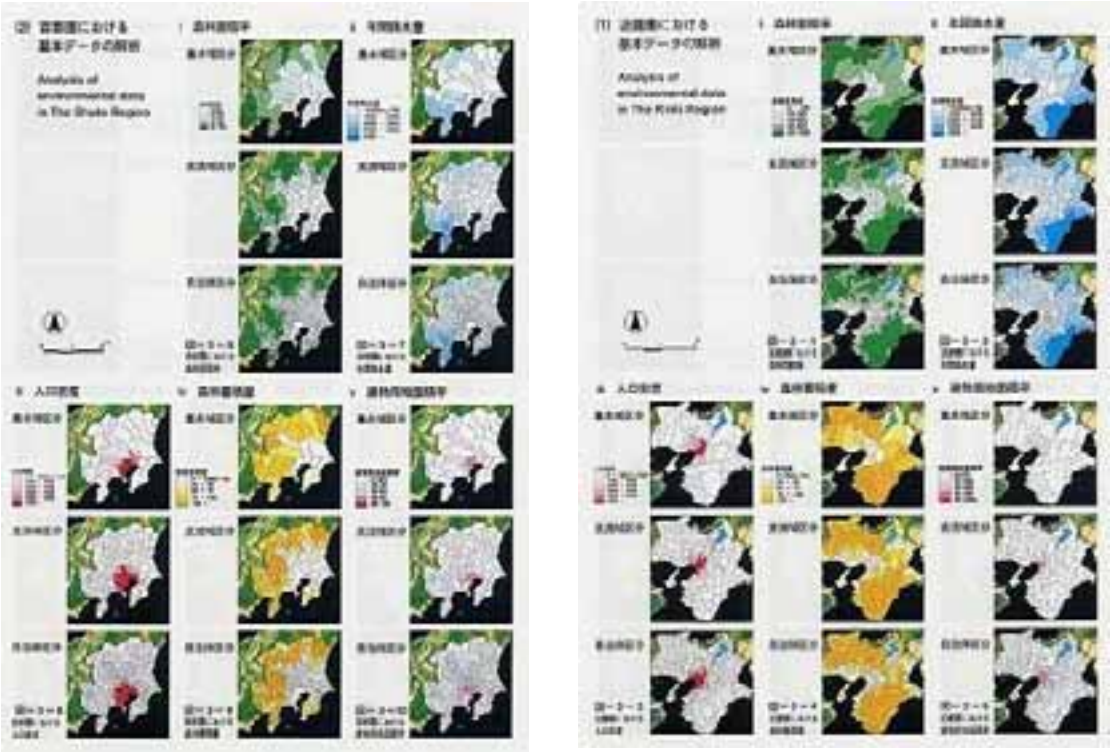


Fig. 7. Hierarchical analysis of basic data based on watershed (Syuto and Kinki region)

Concept of Numerical models

① WEC of CO2 Fixation ：

CO2 fixation / CO2 exhaustion

② WEC of Cooling ：

Cooling amount / Potential cooling amount

③ WEC of Food ：

Population / Self-sufficient population

④ WEC of Water Resource ：

Water demand / Water resources

⑤ WEC of Wood Resource ：

Wood demand / Wood resources

Integrated Scientific Knowledge, Environmental Data by using Numerical Formula and GIS

Fig. 8. Numerical models for Watershed Environmental Capacity (WEC)

3. Analysis result (excerpted from study)

The GIS analysis brought interesting results. The details are described in "Operating Manual for Spaceship River Basin by GIS". The examples of the analysis results are as follows.

3.1 Watershed Environmental Capacity in the Three Metropolitan Areas in Japan

3.1.1 WEC of CO2 Fixation

Syuto (Tokyo) region

Total region: 2.3%

River Basin Unit: The mean: 38.8%, The maximum: 784.6%, The minimum: 0.0%

Sub River Basin Unit: The mean: 32.9%, The maximum: 784.6%, The minimum: 0.0%

Kinki (Osaka) region

Total region: 5.1%

River Basin Unit: The mean: 27.2%, The maximum: 291.4%, The minimum: 0.1%

Sub River Basin Unit: The mean: 64.4%, The maximum: 821.2%, The minimum: 0.0%

Cyubu (Nagoya) region

Total region: 8.8%

River Basin Unit: The mean: 18.9%, The maximum: 66.3%, The minimum: 0.1%

Sub River Basin Unit: The mean: 105.2%, The maximum: 1482.7%, The minimum: 0.0%

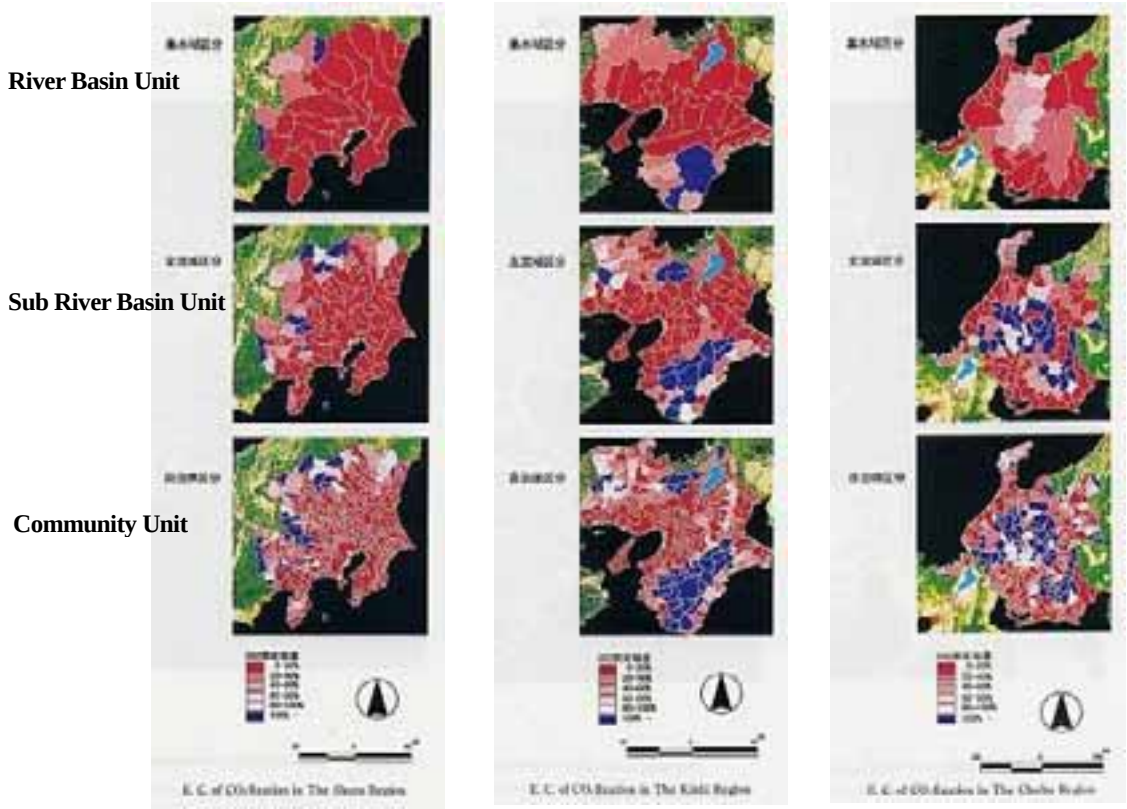


Fig. 9. Analysis result of WEC of CO2 Fixation in the Three Metropolitan Areas in Japan

3.1.2 WEC of Food Resources

Syuto (Tokyo) region

Total region: 24.5%

River Basin Unit: The mean: 76.9%, The maximum: 575.6%, The minimum: 4.4%

Sub River Basin Unit : The mean: 77.3%, The maximum: 575.6%, The minimum: 4.4%

3.1.3 WEC of Water Resources

Syuto (Tokyo) region

Total region: 74.4%

River Basin Unit: The mean: 1408.1 %, The maximum: 29315.2%, The minimum: 1.4%

Sub River Basin Unit: The mean: 1050.6%, The maximum: 29315.2%, The minimum: 1.4%

3.2 Hierarchical analysis of WEC

In this study, WEC of three different scales of River Basin Unit were analyzed. For example, the analysis result of the Kinokawa watershed in the Kinki region is shown in Figure. 10. Watershed is composed of various environmental units. And, we live in one of the environmental units.

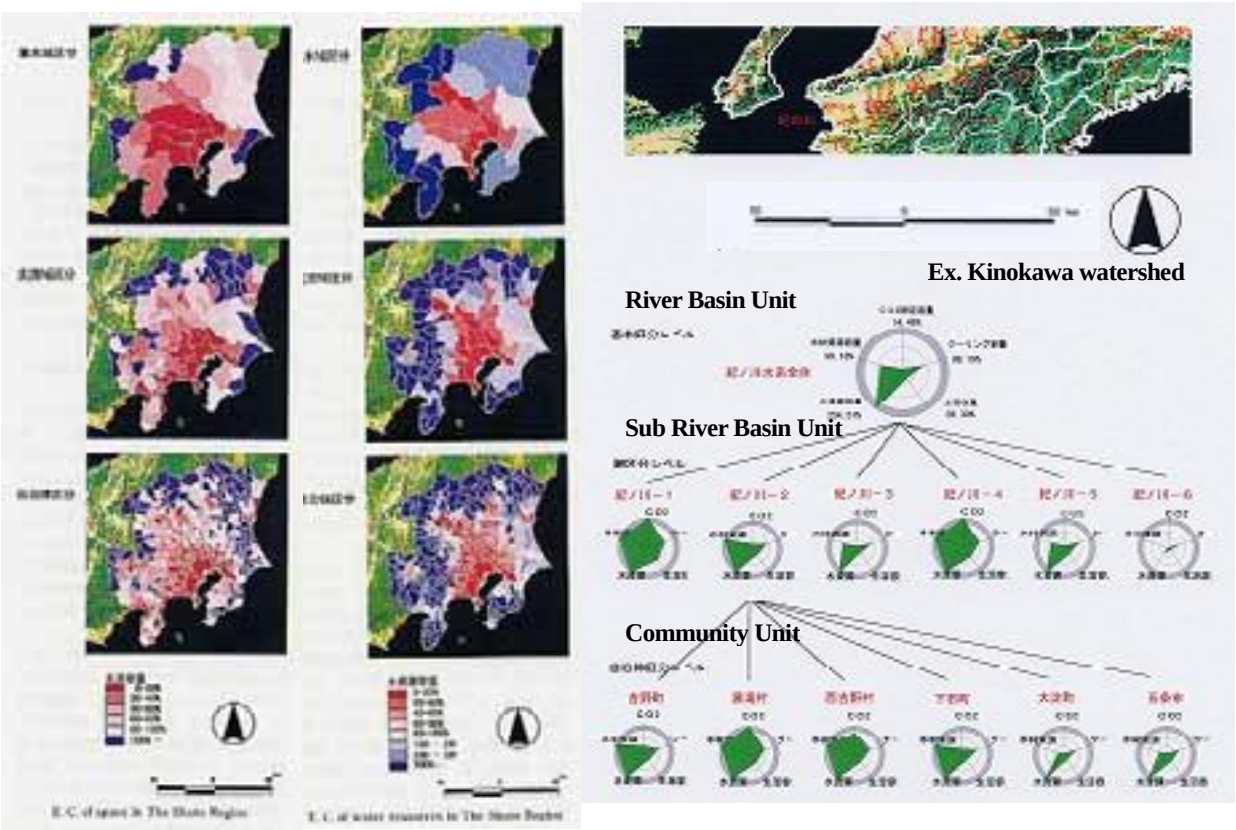


Fig. 10. Analysis result of WEC of foods, WEC of water, and the Hierarchical analysis of WEC

3.3 Fluctuation of WEC on Lake Biwa and Yamato River Basin in the Kinki (Osaka) region

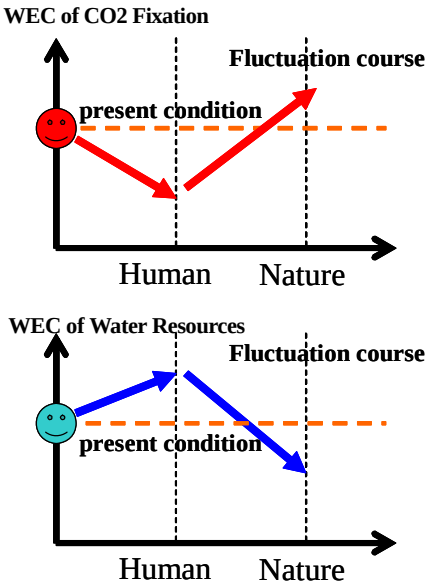
3.3.1 Fluctuations of WEC

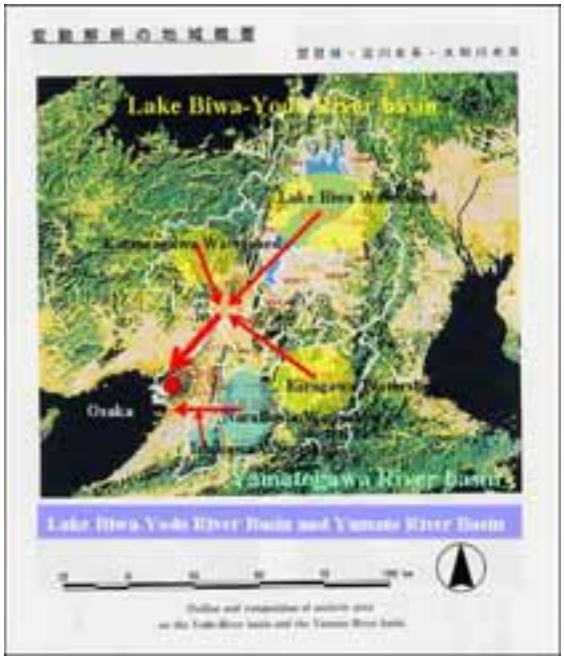
WEC of CO2 fixation: Although the per-capita amount of CO2 emission was increased, WEC of CO2 fixation became upward because of the growing forest. And, WEC of Water Resource: Although the per-capita demand was decreased, WEC of Water Resource became downward because of the decrease in hydraulic permeability caused by urbanization.

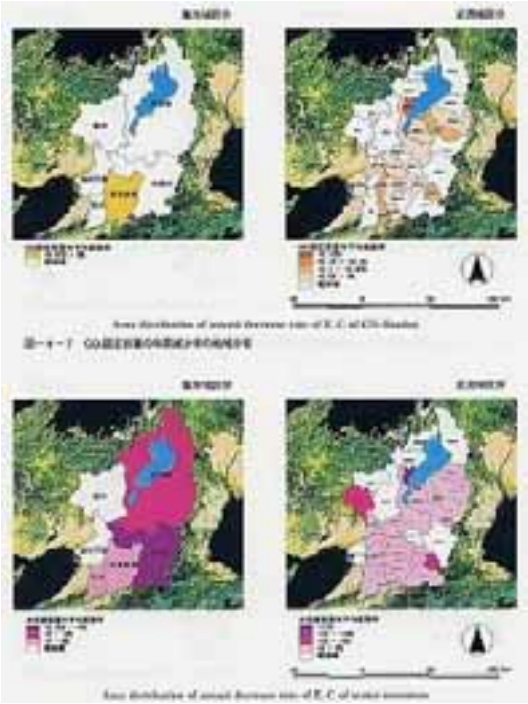
3.3.2 Estimated Duration of WEC (The mean of top 5, Duration at Sub river basin unit)

WEC of CO2 Fixation: 36.4 years

WEC of Water Resources: 25.2 years







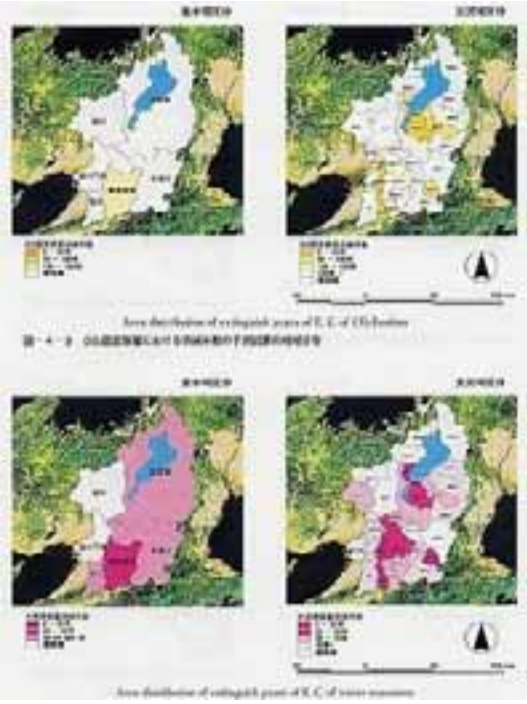


Fig. 11. Analysis result of WEC Fluctuations at Lake Biwa and Yamato River Basin

4. Significance and Objective

The ability to establish the quantitative relationships between humans and nature in the environment within the urban context is in its formative stages. Outcomes from these analyses are the improvement of environmental protection within and around our cities, and through looking globally the entire earth as so much of the world is going through the same or similar processes of urbanization. The WEC Model can also be regarded as an environmental structure. However, as a composite of environmental processes and functions, it is difficult to recognize and to construct it as an absolute system as it is invisible. In this system, we have integrated scientific knowledge and accumulated environmental data through the application of GIS technologies and have tried to render finding for easy conveyance and comprehension. (Fig. 12,13,14,15)

Our target is to promote recognition regarding the raison d'être of nature, human actions and attributes, thereby contributing to the development of more effective environmental planning strategies, and perhaps changes in lifestyles or living patterns, and finally, the promotion and consolidation of knowledge and information regarding inhabitants and planning for the subject areas of urbanism and natural systems.

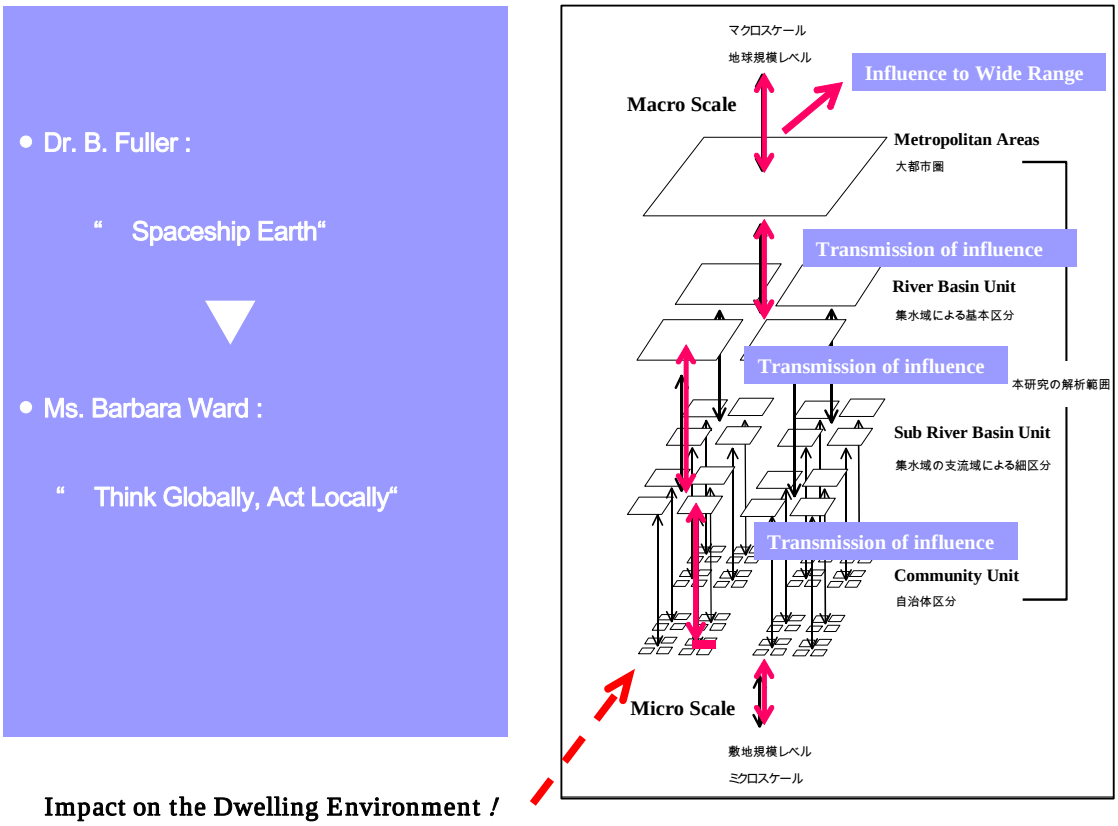


Fig. 12. Hierarchical influence by impact

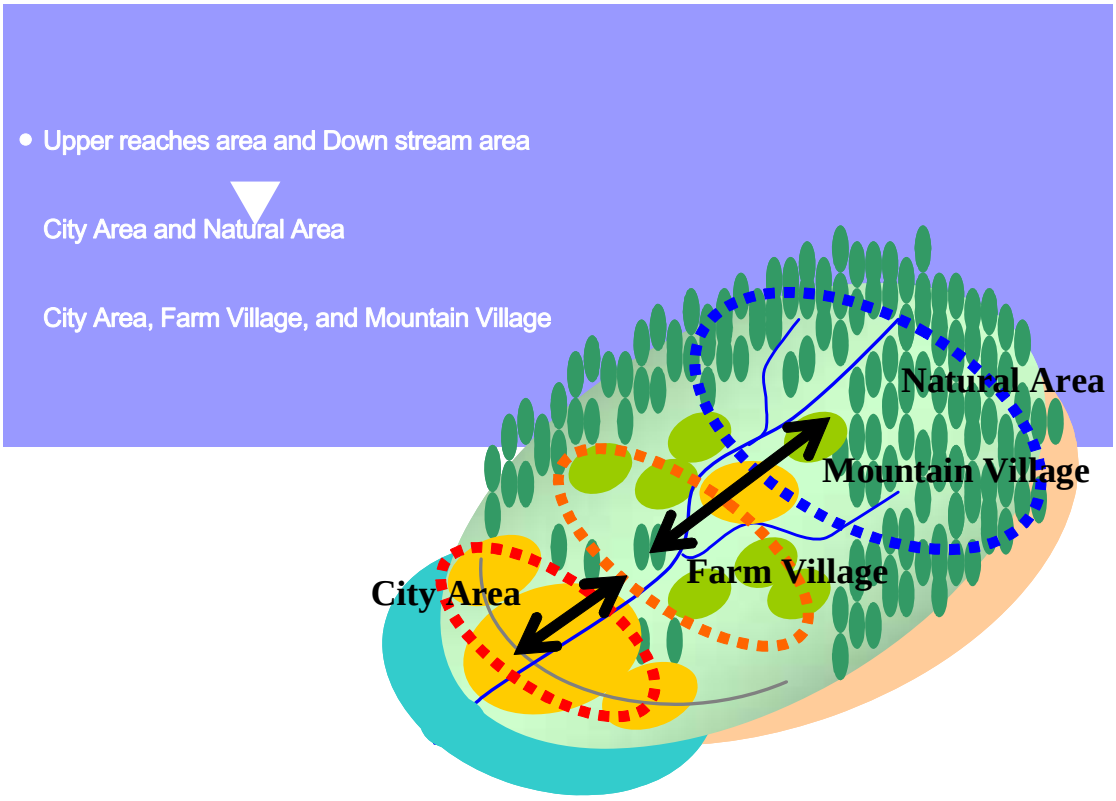


Fig. 13. Relationship between city area, farm area and natural area based on watershed

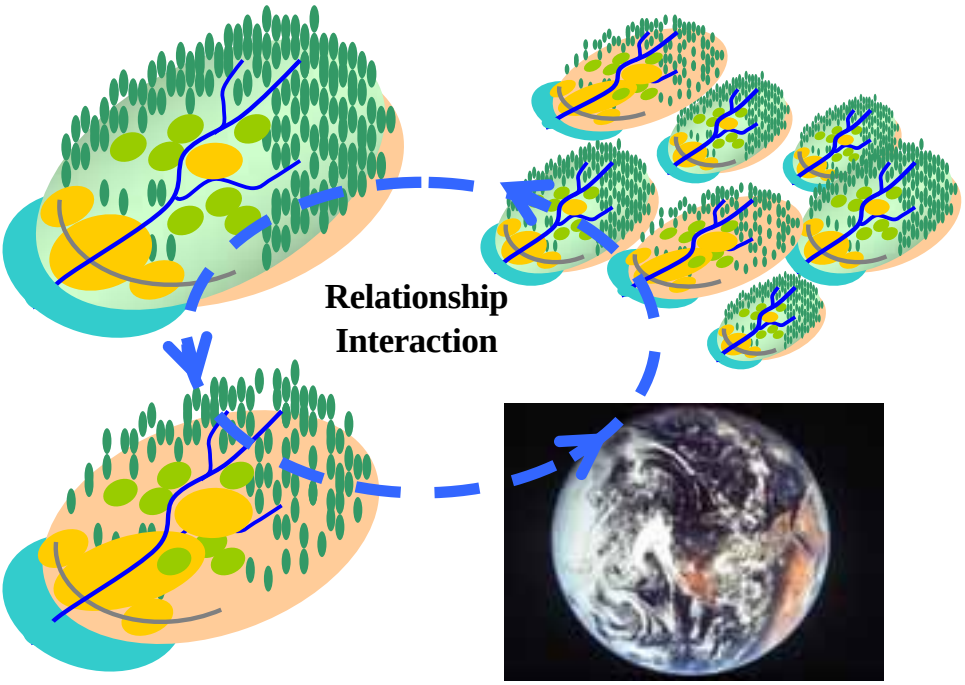


Fig. 14. Relationship between homeostasis of watershed and spaceship earth

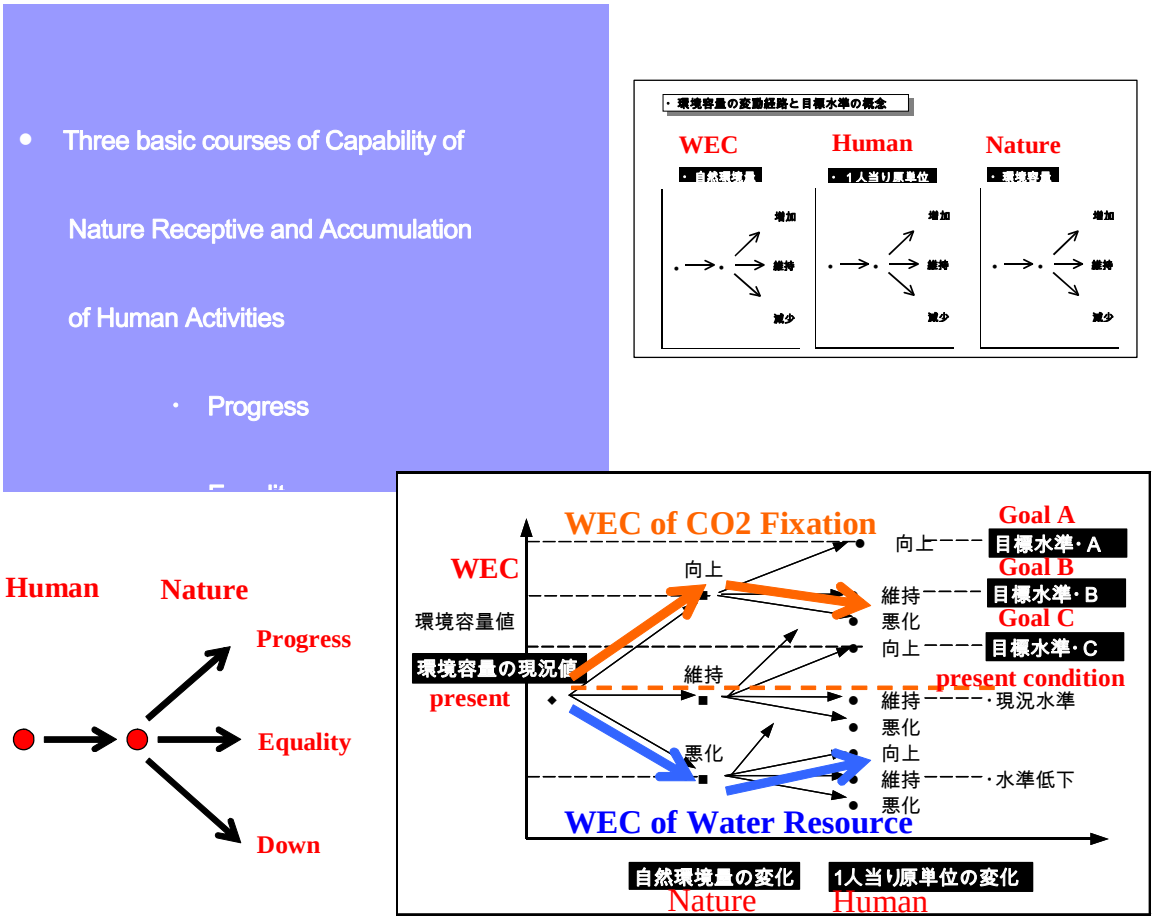


Fig. 15. General idea of change courses of Watershed Environmental Capacity (WEC)

Acknowledgments

I would like to express my sincere gratitude and appreciation to Mr. Brian Collett and the following organizations for assisting with paper, presentation and participation to ESRI-UC-2006.

TAKENAKA CORPORATION
Research Institute for Humanity and Nature (RIHN)
Frontier Research Center for Global Change (FRCGC)
ESRI-JAPAN

End Notes

It is a great honor for me to participate in the 26th Annual ESRI International User Conference. I have been interesting in the Interrelationship between Human and Nature from the point of view of river basin since my school days. This theme is my lifework. And about 35 years ago, our company, Takenaka Corporation has used GIS for the first time in Japan.

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