ENVIRONMENT, TECHNOLOGY AND INSTITUTIONS FOR SUSTAINABLE HUMANOSPHERE: A WATER PERSPECTIVE

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ABSTRACT

Sustainable Humanosphere studies are recently developed field of research where integrated understandings of global climatic, ecological and social systems are pursued to cope with population and economic expansion, climatic changes and environmental degradation. This paper introduces a new perspective of sustainable Humanosphere studies taking a water issue as an example.

1. Sustainable Humanosphere studies

Man-nature interaction is now on the turning point. Human beings have initiated agriculture around ten thousand years ago. Since then, our ancestors have made huge efforts to acquire necessary food and fiber for the survival, and to build civilized societies by means of intervening and utilizing natural environments.

Technology and institutions for these activities, as consequences of repeated tries and errors, differed from region to region in the world, partly reflecting different environments that people have confronted. In Monsoon Asia, characterized by the Himalayan orogenic movement and Monsoon rainfall, people have created lowland paddy-based societies. While in the arid range from the central part of the Eurasian Continent to Northern Africa, people have created oasis agriculture and pastoralism-based societies. Under the given Geosphere, where heat and water is continuously circulating, and ecosystems of diverse flora and fauna, each society has selectively adjusted her livelihood systems. In addition, we have modified the environment for enough and stable production. Agricultural land reclamation simplified original ecosystems, and irrigation development changed hydrological process. The relation between human beings and nature is, therefore, not one way but interaction.

This interaction had been, however, unequal in terms of scale. The environment has a holistic significance on the way of life of human beings, while the impacts of human beings on the environment were limited, localized and temporal. The activities of human beings were supposed not to be as significant as causing irreversible changes in the Geospheric processes and global ecosystem.

We have recognized, however, that this idea might be wrong since several decades ago, and confirmed its correctness through laborious works of the Intergovernmental Panel on

Climate Change (IPCC) and other scientists. The global climatic system and heat and water cycles are undoubtedly affected by human activities, and, of course, the consequent changes also affect our economy, culture, and livelihood.

We, academic scholars, have to respond to this situation by introducing new concepts on climate, land and water, energy, and so on to our studies. Humanosphere studies were initiated under this circumstance in order to combine studies on human beings and societies with global climatic and ecological systems.

Humanosphere was first defined by Prof. Matsui as one of the sub-system of the global system where the activities of human beings extend (Matsui 1998). This concept was then applied when a new research institute was established at Kyoto University in 2004. The research institute aims at integrating material and energy balance studies at the earth surface with space science to identify the structure of the global system, and was named as Research Institute of Sustainable Humanosphere (RISH). In 2007, Center for Southeast Asians Studies, Kyoto University, in collaboration with several graduate schools and research institutes of the same university including RISH, set up a new research program, Global COE Program, and started studies on "In Search of Sustainable Humanosphere in Asia and Africa" under the leadership of Prof. Sugihara, an economic historian. This program aims at conducting a wide range of interdisciplinary studies on sustainable development in Asia and Africa from a global, long-term perspective.

One of the important conceptual frameworks of this program is multiple levels of sphere. We call the global physical system as Geosphere. Biosphere is a sub-system of Geosphere, and activities of a wide range of life, flora, fauna and even micro-organisms dominate this space. Homosphere is a sub-system of Biosphere where activities of human beings extend. Three spheres interact and cause structural changes each other. Incorporating these interactions, we call the overall system Humanosphere.

I would like to focus on water in this paper, as water is one of the most important resources circulating in Humanosphere and essential for the survival of not only human beings but also all flora and fauna.

2. The Earth, water planet

1.4 billion km^3 of water exist on our planet. This means that the Earth is covered with water film of the thickness of 2,700 m in average. The majority of water is, unfortunately, sea water (96.5%), glaciers and snow (1.7%), and deep ground water (1.7%) which we cannot use as fresh water resource (Oki and Kanae 2006).

Renewable fresh water resource (RFWR) for human beings is water circulating between ground surface and the atmosphere. Annual precipitation of the world is 502,000 km^3, indicating the average annual precipitation of 980 mm in the world, of which 111,000 km^3 to the land and the remaining to the ocean. World total annual evapotranspiration is as much as that of annual precipitation, but the proportion between that from land and ocean is different. The annual terrestrial evapotranspiration is 66,000 km^3, 45,000 km^3 small than annual precipitation. This difference coincides with annual runoff to the sea mostly through rivers. This is what we generally recognize as RFWR.

RFWR is unevenly distributed in the world (Table 1). The Oceania (54,800 m^3/person), Latin America (26,700 m^3/person) and North America (29,300 m^3/person) are water-rich regions, while Caribbean (2,400 m^3/person), Asia (3,000 m^3/person) and Africa (4,600 m^3/person) regions are poor in water resource, one third to two third of the world average of 6,900 m^3/person (FAO 2008).

Table 1 Annual supply and withdrawal of renewable fresh water resources

Suply and demand		World	Africa	Asia	Latin America	Caribbean	North America	Oceania	Europe
Supply									
Total volume	(km^3)	43,659	3,936	11,594	13,477	93	6,253	1,703	6,603
Per caput volume	(m^3)	6,900	4,600	3,000	26,700	2,400	19,300	54,800	9,100
Withdrawal									
Total	(km^3)	3,830	215	2,378	252	13	525	26	418
	(% to supply)	8.8	5.5	20.5	1.9	14.4	8.4	1.5	6.3
Domestic	(km^3)	381	21	172	47	3	70	5	63
(% to total withdrawal)		10.0	10.0	7.2	18.8	23.1	13.3	17.5	15.1
Industrial	(km^3)	785	9	270	26	1	252	3	223
(% to total withdrawal)		20.5	4.2	11.4	10.4	9.4	48.0	10.1	53.3
Agricultural	(km^3)	2,664	184	1,936	178	9	203	19	132
(% to total withdrawal)		69.5	85.8	81.4	70.8	67.5	38.7	72.4	31.6

Remarks: Calculated from (FAO 2008)

3. Humanosphere development path in the 20th century

Although the regional averages of the proportion of actual withdrawal to RFWR are rather small with the world average of 8.8%, river water shortage has emerged as a serious environmental degradation during the last several decades even in water-rich regions. The major cause is said to be irrigation water withdrawal for food and fiber production because the agricultural sector is the biggest water user in the world, occupying 70% of the total withdrawal. What was the process to reach this degradation?

The latter half of the 20th century was the era of “civil engineering”, in which water resources development was one of the most significant and popular driving forces. Number of large reservoirs with the capacity over 100 million m^3 in the world was 12 at the end of the 1940s, and sharply increased to 63, 133 and 192 by the end of the 1950s, 60s and 70s (Gleick *et al.* 2003). The idea behind this development was that water was the basis of agricultural production and we could control water flow. “Green Revolution” technically and socially strengthened this idea and challenge. In Monsoon Asia, IR8, a predominant high-yielding variety of rice was released by IRRI in the late 1960s. In order to expand the cultivation of this miracle rice to save food shortage of the region, the first priority was given to irrigation development (Figure 1). It is undoubtedly true that these enthusiastic efforts for water control minimized the hunger and malnutrition of the world.

Prof. Malin Falkenmark, professor emeritus of The Stockholm International Water Institute, proposed to classify RFWR in to two types, and named “blue water” and “green water" based on the hydrological process (Falkenmark and Rockström 1993; Rockström *et al*. 2007). Blue water is a runoff water resource from land to the ocean through rivers, while green water is a soil moisture resource from infiltrated rainfall on its way back to the atmosphere. This hydrological difference affects their characteristics as resource. Blue water is visible. We can measure the volume and control the water flow by storing and transporting, though not peerfectly. Green water exists everywhere, but is invisible. We undoubtedly use it, but the water flow depends on hydrological and biological processes, and effects of human interventions on them are limited.

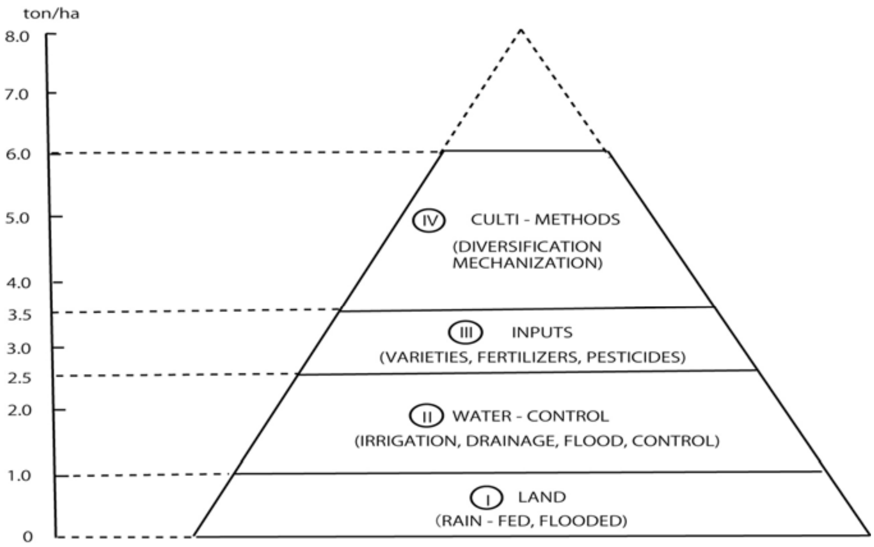

Figure 1 Model for the developing stages of rice yield

Remarks: Modified from (Takase and Kano 1969)

What we achieved during the latter half of the 20th century can be said as blue water-based development. We developed technology and institutions to control blue water, to form the optimum environment regardless to agro-ecological diversity, to apply standardized production methods, and to maximize land productivity. This challenge was partially successful, but, unfortunately, caused environmental degradation particularly in semi-arid regions. Fred Pearce, a well-known environmental journalist, wrote that "Back in the 1960s and 1970s, neither the green-revolution scientists nor the doomsayers fully appreciated that while the new crops were indeed very efficient at delivering more crop per acre, they were often extremely inefficient when measured against water use" (Pearce 2006: 24).

4. Harmonizing with Geosphere and Biosphere

Global warming is expected to accelerate water cycles and thereby increase the available RFWR, but its spatial and temporal distribution is not precisely predicted (Oki and Kanae 2006). This suggests that we have to prepare for both risks of water deficit and excess. Water control is still a necessary and important measure for mitigating natural disaster and increasing agricultural production. It must be better, however, for us to prepare for an alternative strategy to cope with unpredictable future and to achieve sustainable Humanosphere.

One of the key issues is green water management. Annual green water resource is estimated to be 62,000 km^3, of which 8.7% is evapotranspiration directly contributing to agricultural production (Table 2). In the tropics which occupies two third of green water resource of the world, this ratio is 7.5%. It is true that farmers have made huge efforts to develop technologies to utilize green water and succeeded them from generation to generation, but the efforts of scientists and the government sectors are not so remarkable compared to what they did for blue water management. Consequently, technology and institutions for green water management is still localized and not well operationalized for wider communities.

Table 2 Annual water vapor flow by climatic zone and land use

Climatic zone	Forest and grass lands		Crop lands		Total
	(km^3)	(%)	(km^3)	(%)	(km^3)
Boreal	4,780	100.0	0	0.0	4,780
Temperate	13,702	85.6	2,308	14.4	16,010
Tropical	37,990	92.5	3,096	7.5	41,086
Total	56,472	91.3	5,404	8.7	61,876

Remarks: Calculated from Table 1of (Rockström *et al.* 1999)

In order to achieve sustainable Humanosphere, understanding the structure and mechanisms of Geosphere and Biosphere and adjusting technology and institutions of Homosphere to them, instead of controlling Geosphere and Biosphere according to the needs of human beings, is essential. This is particularly important in the tropics because it is the engine of global heat and water circulation and the source of biodiversity for the Earth. Geo-informatics is expected to be one of the major fields of research to integrate knowledge and information on Humanosphere.

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