3-4 Development of indicators for the establishment of a sound material-cycle society
China's sustainability assessment based on decoupling concept: By using Ecological Footprint

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ABSTRACT

This study was undertaken to develop a new assessment index for the creation of a recycling-oriented society and make specific policy proposals by applying the indicator to the Asia–Pacific region. This year, we performed a sustainability assessment of China as a whole, with some regions having different characteristics in the country based on the decoupling concept using the ecological footprint (EF) concept, which has been drawing attention in recent years.

The analysis revealed the following. 1. The EF indicator value of China increased constantly during 1995–2010. The growth after 2000 was particularly notable. 2. The EF indicator value per capita of the city of Shanghai (urban characteristics) is 2.5 times that of the province of Henan (rural characteristics). 3. Growth in the EF indicator values of Qinghai Province (suburban characteristics) and Henan Province are high, not only because of changes in the industrial structure, but because of such factors as changes in dietary habits. 4. The decoupling assessment based on the EF indicator values and GDP has revealed that although China as a whole is in a state of "relatively good decoupling," the rates of change in the EF indicator value and GDP are proportional to each other. 5. Tendencies in the rates vary significantly among different regions.

REPORT ON THE STUDY

(1) Background and objectives of the study

Responses to issues such as global warming and waste management are regarded as an urgent requirement. One specific solution is the creation of a recycling-oriented society. A range of approaches to the creation of a recycling-oriented society has been assessed through experimentation, and an assessment index for them includes greenhouse gas emissions and recycling rates. Nevertheless, studies of them reported in the literature are inadequate.

Meanwhile, the ecological footprint (EF)[1)] index, which allows a composite assessment of environmental burdens of various types such as consumption of resources associated with human activities by converting them into land-area based values (footprint) have been drawing attention in

recent years. This index is beneficial for allowing quantitative assessment of environmental balance and overshooting (ecological deficits [2]) through a comparison with the environmental capacity of the country or regions (the actual natural land use), which is expected to become an assessment index of one aspect for the creation of a recycling-oriented society. It is also a tool that can appeal to a person's intuition, proving the specific ideas of environmental issues as a common image. In other words, it can play an important role as a communication tool for the implementation of this project, "Practical Research and Education of Solid Waste Management Based on Partnership among Universities and Governments in Asia and Pacific Countries."

This study is aimed at development of an assessment index based on the EF indicator concept for the creation of a recycling-oriented society and to suggest specific policy proposals by applying the indicator to certain countries and regions. China has been selected as the subject of the study this year. The reason is that this project targets the Asia–Pacific countries in which environmental problems are increasingly serious as a result of economic development. China, showing such a trend particularly clearly and encompassing a diverse mix of regions from industrialized to developing areas, represents a microcosm of the Asia–Pacific region (which has large regional disparities). As the study for this year, the sustainability assessment (between 1995 and 2010) of all of China and various regions having different characteristics in the country have been examined based on the decoupling concept using the ecological footprint (EF) concept.

(2) Methodology

1) Region to be studied

This study analyzes all of China and several regions having different characteristics in the country. The analysis includes regions having urban characteristics, those with suburban characteristics, and others with more rural characteristics that have been selected based on the composition of urban and rural populations and geographical conditions. The target regions are as described hereinafter.

Shanghai city: Located in coastal China with an urban population of approximately 17 million and rural population of approximately 2.2 million. The urban population comprises approximately 90% of the populace. Therefore, Shanghai is positioned as a region with urban characteristics.

Henan province: Located inland in China, with an urban population of approximately 36 million and rural population of approximately 59 million. The urban population constitutes approximately 42%. Therefore, Henan is positioned as a region with mixed urban and rural characteristics.

Qinghai province: Located in the inland and mountainous areas of China with an urban population of approximately 2.3 million and rural population of approximately 3.2 million. The rural population comprises approximately 62%. Consequently, Qinghai is positioned as a region with rural characteristics.

2) How to calculate the EF indicator

The following are components of the EF indicator used in the study.

EF 1: Farmland used to grow products for food and animal feed
EF 2: Pastures used to feed animals for meat and dairy products
EF 3: Woodland for collecting lumber, raw materials for paper, etc.
EF 4: Land needed for urban activities
EF 5: Forests necessary to limit CO_2 emissions

The indicator used EF 1 through EF 5 as its components. Calculations were performed based on the concept of Equation (1)[1] proposed by Wackernagel et al. Table 1 presents the major types of data used. It is noteworthy that the calculation of the EF indicator values in this study has not incorporated inter-industry relations. Therefore, it excludes the environmental burdens indirectly resulting from the urban activities of the region itself and other regions. EF 3 uses the national average values. These are thought to require continuous improvement through data development.

$$EF_p = \sum_{l=1}^{n} \frac{C_l}{P_l} \tag{1}$$

EF_p: Ecological footprint per capita (ha/person)
C_l: Consumption per capita of consumer goods l (t/person)
P_l: Production per unit area of consumer goods l (t/ha)
l: Consumer goods used in the study

Table 1: Major types of data used for the EF calculation

EF	Component		Major Data Used	Source
1	Farmland used to grow products for food and animal feed (food and feed)	Food	Consumption per capita of cereals, vegetables, fruits, etc. in the country and in respective regions	3)4)5)6)7)
		Feed	Consumption per capita of pork, beef, chicken, lamb, dairy products, etc. in the country and in respective regions	3)4)5)6)
2	Pastures used to feed animals for meat and dairy products (pasture)			
3	Land needed to allow urban activities (size of urban area)		Size of land for urban use per capita in the country and in respective regions	3)
4	Woodland for collecting lumber (lumber)		Wood consumption per capita of all of China	7)8)
5	Forests needed to limit CO_2 emissions (CO_2 absorbing land)		CO_2 emissions per capita of the country and of respective regions	9)10)

3) How to evaluate the state of decoupling [11) 12)]

Decoupling is a concept proposed by the OECD [13)], which means detachment of harm caused to

the environment and benefits to the economy. This study assesses the sustainability of China and target regions using the method of classifying decoupling statuses proposed by Takai et al. [11)12)] The analysis used the EF indicator value per capita as the indicator of environmental burden and GDP per capita as the indicator of the economy. The EF indicators help to elucidate the relation between environmental burden and the economy from a multifaceted perspective, including the dietary habits, resource consumption, and CO_2 emissions of local residents.

First, the value of the EF per capita indicator is expressed as *EF/P* and the amount of change in *EF/P* is represented by □*(EF/P)* where the rate of change in the value of EF per capita indicator is

$$\square\ (EF/P)/(EF/P) \tag{2}$$

in which *EF* is defined as the EF of each province and cities under the direct control of the province (ha) and *P* is the population of each province and cities under the direct control of the province (people). The GDP per capita is expressed as *I/P*; the amount of change in *I/P* is indicated as □*(I/P)* where the rate of change in GDP per capita is

$$\square\ (I/P)/(I/P)\ . \tag{3}$$

In that expression, *I* is defined as GDP in each province and cities under the direct control of the province (yuan).

These two indicators define decoupling statuses, as presented in Figure 1.

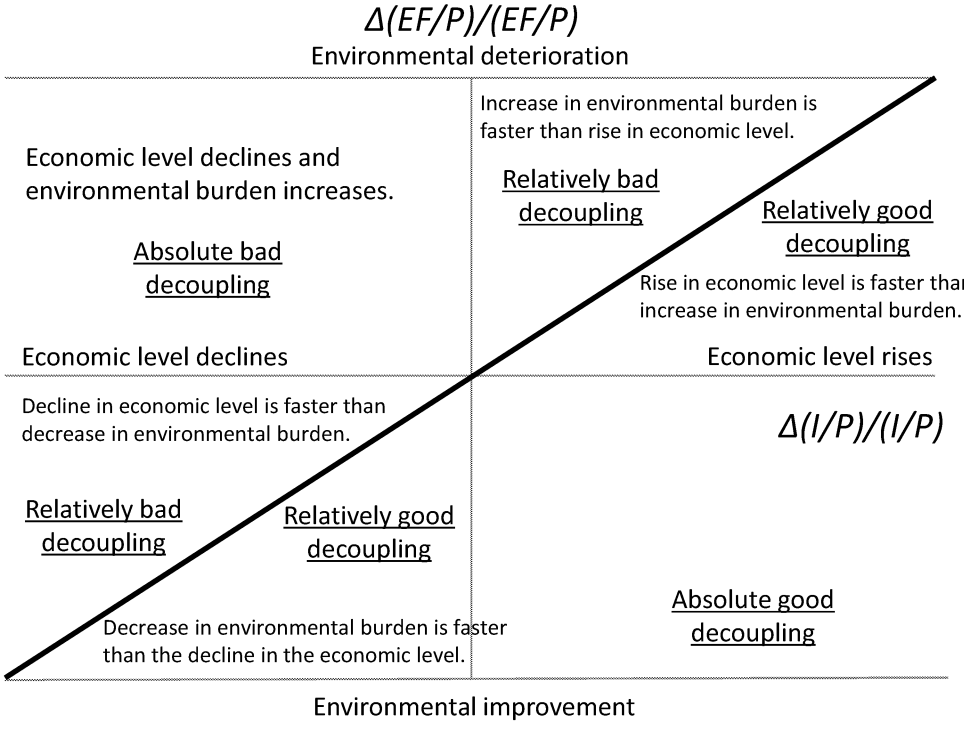

Figure 1 Classification of decoupling statuses according to Takai et al.[11)12)]

(Prepared by the authors by converting the environmental indicator to EF)

(3) Results of analysis

Figure 2 presents changes in the EF indicator of China as a whole and those of respective regions during 1995–2010.

Major results of the analysis are explained below.

1) The EF indicator value of the entire China tends to increase. The rise after 2000 has been particularly large. The value of EF per capita in Shanghai (urban characteristics) is 2.5 times that of Henan province (rural characteristics)
2) A rapid increase in the EF indicator value was found in Qinghai and Henan provinces, unlike the unchanged values in mature cities such as Shanghai. In other words, these regions might have been significantly responsible for the recent increase in China's environmental burden.
3) Although this increase is caused primarily by growth in CO_2 emissions caused by changes in the industrial structure, recent changes in the people's dietary habits in China (Westernization of diet) also have a considerable effect.

Figures 3 through 6 present changes in the decoupling statuses in the entire China and in each region.

The major results of the analysis are as follows:

4) The possibility of a substantial effect of an increase in the EF indicator value on GDP growth is inferred from the proportional relation between the rates of changes in the EF indicator value and GDP despite the status of "relatively good decoupling" for all of China.
5) Meanwhile, changes in the decoupling status of respective regions vary considerably depending on regional characteristics. In Qinghai Province, for instance, the rate of change in the EF indicator value has clearly been increasing despite the constant rate of change in GDP since 2000. In Henan province, the rate of change in the EF indicator value has been constant, unlike the decline in the rate of change in GDP since 2000. In other words, results of the study have revealed that while the rates of change in GDP and EF value of China as a whole show a simple proportional relation, changes in the decoupling status vary substantially depending on the regional characteristics when broken down to the regional level such as each province and cities under the direct control of the province.

FUTURE PLANS

The project undertaken this year has involved experimentation with analysis of the relation between the changes in EF indicator values and economic indicator at the national and local levels. Future studies will link the creation of a recycling-oriented society with people's lives by breaking down the levels from regions to people's lifestyles to examine the differences in the EF indicator values caused by varying lifestyles and the effect of such differences on sustainability at the regional level.

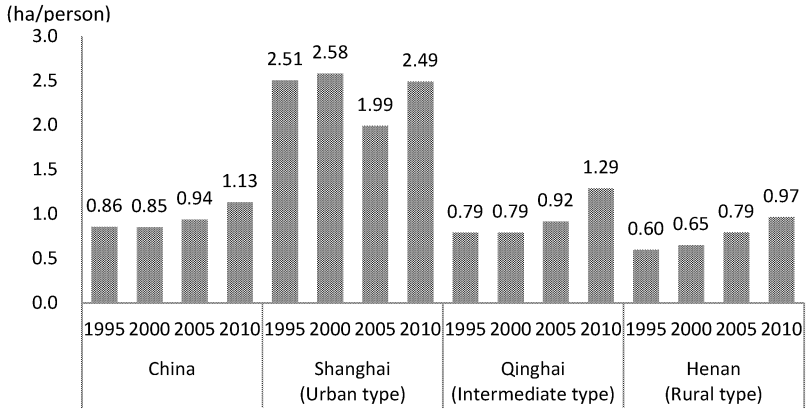

Figure 2 Changes in the EF indicator values of China and target regions.

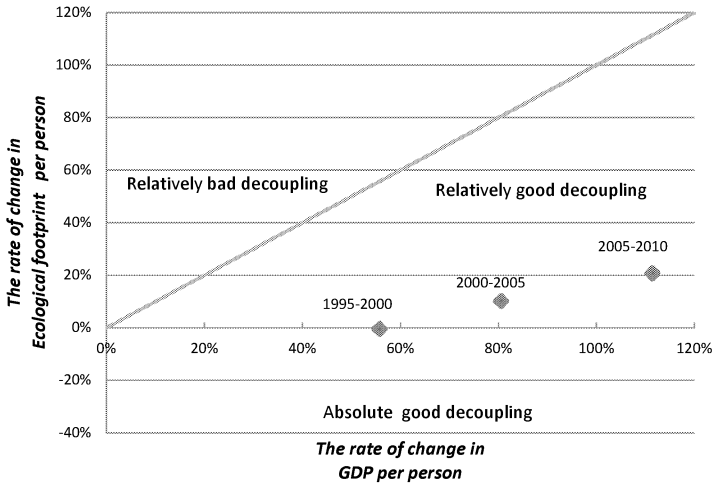

Figure 3 Changes in the decoupling status of all of China.

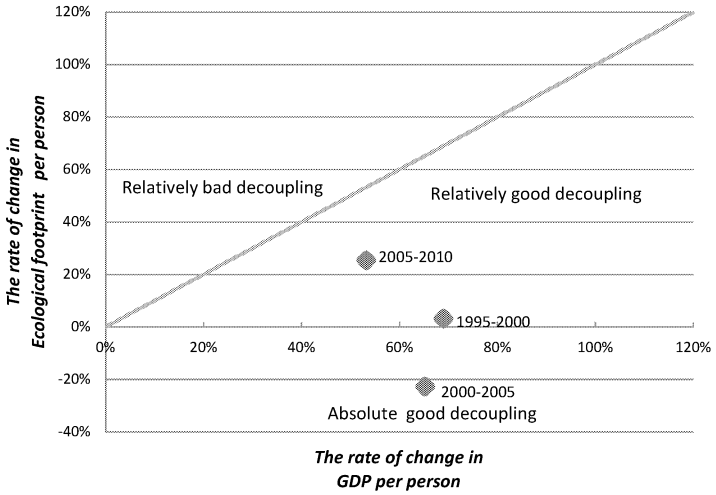

Figure 4 Changes in the decoupling statuses of Shanghai city.

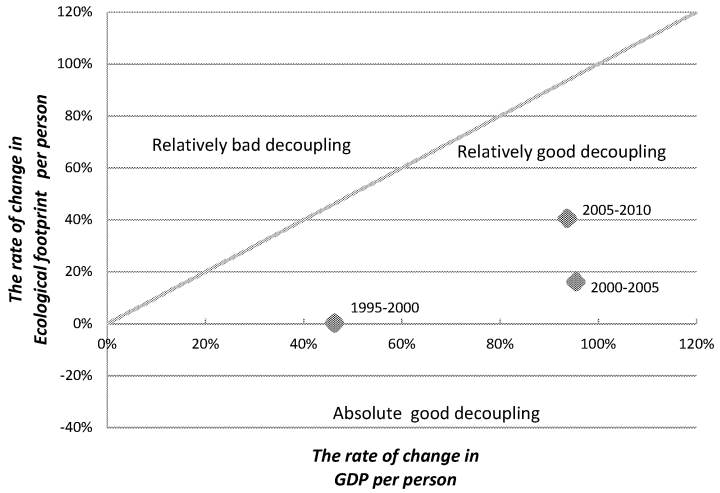

Figure 5 Changes in the decoupling status of Qinghai province.

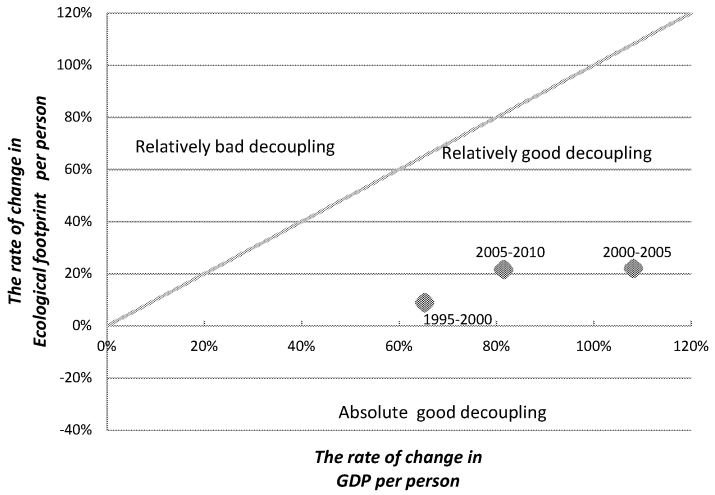

Figure 6 Changes in the decoupling status of Henan province.

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