Framework for Regional Partnership between Urban and Rural Area towards a Low Carbon Society

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Abstract: The purpose of this study is to develop a framework for regional partnership between urban and rural areas by focus on designing regional circulation of energy and resources. Firstly, we listed the general characteristics of urban and rural areas, and the corresponding examples of urban-rural partnership. Here, from the viewpoint of low greenhouse gas (GHG) emissions, the pattern of urban-rural relationship was reviewed. Secondly, we developed two analytical tools: stock and flow accounts and causal models by using life cycle simulation. The former tool is based on material flow accounting and analysis (MFA) and modified as an analytical tool to evaluate the regional sustainability by the partnership between urban and rural areas. The latter tool models a network of processes and runs a simulation based on the discrete-event technique in order to quantify the constraint requirements of partnership. Finally, we applied these tools to pilot models in Zhejiang province, China. Based on the simulation result, we described possible future scenarios of the region toward 2030, where the supply-demand balance and GHG emissions due to energy consumption are estimated.

Key words: Low Carbon Society, Urban-Rural Partnership, Regional Circulation, Natural Resources, Design for Sustainability.

1. Introduction

National and local governments have started to construct low carbon societies by setting medium and long-term goals for each sector of concern. Design of regional circulation of natural resources across urban and rural boundaries is a hopeful measure for low greenhouse gas (GHG) emissions as well as extending co-benefits such as pollution prevention and industrial development in rural areas. However, primary sectors with weak economic bases are exempt from meeting emissions reduction targets in Japan. In addition, material exchange between rural and urban areas is insufficient. Urban-rural issues are also gaining importance outside Japan; for example, in China, the income gap between urban and rural areas has been increasing with rapid economic growth and urbanization.

Therefore, under the objective of building a low carbon society, we should reconsider the relationship between urban and rural areas and plausible forms of partnership between them. For this purpose, it is necessary to estimate the potential reduction of GHG emissions by the partnership and to describe images and scenarios of the desired society as a result of such partnership. Additionally, in order to guide these activities, research and development for assessment methods of these partnerships and sustainability indicators is required.

The purpose of this study is to develop a framework for regional partnership between urban and rural areas by focus on designing regional circulation of energy and resources (*e.g.*, biomass). We seek this objective by executing fieldwork in selected pilot model areas in Asian countries and constructing regional partnership models. The research result is planned to be summarized as a multi-beneficial scenario that realizes low GHG emissions, pollution prevention, and social development on the basis of the urban-rural partnership.

Moreover, in order to integrate the regional partnership models, we develop a modeling framework for material and energy circulation in a chosen area and an analytical tool that evaluates the potentiality and availability of the partnerships by using various analytical methods such as what-if analysis. Meanwhile, by using a rational scenario planning methodology, we conclude this research in the form of future scenarios that suggest future directions of the regional partnership between urban and rural area. We believe that, by clarifying the synergy effects of the suggested pilot models, we are able to suggest how partnership between urban and rural areas will be multi-beneficial for sustainable society and this will contribute to Japan's environmental policies towards construction of low carbon societies in Japan and Asian region.

2. Urban-rural partnership

Internationally an urban-rural classification has yet to be clearly defined, and the national statistics office definition differs from one country or area to another. National statistics office definitions are usually based on criteria that may include any of the following: size of population in a locality, population density, distance between built-up areas, predominant type of economic activity, and legal or administrative boundaries, *etc.* [1]. In this study, urban and rural areas are firstly distinguished by these several criteria. And then, the general characteristics of urban and rural areas, and the corresponding examples of possible urban-rural partnerships are listed by brainstorming using examples from a listing of synergies and antagonisms between urban and rural land resources use in the Planning for sustainable use of land resources: Towards a new approach report by the FAO [2], as shown in Table 1. The term "urban-rural partnership" here means that the appropriate bilateral flows and circulations of materials, energy, information, monetary, and population, contributing to the followings:

- disparity adjustment and equitable distribution of wealth,
- win-win situations making full use of each characteristics,
- coexistence with mutually embedded structures; that is, urban functions in rural area and rural functions in urban area, and
- cooperative conservation of ecosystem services mainly in rural areas.

We should add that the items are not fully detailed, and the partnerships are practically conducted with the combination of these aspects. In this paper, especially, we focused on the "maintenance and optimum utilization of biological resources by regional circulations" (see Table 1).

Table 1. Major characteristics of urban and rural areas, and examples of urban-rural partnership

Item	Urban	Rural	Examples of partnership
Population size in locality	Large and growth	Small and dwindling (growth in peri-urban area)	Population optimization
Population density	High-density (DID, in Japan)	Excessively declining population	Decentralization of population and gorvernment Living in two areas
Predominant type of economic activity	Industry and commerce (secondary and tertiary sector)	Agriculture, forestry and fisheries (primary sector)	Agriculture, commerce and industry symbiosis Industrialization in rural area Urban agriculture and horticulture
Job and income	Mass-influx of rural population Relatively high income	Lack of labor for primary sector Relatively lower income	Socio-economic support mechanisms for disparity adjustment Bolstering of local finance
Medical welfare	Large-scale and centralized complexes	Home care and community welfare Inadequate healthcare service	Community-based healthcare and regional medical plan Taking oriental medicine with herbal plants
Trend of education	Indoor and information-type with cramming of knowledge	Outdoor and practical -type involving physical activity	Mix and exchange programs
Resources of tourism	Historical and cultural sites	Landscape and natural sites	Eco-tourism, Green tourism and intercity travel
Information	Centralization and overabundance of information	Inadequate infrastructure of information technology	Bridge the digital divide Enhancement of information sharing
Geomorphic characteristics	Plain field, coastal area	Intermediate and mountainous area	Land use according to the land features Good access and transport optimization
Water use and management	For human and industrial use	For irrigation, agricultural produce processing	Water storage for both energy and irrigation Water management in watershed areas Afforestation program
Foods	Fast foods and various foods from all over the world	Slow foods and local dishes from nature	Promotion of credit and markets for locally- produced food Consideration of food mileage
Predominant biological resources (biomass)	Foods waste and sewage sludge	Crop, livestock, wood, and aquatic biomass	"Maintenance and optimum utilization by regional circulation" Reuse of treated waste biomass on peri-urban agricultural lands
Manmade resources	High-density high-rise buildings, industrial areas, and (peri-)urban infrastructure	Low-density Expressways, power plants	Urban mining Effective utilization of existing infrastructure

Note: DID stands for Densely Inhabited District. When a research zone with high population density (around 4,000 per km^2 by Census) is adjacent to another high-density research zone, and the total area encompasses a population of more than 5,000, the total zone is defined as a DID

3. Analytical tools

We integrated the regional data, obtained from the pilot model areas, into a common framework and established a methodology of regional modeling in order to clarify the properties of the pilot model areas. Specifically, we developed the following two analytical tools that evaluate the resource circulation system under the regional partnership between urban and rural areas, based on energy and materials balance of stocks and flows.

3.1 Development of stock and flow accounts

This analytical tool is based on material flow accounting and analysis (MFA). MFA is a comprehensive and systematic assessment methodology of the stocks and flows of materials and substances within a system defined in space and time [3-7]. MFA is an important tool of industrial ecology [8], and is used to investigate the material metabolism of anthropogenic systems [9], to calculate physical indicators of sustainability [10], and to make policies for improving the resource management, environmental management, and recycling and waste management [11]. MFA is essentially concerned with the interface between anthroposphere driven by humans and environment driven by nature.

In this paper, MFA was modified as an analytical tool to evaluate the regional sustainability by the partnership between urban and rural areas. This tool models inputs, outputs, and economic activities of the flows of energy and materials needed to satisfy each sector's needs in a given pilot model area, describing linear relations between inputs and outputs. Meanwhile, natural capital, artificial capital, and land resources are accounted as stock. By distinguishing between flows of biotic resources and that of fossil fuel, and between flows within and beyond the region, this tool calculates demand-and-supply balance of energy and materials such as substitution from consumption of fossil fuel to regional cycles of renewable resources and increase in food and energy self-sufficiency, promoted by the regional partnership between urban and rural areas.

At first, we set the components of stock and flow account according to the following six factors:

- Definition of "systems boundaries"
- Classification of "sectors" that are subdivisions in an economic system of the region
- Estimation of "resources" that produce products accounted as flow
- Setting of "product and by-product(s)" that are yielded or produced by each sector
- Clarification of the amount of "demands" for resources input in each sector
- Assessing environmental load caused by "emissions and wastes" from each sector

Figure 1 shows the format of stock and flow account used in this study. This account consists of economy, livelihood, input, output, and stock accounts, and is described as follows:

- Economy: the economic activities (production value, number of employees) and amount of product are completed by inputting the corresponding figures from each sector. The sum of production value and number of employees are shown in the right edge of the sector cells. The industrial type (primary, secondary, and tertiary sector) is marked and the population balance (composition ratio of urban and rural population) calculated.
- By use: the table calculates the demand for resources as the result of the described economic activities. By distinguishing between the flow of natural resources and that of fossil fuel, transition from consumption of fossil fuel to regional cycles of natural resources is estimated.

- Input: the sum of the demand is clearly distinguished between flows within and flows beyond the region, and the input flows then calculated. This then allows for the assessment of the inter-industry relationship within the region, and the dependence on resources from outside the region.
- Output: environmental indicators are formulated in accordance with assessment based on GHG emissions and carbon fixation by ecosystems. Also, environmental waste stream (solid, liquid, gas) emissions by each sector are estimated.
- Stock: stock in this case is based just on the natural and manmade capital associated with regional biomass. Natural capital is expressed by the amount of land required to support the biomass consumed within the region. A constraint results when the consumption is greater than the equivalent regional capacity. Manmade capital is represented by the biomass processing equipment and facilities, with obsolete equipment treated as waste under the economy cells.

					Sector				Industrial structure			Population		Land use	Indicators	
					Production	Conversion	Consumption	Disposal	Gross produce/employee			Total		Classification	GHG emissions	Carbon fix
									Primary	Secondary	Tertiary	Urban	Rural			
Economy	Activity	Production value		[Sum]								-	-	-	-	-
		Employee		[Pop.]										-	-	-
	Product	Main product	i	[WT]			-	-	-	-	-	-	-	-	-	-
		Waste							-	-	-	-	-	-	-	-
By use	Intermediate commodity	Biotic resources	i	[WT]			-	-	-	-	-	-	-	-	-	-
		Fossil fuel														
	Foods	Biotic resources	i	[WT]	-	-		-	-	-	-	-	-	-	-	-
	Final energy	Biotic resources	i	[WT]					-	-	-	-	-	-	-	-
		Fossil fuel														
		Electricity														
		…			-	-	-	-	-	-	-	-	-	-	-	-
Input	Material	Product (within)	i	[WT]		-	-	-	-	-	-	-	-		-	-
		Product (beyond)	i	[WT]		-	-	-	-	-	-	-	-			
	Water	Water (within)	i	[WT]		-	-	-	-	-	-	-	-			
		Water (beyond)	i	[WT]		-	-	-	-	-	-	-	-			
	Land	Land resource	i	[Area]		-	-	-	-	-	-	-	-	-	-	-
Stock	Manmade capital	Biomass conversion tech.	i	[-]	-	-	-		-	-	-	-	-	-	-	-
		Inverse manufacturing	i	[-]	-	-	-		-	-	-	-	-	-	-	-
Output	GHG Emissions (from energy consumption)			[CO_2]					-	-	-	-	-	-		-
	Carbon fixation by ecosystems			[CO_2]	-	-	-	-	-	-	-	-	-		-	
	…				-	-	-	-	-	-	-	-	-	-	-	-

Figure 1. Basic format of stock and flow accounts

Table 2 also shows the stocks and flows for the subsequent case study.

3.2 Causal models of partnership clusters between urban and rural areas

Additionally, we developed causal models of regional partnership clusters between urban and rural areas by using a life cycle simulator [12], as shown in Figure 2, which models a network of processes and runs simulation based on discrete event technique. The simulation executes procedures as defined in each of the relevant processes and generates parameter values for the process network according to parametric dependency of the process network. The parametric dependency is automatically derived by the system from the process definitions. By describing a process as a node, linking the processes, and describing the input-output properties of processes, we can achieve detailed models and dynamic simulation. The synergy effects (*e.g.*, a pilot model of the partnership realizes GHG emissions reduction, conservation of soil and water and job creation) and the constraint requirements (*e.g.*, demand for natural resources, land area, water *etc.*) of clusters were quantified.

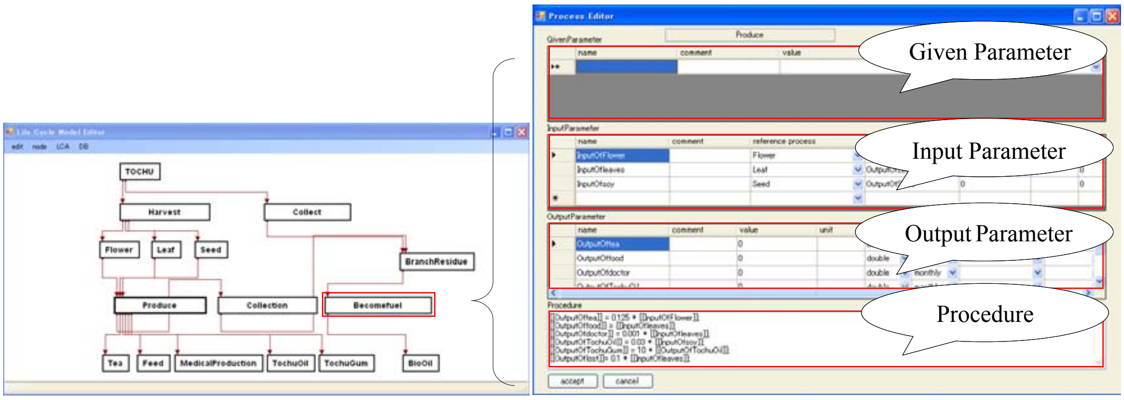

Figure 2. Screen hardcopy of the life cycle model editor

4. Case study

4.1 Application to Zhejiang province

Zhejiang province is an eastern coastal province of China, and the north of the province is just south of the Yangtze River Delta. The population is approximately 46.29 million people and the area is 101,800 km^2. The forest resources are rich, and the area is 66,900 km^2 and covers 65.7% of the total area of the province. For the primary sector, the breakdown of production values are; agriculture 52.571, forestry 5.574, livestock 11.172, and fisheries 23.023 billion Yuan (fiscal 2006 figure), agriculture sector is the largest in primary sector. In the coastal areas, chemical industry, especially, chemical fiber industry has been developed. The production value of fiber fabrics and textile is the largest in the industry sector, and covers 19.8% of the total industry sector [13].

4.2 Describing scenarios toward 2030

In Zhejiang province, we described two future scenarios; industrial development (ID) scenario and urban-rural partnership (UR) scenario. The base year is fiscal 2006, and we describe both scenarios in the span of the three decades until fiscal 2030. The supply-demand balance and GHG emissions by energy consumption are calculated by completing the values for the three scenario operational variables of industry growth rate, land use rate by the biomass conversion sector, and biomass utilization rate by the biomass conversion sector.

The ID scenario is so-called business-as-usual (BaU) scenario that industrial developing process follows the present trend. In the UR scenario, industry growth rate of primary sector increases more than the ID scenario and the land use rate and biomass utilization rate by the biomass conversion sector increased. In this case study, production of organic feeds, methane fermentation system, bio-ethanol production, and gasification power generation are selected as processes of the biomass conversion sector. The organic feeds are produced by composting any kind of food waste emitted from urban areas, and supplied to livestock sector in rural areas. The methane gas is produced from livestock, human, and kitchen waste, and the gas is used in place of gasoline fuels. The materials of bio-ethanol production are thinned wood, waste wood in lumbering, clipped branches, and waterweed. In order to generate electricity by gasification power generation, the following biomass are used; *viz.*, rice straw and husk, sewage sludge, sludge from human waste digestion tanks, and burnable waste *e.g.* used paper, used fabric, and used wood.

Table 2. Accouting items of stock and flow in case study

Item		Coverage
Flow	System boundary	Zhejiang province
	Sector	Agricultural, forestry, and fisheries, Industry, Service, Construction, Biomass, Disposal, Household
	Resource	Biological resources, Fossil fuels
	Product and by-product(s)	Edible crops, Livestock, Forest products, Fisheries, Petroleum refinery products, Processed foods, Fiber yarns, Fiber fabrics, Ply wood and woodchip, Wooden products and furniture, Paper, Chemicals, Construction, Electricity, Bio-energy, Waste biomass, Plantation biomass
	Demands (by use)	Intermediate commodity- Raw materials, Fuels for electricity and gas; Commodity consumed – Foods; Final energy, Waste and drainage treatment, Land resources
	Emissions and waste	Greenhouse gas emissions
Stock	Natural Capital	Land resources
	Manmade Capital	Biomass conversion equipment, End-of-pipe disposal equipments

5. Results and discussion

The calculation results of the demand-supply balance of energy in Zhejiang province is shown in Figure 3. The final energy demands have increased 108.67 million toe (in the case of the ID scenario), 109.04 million toe (UR scenario) in 2030 from 64.46 million toe in 2006. In the UR scenario, 17.14 million toe of biomass, 83.6% of the production of biomass within the region, was converted to energy; *viz.*, 2.54 million toe of methane gas, 3.18 million toe of bio-ethanol, and 2.41 million toe of electricity from gasification power generation were produced. As a result, it was estimated that 7.5% of final energy consumption can be covered by the selected four biomass energy technologies. The potential of GHG emissions reduction by introduction of the biomass energy technologies is 25.31 million ton-CO_2 which represent 5.7% of the total GHG emissions accompanying the final energy consumption. Replacement of fossil fuel by biomass energy, especially from just waste biomass, is limited.

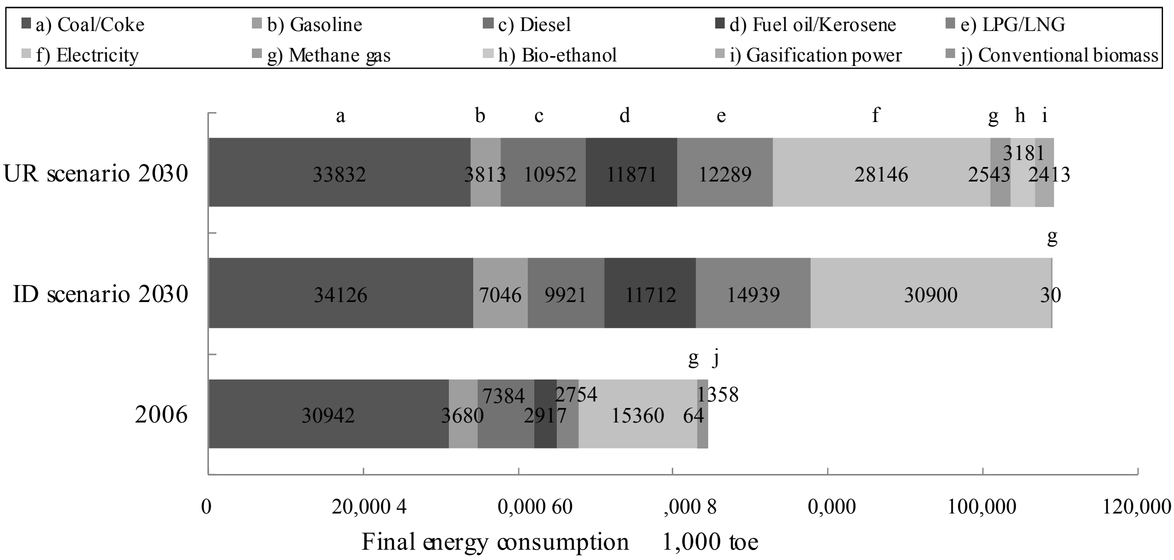

Figure 3. Calculation results of the demand-supply balance of energy

Table 3 shows the results of changes in the amount of economic activities and self-sufficiency rate. For the UR scenario, the production value per employee in primary sector increased in 60,161 Yuan per capita in fiscal 2030, and is approximately equal to 140% compared to the ID scenario. The self-sufficiency rate for food and for wood in the UR scenario increased drastically as compared with the ID scenario.

Table 3. Changes in amounts of economic activities and self-sufficiency rate

Item		2006	2030	
			ID scenario	UR scenario
Economic Activity	Production value (billion Yuan)	1,574.3	7,286.6	7,064.8
	Industrial type	5.9%, 54.1%, 40.1%	2.3%, 56.1%, 41.6%	4.1%, 51.9%, 41.0%
	Population (1,000)	46,290	51,330	51,330
Self-sufficiency rate	Energy	0.1%	0.0%	7.5%
	Food	118.4%	103.7%	134.1%
	Feeds	9.5%	8.3%	10.2%
	Wood	30.3%	8.3%	47.2%

Note: In the item of "Industrial type", the values indicate the rate of primary, secondary, and tertiary sector from left to right.

The method of combining the stock and flow accounts with causal models by using life cycle simulation allows us to model the state of economic activities and material flows in regional areas, to design the resources circulations of energy and materials on the basis of the urban-rural partnership multilaterally. Furthermore, these tools enable evaluation of synergy effects, constraint requirements, and potentiality and availability of the partnerships.

6. Conclusions

In this paper, a framework was developed for regional partnership between urban and rural areas by focus on designing regional circulations of energy and materials from the viewpoints of hopeful measures towards a low carbon society. Firstly, the characteristics of urban and rural areas, and the corresponding examples of urban-rural partnerships were generally defined. Then, in order to evaluate regional sustainability by partnerships between urban and rural areas, two analytical tools were developed. To show the workings of the tools, they were applied to pilot models in Zhejiang province, China. Possible future scenarios towards 2030 were estimated, and the supply-demand balance and greenhouse gas (GHG) emissions by energy consumption were estimated. We believe that, by clarifying the synergy effects of the urban-rural partnership, we are able to suggest how the partnership will be multi-beneficial for the sustainable society and this will contribute to Japan's environmental policies towards construction of a low carbon societies in Japan and Asian region. Future work could be to cover urban-rural partnerships other than the "maintenance and optimum utilization of the biological resources by regional circulations", in order to evaluate the patterns and effects of relationships between stakeholders, and change in people's lifestyles, for inclusion in future scenarios towards a low carbon society.

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References

[1] United Nations, Department of Economic and Social Affairs, Population Division, 2007, World Urbanization Prospects: The 2007 Revision

[2] Food and Agriculture Organization of the United Nations (FAO), 1995, Planning for sustainable use of land resources: Towards a new approach

[3] Paul H. Brunner, Helmet Rechberger, 2003, Practical Handbook of Material Flow Analysis, Lewis Publishers

[4] Robert U. Ayres, Leslie W. Ayres, 1998, Accounting for Resources, 1: Economy-Wide Applications of Mass-Balance Principles to Materials and Waste, Edward Elgar Publishing

[5] Robert U. Ayres, Leslie W. Ayres, 1999, Accounting for Resources, 2: The Life Cycles of Materials, Edward Elgar Publishing

[6] Products, and Residuals Committee on Material Flows Accounting of Natural Resources, Committee on Earth Resources, National Research Council, 2004, Materials Count: The Case for Material Flows Analysis, The National Academies Press

[7] Rutger Hoekstra, 2005, Economic Growth, Material Flows and the Environment: New Applications of Structural Decomposition Analysis and Physical Input-Output Tables, Edward Elgar Publishing

[8] Robert U. Ayres, Leslie W. Ayres, 2002, A Handbook of Industrial Ecology, Edward Elgar Publishing

[9] Peter Baccini and Paul H. Brunner, 1991, Metabolism of the Anthoroposphere, Springer

[10] Stefan Bringezu, 1997, Accounting for the physical basis of national economies: material flow indicators, In: Molden B. Billharz S (eds) SCOPE 58: Sustainability indicators. Wiley, Chichester, pp170-180

[11] Yuichi Moriguchi, 1999, Recycling and waste management from the viewpoint of material flow accounting, J Mater Cycles Waste Manag, Vol.1, pp2-9

[12] Yasushi Umeda, Akira Nonomura and Tetsuo Tomiyama, 2000, Study on life-cycle design for the post mass production paradigm, AIEDAM, Vol.14, No.2, pp149-161

[13] Zhijiang provincial bureau of Statistics, 2007, Zhejiang Statistical Yearbook 2007, China Statistics Press