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From economic prosperity to ecological sustainability —— A theoretical and practical concern of sustainable development in China

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Abstract China, a country with more than 1.2 billion people, is undergoing a rapid industrialization and urbanization. While brings wealth and hopes to people, the economic prosperity has to pay the price of the ecological degradation. What kind of dynamics and cybernetics is needed to lead a sustainable development and ecological health? How to deal with the complicated relationships between social transition, economic growth and environmental change? This article is to present some theoretical and practical concerns from the viewpoint of human system ecology with some cases of small towns in the coastal area of China.

Keywords: sustainable development; economic prosperity; ecological sustainability; China.

1 Introduction

The term "sustainable development" was first put forward by the World Conservation Strategy (WCS) in 1980. In 1987, The World Commission on Environment and Development (WCED, 1987) has defined it in the book "Our Common Future" as a development that "meets the needs of present without compromising the ability of future generations to meet their own needs". The Rio Manifesto and the Agenda 21 formulated in the Earth Summit of the United Nations' Conference on Environment and Development in 1992 proposed principles for its further practice. But to realize a real sustainable development there is still a long way to go in developing a sound methodology and operational instrument.

Since the origin of human civilization, human being has been gaining much ecological knowledge in dealing with the man-environment relations through learning andexploration in its formed a set of naive human ecological outlook. But as an independent discipline, human ecology did not come out until the 20's of this century when urban ecology was becoming prosperous in America. It was later revived by the zest of systems ecology and environmental study in the 60's when the environment and energy crises was besting the world; and finally it has been booming in dealing with the issues of global change and sustainable development since 1980's. At present, a lot of international and regional organizations in human ecology have sprung up in the world which are dedicating themselves to the movement of sustainable development.

The fact that Professor E. P. Odum, a famous American ecologist, added to his

book "Ecology" (the second edition) a subtitle "The Link between the Natural and the Social Sciences" implies a turning point of emphasis of ecology from a pure biological ecology to a human-involved holistic ecology (Odum, 1975). In fact, any enterprise, industrial sector, governmental agency, region, and even a family have to interact with their internal and external environment for their own survival and development. The history of human civilization is in fact an ecological struggle history of competition and symbiosis, exploitation and adaptation between man and its physical and social environment. The purpose for sustainable development is to treat wisely the complicated ecological conflicts between present and future, between part and whole, between environment and development, between nature and man, and among government, enterprise and the publics. Such efforts bear distinct characteristics with complexity and multi-discipline which involve technological, institutional and cultural aspects in human society. To realize an environmentally sound, economically productive, systematically responsible and behaviorally feasible development, human ecology puts its emphasis on the dynamics, cybernetics and technological instruments with regard to eco-flows or process-oriented issues, eco-networks or structural issues, and ecological orders or functional issues.

2 Production, consumption and buffering——three basic functions of human ecosystem

Human society is a kind of artificial ecosystem which is dominated by human behaviors, sustained by natural life support system, vitalized by resource flows which was named by Prof. Ma Shijun as Social-Economic-Natural Complex Ecosystem (Ma, 1984). Its structure is expressed as a complexity between human being and its working and living settlement (including geographical, biological and artificial environs), its regional environment (including sources for material and energy, sinks for products and wastes, pools for buffering) and its social networks (including culture, organization, technology and so on). Its function includes production, consumption, supply, assimilation, steering and buffering, which play a key role in sustaining the complicated human ecological relationships such as that of exploitation, adaptation and reformation between man and nature, and that of competition, symbiosis, and multification-and-compensation in human activities of production and living.

Traditional development view pays attention to only two kinds of function as economic production and social consumption, but neglects the function of supply, assimilation, steering and buffering among man, resources and environment. In fact, the production function in a human ecosystem includes not only the production of material and spiritual products but also the production of wastes and the production of labors and intelligence. The function of consumption in a human ecosystem includes not only the con-

suming of commodities, utilization of infrastructure, but also that of those resource and environment which possess no direct value of labor.

The third and also the most important function human ecosystem plays is the ecological regulation driven by an "invisible hand" behind human production and consumption, that is the systematic feedback or cybernetical mechanism. It includes the sustainability of resource supply, the sustainable environmental carrying capacity, the sustainability of ecological buffering, and the vitality of self-organization and self-regulation in human society. It is just this type of specific function that economy, society and physical environment may interact one another as to sustain a harmonized human ecosystem. According to Lao Dan, a famous ancient Chinese philosopher, this steering function is "such a thing which seems to forth from nowhere, and yet it penetrates everywhere". "It is formless, shapeless, vague, indefinite, imperceptible and indescribable, always changing, and reverting to the state of nothingness" (Yang, 1968). This nothingness is a kind of accumulated emergy described by H. T. Odum (Odum, 1983), a kind of steering force or QI in Chinese word, a kind of higher hierarchy information of orderness, or a kind of "holly spirit".

Table 1 Basic functions of human ecosystem

	Economy	Society	Nature
Production	Production of material as well as spiritual product. production of end product as well as waste	Human production (labor, intelligence, culture)	Production of renewable resources (fresh water, living beings, etc)
Consumption	Consumption of commodities (productive resources and daily necessities.)	Enjoyment of information and cultural environment, social welfare and infrastructure	Consumption of resources and environment, expenditure of time and space
Buffering	Balance between supply and demand; market steadiness; circulation of capital	Social stability, assurance, law; social ethics, morality, belief	Natural buffering as reduction and regulation artificial treatment, conservation and restoration.

The task of human ecology is to probe into and to let people understand and conform with this nothingness, which can not be fulfilled by using only the traditional methods of either natural or social science. This is why the human ecology as a formal discipline, trough has nearly one century history, is still a multi-rather than inter- disciplinary intellectual endeavor, coordinated to date only by the loose ties of that common interest in human activities among the various social and natural science (Young, 1983).

The ecosystem concept, one of the key concepts in ecology, has been used for more

than half a century since Tansley defined it as "the biome considered together with all the effective inorganic factors of its environment" (Tansley, 1935). People are used to call a biome and its physical environment in a specific area as an ecosystem and pay more attention to its inner physical and biological entities. Trough it may be appropriate for studying the relatively isolated biome such as a lake or an island, it is difficult to deal with those ecosystems which have more material, energy, information exchange and biological migration with outside. In fact, ecology is essentially the study of the interaction and the core of Tansley's definition is also the interaction. It should be the interaction set rather than the physical entity that composes the specific target of ecology. An ecosystem consists of all organic and inorganic realities in a special space is a good tool for teaching rather than for studying in ecology. If we subtract those realities from the system, there are only all intangible relationships left, of which consists a new abstract ecological system (AES) we want to deal with. It consists of following three kinds of fundamental interactions (FI): Physical interactions between organisms and their inorganic environment (PI); Biological interactions among different organisms (BI); Cybernetical interactions between part and the whole ecosystem (CI).

$$FI=PI+BI+CI.$$

These fundamental interactions bring about five fundamental flows (FL) of material metabolism, energy transformation, information accumulating, values variation and organism migration in the system, result in its cybernetical behavior and formulate the specific ecological field (FD) of the system's production and consumption. Thus we have the expression of

$$AES=\{FI, FL, FD\}=\{PI, BI, CI; M, E, I, V, B; FD\}.$$

As for human ecosystem, we define any functional human unit (either an individual or a family, a community, a factory, a city, a region, or a country) as an eco-unit, which occupies a specific eco-niche and has certain ecological process; and the physical resource and environmental base (including source, sink and store) as its eco-pool, which can supply, store, transport and accept material, energy and information for the host eco-unit, and plays an important role in its survival, development and succession (Liu, 1988). Then we can classify the human ecological interactions as following 20 categories:

1. Unit-Pool relationship (U-P)

Demand (D) and supply (S) relationship; forcing (F) and adaptation (A) relationship; exploitation (E) and resilience (R) relationship.

2. Inter-units relationship (U-U)

Competition; Parasite; Symbiosis.

3. Part-Whole relationships (P-W)

(1) Chain-type: subordination

Promoting; Inhibiting; Transgression; Counteraction.

(2) Loop-type: feedback

Multification (positive); Buffering (negative).

(3) Functional link: role

Active; Passive; Critical; Intertial.

(4) Network connection: cybernetics

Dominance and diversity; Dependency and self-organization; Compensation and substitution; Risk and opportunity.

It is these 20 invisible relationships that govern the dynamics and cybernetics of the whole human ecosystem and determine its function, order, vitality, its past, present and future state (Wang, 1992).

The method of integration in human systems ecology may be more effectively developed in practice than in theoretical study. In recent years, a so called ecological construction campaign has sprung up in some Chinese rural and urban areas, which includes the construction of ecological engineering, ecological institution and ecological culture. It aims at interregional, intergenerational, intersectional, interdisciplinary and interinstitutional planning and reforming of the originally isolated entities, causes and consequences, and tries to tap the latent resource from the "nothingness" (Wang, 1990). Ecological construction can be implemented by technological innovation, institutional planning and behavioral management. These three processes are all integration.

3 From "Man Conquer Nature" to "Man and Nature Be in One"——Ten principles of ecological cybernetics

Through observation and study of the dynamics of natural and human ecosystem, the following cybernetical principles may be summarized:

3.1 Principle of exploitation and adaptation

Any enterprise or region has its own ideal and realistic eco-niche. A successful development is the one which is good at exploiting its available eco-niche and condensing its demanding eco-niche in order to adapt itself to and to reform of the environment. Those only over exploiting and not adapting to their environment are lacking of stability and pliability in their development.

3.2 Principle of promotion and restraint

Any ecosystem has always some favorable factors to dominate its development, and some limiting factors to restrain its growth in quantity. The pressure of resource shortage leads to competition and symbiosis in an ecosystem. Such interaction of promotion and restraint is the indispensable conditions for enhancing the efficiency of resource utilization, for strengthening the vitality of the ecosystem, and for realizing the sustainable development.

3.3 Principle of competition and symbiosis

All natural creatures survive through competition for resources as well as symbiosis for sustainability. Those species lacking either competition or symbiosis are weaker in vitality and will eventually be replaced by others. This principle is a common rule exists in both natural and human ecosystem.

3.4 Principle of interlocking positive and negative feedback

Generally the evolution of an ecosystem is regulated through two kinds of feedback mechanisms: one is positive feedback, in which the action and reaction are reinforced by each other and lead continuously to enhancement or declination of the system; the other is negative feedback, in which the action and reaction are counteracted by each other and therefore lead to maintain the system in the current status. In an ecosystem, positive feedback usually assumes dominant role at the initiating stage, and negative feedback replaces the dominant position at the nature stage of its development. The machanism of positive and negative feedback should balance in a sustainable ecosystem.

3.5 Principle of multiplication and compensation

When the function of an ecosystem has troubles, some of its components might take a chance to expand or multiply unusually as to dominate the system and make its function out of order. While other components might make up the missing function or substitute automatically the malfunctioned components as to maintain the normal function of the system. An ecosystem may benefit or suffered from these multiplication and compensation mechanism. To stabilize a system, the compensation mechanism should be emphasized. While to reform a system, the multiplication may play a key role.

3.6 Principle of exponential and sigmoid alternative growth

An ecosystem may develop slowly at its initial stage, then speed up towards an exponential growth, then become slower and slower and press on towards a threshold of the carrying capacity of its environment. As man can reform its environment and enlarge its eco-niche, the develop may speed up again with a new sigmoid and exponential growth after the bottle-neck is widened, while a new limiting factor will be working upon it through forming a new bottleneck. A sustainable development will be realized according to this alterative exponential pulse growth and combined sigmoid development.

3.7 Principle of circulation between wastes and products

Any product created by man will inevitably be turned into waste at the end; yet every "waste" is bound to be a "resource" useful elsewhere in the biosphere. Any action is bound to have a feedback or retribution upon itself. The mechanism of the material cycling and information feedback are certianly the essential drives or "engines" of sustainable development in an ecosystem.

3.8 Principle of diversity and dominance

The development strength of an ecosystem depends mainly on the behavior of its dominating components like "dominating species" in a biological community; yet the

stability depends mainly on its structural diversity and the variability of products. Thus a sustainable development will be facilitated through a reasonable compromise between dominance and diversity.

3.9 Principle of ecological design

The ecological succession is orientated towards rather functional perfection than structural growth. The purpose of production is to serve whole system rather than maximizing the quantity or quality of its products. Ecological design here means holistic, biological, evolutionary and multi-objective design in contrast with the traditional cause-effect, mechanical, stationary and mono-objective development.

3.10 Principle of turning risk into opportunity

To sustain an ecosystem, one has to head for opportunity and turn risk into chance. Bigger opportunity is always accompanied by higher risk. To be good at seizing all the opportunities available and taking advantage of all favorable and antagonistic forces to serve on the system, one has to remember the ancient Chinese thoughts of "the meaner, the better" or "keeping equal distance from both the risk and the opportunity".

4 Transition from economic prosperity to ecological sustainability ——Case studies of town development in east coast of China

China is now under a far-reaching transition from planning economy to market economy, from rural society to industrial society. The rapid economic growth, the deep structural reform, the large scale construction, and the remarkable immigration of farmers from rural to urban and suburban areas have brought about significant ecological impacts on the local and regional life support system. The biggest change has been taken place in the development of township industry and rural urbanization in the coastal area of China. From 1978 to 1992, Chinese rural industry increased 29% on average, substantially higher than the national 9.5% annual growth rate. The profits and taxes increased 16 times from 1978 to 1992 (Table 2). Though this process is the essential path and the hope for Chinese farmersto get rich and modernized, the contradiction between development of rural industry and its impacts on the agricultural ecosystem is very severe. There were only about 40,000 state owned industries over the country, while the total number of rural industry were more than 20 million in 1992. With such a great number of rural industry which are characterized by the diversified and rapid changed production, small business size, out-of-date techniques, labor force intensified and heavy pollutants generation, there are a relatively very small number of environmental protection agencies to monitor and manage the increasing problems of environmental pollution. The rural industrial development will have to pay the price of destroying the regional ecosystem, and will probably place both 1 billion people's better lifestyles and the critical food production system in jeopardy.

Table 2 Current situation in China's rural industrial developments

Item	Unit	Year		
		1978	1990	1992
Number of enterprises	10^3	152.4	1850.4	2079.2
Workers employed	10^3	282.7	9264.8	1058.1
% in social labors	%	7.0	16.3	17.8
% in total rural labors	%	9.2	22.1	24.2
Total industrial output value	10^4 RMB Yuan	493.1	9581.1	17584.0
% in total social output value	%	7.2	25.2	32.1
% in total rural social output value	%	24.3	57.7	66.0
Total rural industrial output value	10^8 RMB Yuan	385.3	7097.0	13193.4
Total profits & taxes	10^8 RMB Yuan	110.1	1012.1	1797.7
Total profits	10^8 RMB Yuan	88.1	588.0	1044.1
Total taxes	10^8 RMB Yuan	22.0	391.6	636.9
% in total national taxes	%	4.2	13.6	20.3
Total amount of worker's wages	10^8 RMB Yuan	86.7	1129.6	1738.4
Overall labor probuctivity	RMB Yuan	1744.0	10893.0	17455.0
Profits & taxes per 100 RMB Yuan fixed assets	RMB Yuan	48.0	35.4	38.6
Number of enterprises in deficit	10^3	1.1	8.6	4.8

Taking four typical towns, Fuyang, Hengdian, Yangxunqiao and Qiuga in the east-coastal province of Zhejiang as examples, we hope to analyze this extraordinary development and try to find a feasible way towards sustainable development. These four towns are the microcosm of the rural industrialization in east coastal area of China where the economic reform and open-to-outside policy has taped the suppressed productivity and stimulated the symbiosis relationship with outside. Led by distinguished entrepreneurs, these rural areas have smashed down the old economic institution, and become economic star on the hopeful land. Their annual economic growth rate ranges from 50% to 95% in recent years (Fig. 1). and 60% to 90% farmers in these towns have left their cropland and turned to rural industry. Some main features of their development are listed in Table 3.

These towns share some common characteristics as follows: The economic development is prior to social development, while social development is prior to ecological development; there are strong economic competition desire and well symbiosis relationship with outside but the residents' awareness of sustainable development and the people's quality are relatively low; the institutional reform is prior to life style reform, and the life quality improvement is prior to the ecological relationship improvement; the hard-

ware construction is prior to software construction, and the short term development is overwhelming the long term development; most development project is mono-objective oriented, structural expanded, external implored. The emphasis is put on external investment rather than the internal potential; the positive feedbacks overwhelm the negative feedbacks.

Table 3 Basic features of human ecosystems development in the four towns of Zhejiang Province

Indexes	Yangxunqiao Town in Shaoxin City	Hengdian Town in Jinghua City	Qiuga Town in Ningbo City	Fuyang Town in Hangzhou City
Socio-economic and environmental advantages and disadvantages	Very convenient in transportation, diversified landscape for tourism	Inconvenient in transportation, located in the mid-mountainous-area Zhejiang and resources in scarcity	Very convenient in transportation, located in the suburban district of Lingbo City	Convenient in transportation, tourism resources in plenty
Population density, persons/km^2	769	644	1327	675
Increase rate in gross product of industry & agriculture, %				
1979 - 1990 in average	28.2	31	23	24
1991	51.5	67	42	69
1992	81	95	77	71
Percentage of output indust rial value in total in 1992, %	95.4	94.3	92.5	86
Per capita output value of industry & agriculture, 10^4 RBM Yuan	1.584	1.685	1.871	1.295
Per capita income, RMB Yuan	2064	1524	1626	1500
Industrial labor productivity 10^4 RMB Yuan/person	3.92	5.54	4.06	2.30
Enrollment percentage of preliminary school for scholling age children, %	98.2	98	100	100
Green coverage, %	30	15	21	12

Using the principles of ecological cybernetics and ecological order analysis, a case study has been conducted concerning ecological order assessment on the sustainability of

these four towns.

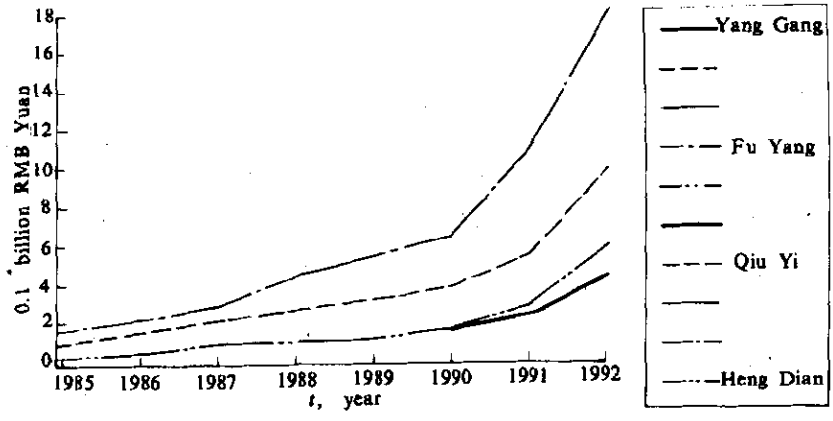

Fig. 1 Increase in total product of industry and agriculture in the four towns of Zhejiang Province, China

4.1 Ecological dynamic analysis of the four towns

4.1.1 Tapping up local developmental potentials and dredging internal/external eco-flows, including introduction of a great deal of capital, technology and technicians, dredging the stagnant eco-flows, enhancing of the efficiency of output/input.

4.1.2 Adjusting the production structure according to the rules of market economy which is headed by one or two dominant industries and stabilized by multiple production;

4.1.3 Enhancing the competition function through turning the vertical-dependent production into self-organized production, the close community into symbiotic open society, and making full use of the internal and external advantages.

4.2 Ecological order analysis of the four towns

4.2.1 Efficiency

The common characteristics of these four towns are that their economic structure has been greatly changed from labor-intensified agriculture and raw-material-export handicraft industry to high-technology, capital intensified and deep resource processing economy. All of these towns have taped out their own superiority of location, resource and other advantages. The labor productivity, the contribution of technological progress, and the percentage of the tax and net profit in the total output have sharply increased. While, in the same time, the efficiency of material and energy using is relatively low which resulted in considerable environmental contamination. Among other things, the living style of rich farmers has been transferred from low level energy consumption to high level. In some households, for example, the newly built up housing

area per capita exceeds 150 m^2, about 25 times of the average figure in Chinese cities. This tendency of imitation of the west countries' living style will certainly threaten the sustainability of the limited resource in these areas.

4. 2. 2 Equity

The majority of the population in these four towns was farmers before they became prosperous. The large-scale construction and intensified inputs of capital and energy has dramatically changed the physical and human ecological patterns. A large amount of high-fertility farmlands which have supported local residents for thousands of years is being transformed into the "open economic zone" waiting for cooperation with foreign or domestic investors in initiating secondary and tertiary industry, or abandoned for its low profit and high risk resulted from the enlarged "scissors differential", the price difference between agricultural and industrial products, compared with the highly profitable rural industries or trade. According to a statistics, the total newly developed area transformed from arable farmland in China since 1978 is more than the total urban area built up during the past 5000 years in Chinese history. "Off the land, off the poverty" is the sincere desire of the poor farmers for modernization who have been beset in the land for thousands of years. Sure enough, these towns have now got rid off poverty, but the degradation cost of the regional ecosystem and the potential impacts of farmland reducing on their offspring have resulted in new inequity between generations, and between man and nature.

The additional pressure has been imposed upon agricultural ecosystem with overloaded carrying capacity because of the overgrowth of population and the reduction of the per capita arable land, which has put condiserable negative impacts upon the development for future's generations. In addition, with the rapid growth in total output value of agriculture and rural industry, many problems in environmental pollution have produced and then lowered the environmental quality, such negative effects has penetrated into other neighboring regions. As a result, these agricultural and environmental issues broaden not only the inequity between generations, but also one between regions.

Though, general speaking, the development process from unitary to diversified, from close to open, from household managed to grouping cooperation is relatively healthy, their dominating cybernetical characteristics is positive feedback and high dependency on outside which have augmented the imbalance and instability of the economy, society and physical environment. A public opinion survey of 10% sampling in Yangxunqiao Town shows that more than 50% citizens are dissatisfied with 13 items of the 43 social, economic and environmental indicators. Most of these dissatisfactions come from the social and environmental consequences of the rapid economic development.

4. 2. 3 Vitality

The green and blue space is being displaced by the yellow and grey industrial land-

scape and the bio-diversity is dramatically declining. The hydrological process stays at an unhealthy level because of the stationary or blocked waterways and water eutrophication in these four towns, which indicate that the natural ecological vitality is weakening. The economic system has been vitalized by the flexible institution, high public awareness of competition and symbiosis, and sensitive feedback of information. But the extraordinary fast economic growth can not be matched by the limited carrying capacity of their environment and resource, and the over-dependence on the external capital, technology and market, and the low diversity of products have reduced the system's stability.

Though the income and the material life quality in these four rural towns are much higher than the average level of urban citizens, the low education level, the backward feudal consciousness, the low quality of infrastructure and the low management level have blocked their social development and weakened the social vitality.

In order to implement the Agenda 21 of China for sustainable development, and to raise the efficiency, equity and vitality of these developed areas, 22 State Departments led by the State Commission of Science and Technology, the State Commission of Planning and the State Commission of Institution Reform, have recently initiated a project and chosen 15 towns, counties and cities as the National Integrative Testing Zones of Case Study on Sustainable Development, most of which locate in the coastal area of China. Hengdian, Yangxunqiao and Qiuga towns are among these 15 testing zones.

These testing zones put their emphasis on systematically and ecologically oriented sustainable development. System here means long term, large scale, holistic scope, balanced flow and harmonious function, while "eco" means efficient competition of resource, harmonious symbiosis within the system and self-regulation vitality.

Integration here means a synthesis of the bio-physical, socio-economic and psycho-cultural factors of the production, consumption and buffering functions, of the long term, large scale and holistic consideration, of the technological, institutional and cultural instruments; of the mechanism of competition, symbiosis and self-organization; of the compromise between decision makers, enterprises, experts and the publics, and of the exploitation of external and internal potentials.

The main goal of these zones is to search and test feasible ways towards sustainable productivity, sustainable institution, sustainable life style, sustainable human ability and sustainable life support system, which should be environmentally sound, economically productive, and ecologically responsible.

5 Conclusion

Faced by the great pressure of population, resource and environment, and the urgent demands on economic growth, China has to march towards sustainable develop-

ment, which is neither the traditional feudal or highly centralized development, nor the western model of development characterized by the high energy input, huge material consumption and heavy environmental impacts. The ultimate goal of ourdevelopment is rather ecological health than economic wealth. Ecological health should be enhanced through raising its efficiency, equity and vitality. An emerging subject borne form the discipline of ecology human ecology will become a hopeful theoretical basis for the urgent solution to the global demand on man-nature coordination. Human ecology is aimed at how to interact one another between man and nature under the prerequisite of human development at an ecosystem scale. The three types of ecological functions as production, consumption and buffering form a perfect cycle connecting man with nature. The ten cybernetical principles can be summarized as three mechanisms: competition, symbiosis and self-organization, their synthesis is the internal basis for human sustainable development. As the economic growth in these towns is still kept as dominate, a physical and human ecological restoration is necessary to enhance the third function of the complex ecosystem. Having been involved in the Integrative Case Study on Sustainable Development Testing project, the four towns are developing towards a higher-level of ecological order and the sustainability of their development is gradually increasing.

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