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An ecosystem-based understanding and analysis for SENCE toward sustainable development

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Abstract: There is a need to find a comprehensive approach focusing on the conflicts between economical growth and environmental protection. Chinese scholars advocate a comprehensive ecosystem viewpoint named social-economic-natural complex ecosystem(SENCE). The kernel of the concept lies in the hierarchical structure of SENCE, through which methods from ecological network can be useful to the compound system. The author gives a schema depicting its structure; following a model analysis to help understand the reliance of economy on ecosystem. It is obvious that more actions should be done to strive for sustainable development.

Key words: social-economic-natural complex ecosystem(SENCE); ecosystem model; sustainable development

Introduction

Researchers have been paying more and more attentions to ecosystem to support the research of sustainable development. Chinese scholars favor to expand the scope of ecosystem from its naturalness to its sociality, from local to global, from material to abstract, etc. In fact, the attitude could benefit the research of SD, especially the conflict between environment and economy. Ma Shijun(Ma, 1984) explicitly advocate a social-environment-nature complex ecosystem(SENSE) as the main frame analyzing the relationships among Homo Sapiens, nature, economy, ecology, and resources. Wang(Wang, 1984; 1995) and others(Yue, 1991; Zhao, 1992; 1995; Yuan, 1992) continue their research on it. Partially due to SENCE, urban ecology(Yang, 1997; Shen, 1998), industrial ecology and other ecology-based subject received more attention than ever in China.

The main reason for the promotion of SENCE is the serious problems in China. Its population (1300 million) has overly exceed the rational one(680 million, Cao 1993), which forms huge pressures on Chinese economy, resource, ecology, and society. The rapid growth in GNP does not diminish but enhance those pressures. Chinese Environmental Bulletins annually gave clear data describing those. So a huge systematic thinking, like SENCE is very important to form a schema from the chaotic problems in China, and can be seen as a prerequisite to understand Chinese development and find methods to coordinate the relationship between environment and economy.

A useful way to understand the architecture of SENCE is extending ecosystem concepts and theories to SENCE, while energy flow and material flow are taking key role in the process. For example, entropy, energy, emergy, exergy and other energy-related concepts have been used in the analysis of economy, society, as well as whole SENCE. Georgescu-Roegen first applied entropy in economics, followed Daly's replenishment. Anyre(Anyre, 1998), Jφrgensen(Jφrgensen, 1998), and others practiced the energy, emergy and exergy approaches in industry and resources. In China, Ge(Ge, 1996) measured the energy flow in cotton ecosystem among primary product (cotton plant), secondary product (pest and predator) and decomposer in soil. Ouyang(Ouyang, 1994) focused on the temporal energy flow in the forest in Changbai Mountain, China. Xu and Pan (Xu, 1995) established a compartmental model for energy flow and simulated its dynamics mathematically, they concluded that the agroecosystem they investigated was deviating from its balance of energy flow and the present utilizing pattern is defective through an analysis of Liyabunov stability. Liu and his colleague(Liu, 1992) build an input-output model of energy composed with organic and non-organic fertilizer and other economical inputs. Both mass exchange and remained nutrient in soil were used to evaluate the performance of whole system. In methodology, the concept of ecological network(Patten, 1995; Sφren Nors Nielsen, 1995; Han, 1993; 1995) and compartmental model(Fan, 1999); as well as loop analysis(Guo, 1993) reveal the marrow of ecosystem which should been spread further.

There are so many achievements that can help us understand ecosystem, economy, society, etc, however, it is still very critical to form a wholly framework of SENCE. This paper focuses on the kernel ideas of social-economic-nature complex ecosystem, and gives a conceptual frame to describe the model structure of SENCE.

1 SENCE and its structure

Ecological network in ecosystem prevails which resembles food links/webs. Compartment model depicting the network is an extraction from logical concept to mathematical model. The essence comes from the structural relationship between subsets

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and their quantitative reliance. The hierarchical structure in SENCE will be similar with Fig.1.

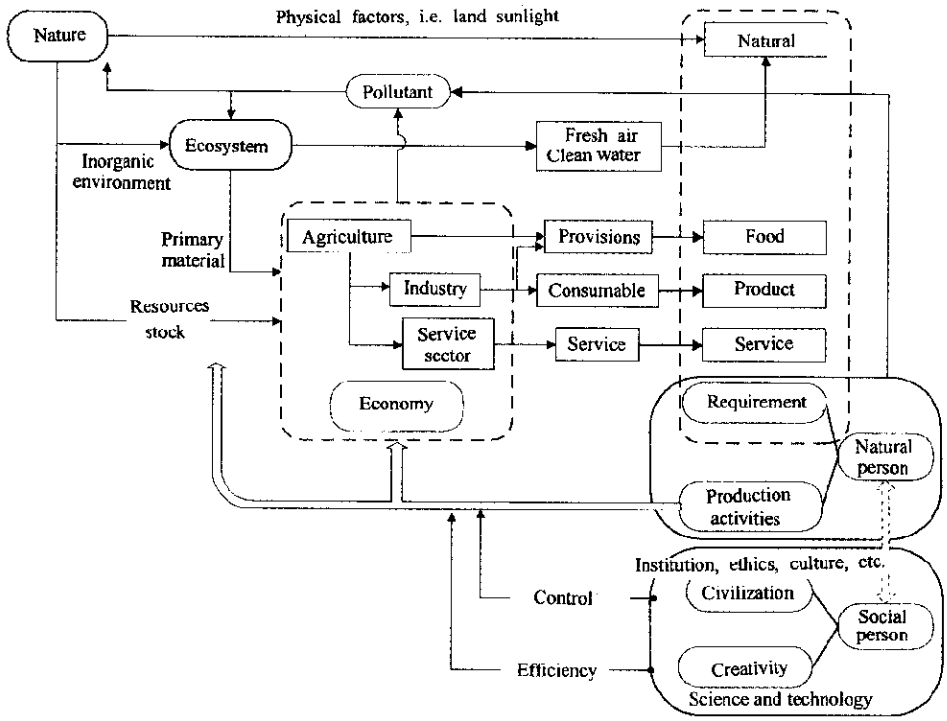

Fig.1 The comprehensive structure of compound ecosystem

Nature is sundered from ecosystem because it is supporting both the biogenic system and human system. This argues that we should make nature an integral part both to ecosystem and to Homo sapiens. Human cannot dominate the competition with ecosystem when exploiting the nature, a deficient ecosystem is also harmful to people.

Treating person as the combination of natural person and social person is amiable. Men participate the food webs as a kind of animal though they require more. The pessimists look human as natural person who is imprisoned by natural laws especially the limited minerals and CH-energy. However, human creates its civilization that can control the whole system wholly or partially and help the economy produces more with less inputs. Even if we do not agree the techno-optimism, technology postponed the adventure of resource crisis.

Food web as a main character has played a key role in analysis of ecosystem's structure. A similar web exists in SENCE and its components, thus by emulating the material and energy flows through food web in ecosystem, we can analyze the structure of SENCE and its components through their material and energy flow in an analogous "food web", using ecological network approach.

Nature, ecosystem, economy and natural persons form a passive object which should be optimized and controlled. Social persons analyze the complex system and find solutions for the plights we are facing or we will be facing. The conflict between optimism and pessimism reflects their preference which kind of person they think human being as. In fact, solution for sustainable development must be a solution to transfer human consciousness from barbaric toward nature to sagacious toward nature. Now, we should think men are more barbaric than sagacious. The pollutant works as a feedback factor for its serious side-effects to ecosystem and its impedance against economy and society.

Ecologists, critical to people's expanding consumption desire, appeal to citizens cutting down their consumption. On the other hand, the GNP-based economy prefers huge productivity and consumption. If we can give more attentions to the evolution of human requirement, conflicts between two attitudes toward consumption can be diminished.

Economic development is one of the primary requirements of human. Humanistic psychology recognizes human requirement by a hierarchical structure. American psychologist, Maslow Abraham Harold (Maslow, 1908 1970), developed a theory of motivation describing the process by which an individual progresses from basic needs such as food and sex to the highest needs called self-actualization. The theory helps understand people's attitude toward nature and economy. If the land is insufficient, men fight for lands; if land is sufficient, men exert themselves for property; if men are wealthy, they are eager to healthy; if all concerns are satisfied, they seek self-fulfillment. This deduction is also applicable to the thinking the dilemma between pollution and poverty. A person in poverty, such as one in undeveloped country, is reluctant to cherish soils or forests if this damages his profit. This is a reason why developing countries would rather face a weak ecosystem than decelerate their economic growth, and why scholars appeal citizens reducing their consumption, people continues buying new commercial though the old one is functionally okay.

Hierarchical theory helps us define and fulfill sustainable consumption: a set of actions which can satisfy human basic requirements, decrease the consumption of luxury, advocate the consumption of functions of goods rather goods per se, encourage enjoyment and achievement in spirits, and all others which help cut down material use without negatively affect consumer's welfare or utilities.

2 Model of the SENCE

We begin our model with a modified logistic model proposed by Smith(Smith, 1963) with the assumption that the relative increase rate of a species is density-restraint and proportional to additional food.

$$\frac{1}{P} \cdot \frac{\mathrm{d}P}{\mathrm{d}t} = r_p\left(1 - \frac{F_p}{T_p}\right), \tag{1}$$

where P is the population of a species, r_p represents the specific growth rate of the species, T_p is the food requirement when the species reaches its balance, and F_p denotes the food needed by the present number (i.e. P) of the species.

Giving an egregious exaggeration, we extend the logistic model of one species to SENCE and its subsystems, i.e. ecosystem, economy, and Homo sapiens. Georgescu-Roegen pinpointed that perfect recycling is "categorically impossible", whence matter becomes dissipated and unavailable for human use, so economic growth will stop even there are enough energy left. However, Alvin Weinberg, among others, has noted that exergy is the only scarce element because all other elements can be captured and concentrated from the atmosphere, oceans, or the crust if enough of exergy is available(Ayres, 1998). Two views differ in whether exergy can absolutely substitute matter in productions. Compared with this, we first suppose that the dependence between subsystems in the hierarchical system cannot be fully substituted. So we get the structural model for SENCE, considering the mass balance.

$$\frac{\mathrm{d}P}{\mathrm{d}t} = r_p P\left(1 - \frac{F_{ep}}{T_{ep}}\right)\left(1 - \frac{F_{bp}}{T_{bp}}\right)\left(1 - \frac{F_{rp}}{T_{rp}}\right), \tag{2}$$

$$\frac{\mathrm{d}E}{\mathrm{d}t} = r_e E\left(1 - \frac{F_{be}}{T_{be}}\right)\left(1 - \frac{F_{re}}{T_{re}}\right) - F_{ep}, \tag{3}$$

$$\frac{\mathrm{d}B}{\mathrm{d}t} = r_b B\left(1 - \frac{F_{rb}}{T_{rb}}\right) - F_{be} - F_{bp}, \tag{4}$$

$$\frac{\mathrm{d}R}{\mathrm{d}t} = R - F_{rb} - F_{re} - F_{rp}. \tag{5}$$

Equations (2)—(4) depict the growth model of human being, economy, and ecosystem respectively, abstracting the three systems to three species. Each is density-restraint and limited by available food. T_{ij} is the maximal carrying capacity of i subsystem to j subsystem. F_{ij} is the present requirement of subsystem j from subsystem i. Supports from different systems cannot be substituted completely, though technology innovation and system evolution will improve the substitution rate among different productions.

The model is a stiff one, yet divulges the author's thought. First is about the direction of material flow. Anthropocentrists and biocentrists dispute whether men or ecosystem should be favored first. However, it is futile to judge the ecosystem without human. Men should be the center of the planning of relationship between human and nature, as the laws Billiam Burch summarized for resource management(Grumbine, 1997), people and political beat technology and facts in practice. Human is the upmost, which is reflected through the hierarchical structure.

The second idea is the practicability of SENCE structure in environmental and economic planning. Our discussion could not merely rest on the questions such as whether a growth limit exists, whether the resources is absolutely scarce, and whether human knowledge and technology can save us from the economy collapse. As yet, the gloomy imagination of Malthus about population boom and the resource crisis described in the Repot to the Club of Rome(Meadows, 1972) did not happen, however we would rather say that remedial actions human applied consciously or unconsciously were worked than they were wrong. Sustainable development needs our actions instantly, if human think sustainable development will be fulfilled naturally and without any extra action taken, sustainability is impossible.

3 Simulation of a simplified model

We cannot solve the Equations (4) (7) directly, not only because it is difficult to afford a proper parameters to the equations, but also because of their multivariable and dynamics. In this section we simplify the equations and simulate it in a SD model.

Reduction 1: We focus our attention to the reliance of economy on ecosystem, so natural resource R is so plenty that it do not impede the growth of ecosystem, economy and population. That means Equation (5) can be removed and $T_{re} \to \infty$,

$T_{rb} \to \infty$, $T_{rp} \to \infty$.

Reduction 2: Artifices of Homo sapiens make them hold their lives in hand, and can defeat many difficulties like food scarcity through plunders from animals and plants, which makes human population in less elasticity. Another reason is the family planning in high-population countries, which help bound the population in suitable ranges. So we cut all factors relevant to population and combine these with associated factors in economy. That means Equation (2) can be removed and $T_{rp} = 0$, $T_{bp} = 0$, $T_{rp} = 0$.

Replenishment: We add a depreciation rate red denoting that economy scale will degrade as the time goes by, and give a simple assumption that the material need of economy from ecosystem is linearly proportional with economical accumulation ($F_{be} = \lambda E$) and all ecosystem accumulation can be consumed by economy($T_{be} = B$). λ denotes the reliance of economy on ecosystem, and technique innovation help reduce λ value.

So the simplified model will be:

$$\frac{dE}{dt} = r_e E\left(1 - \frac{F_{be}}{T_{be}}\right) - r_{ed} E, \tag{6}$$

$$\frac{dB}{dt} = r_b B - F_{be}, \tag{7}$$

$$T_{be} = B, \tag{8}$$

$$F_{be} = \lambda E. \tag{9}$$

The model above can help us understand the reliance of economy on ecosystem. I simulate its running in a SD model, using parameters as: $E(t = 0) = 10$; $B(t = 0) = 1000$; $r_e = 0.2$; $r_{ed} = 0.1$; $r_b = 0.01$; $\lambda = (0, 1)$. $r_e > r_b$ gives a present picture that economy expands more rapidly than ecosystem does.

Fig.2 is the simulation result at $\lambda = 0.2$, the time space can be divided into four phases. At the first phase, economy growth affects little to ecosystem due to the low base-value of economy. At the second phase, economy grows while the ecosystem keeps stable. Then the ecosystem's health degrade continuously while the economy get a remarkable increase, however, this is the most dangerous phase which damages the foundation of ecosystem-economy compound system. At the last phase, economy depreciates gradually due to zero support from ecosystem.

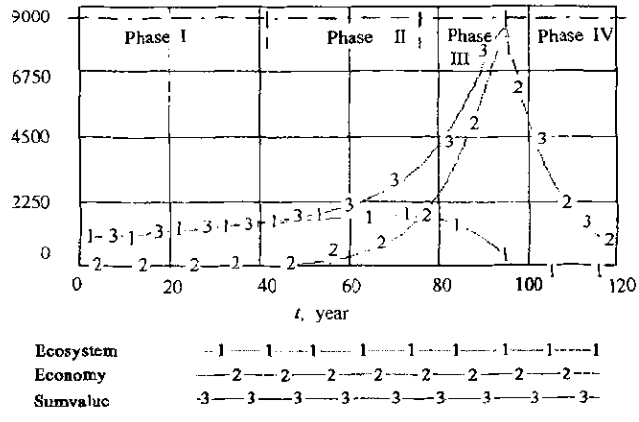

Fig.2 A simulation result reflecting the reliance of economy on ecosystem

One interesting result is no matter how low the λ value is preassigned, economy will absolutely collapse at certain time. This is because the assumption food needed by economy is linearly proportional to the economic scale is controvertible. However, watching our world, the production of our economy is proportional to its material input. So, even to techno-optimism, the technique innovation they acclaim is far behind the requirement for a sustainable utilization of ecosystem.

4 Conclusion

The promotion of social-economic-natural complex ecosystem (SENCE) shows Chinese wisdom in philosophy, whose skeleton has been braced both by the research of Chinese scholars and western scholars. The author here describes its static frame with several considerations. A model originated from biological ecology is proposed which gives the directions for further research. Theoretical discussion is important to the analysis of the SENCE structure, there is a need to delve into the discussion of human attitude, technological influences, and others. Also the model listing here need to be refined, such as the choosing of a reasonable (or its variation, the technique innovation and its influence to parameters, as well as how to make connection between present statistical data and parameters.

References:

Ayres R U, 1998. Eco-thermodynamics: economics and the second law[J]. Ecological Economics, 26:189—209.

Cao M K, 1993. Production potential and population carrying capacity of Chinese Agro-ecosystem[J]. Acta Ecologica Sinica, 13(1):83—90.

Dai J H, 1998. Retrospection of environmental-economic studies[J]. Human Geography(China), 13(4):27—29.

Fan A J, Wang K F, 1999. Analysis of compartment model of energy flow in econetwork[J]. Journal of Chongqing Normal College(Natural Science Edition)(China), 16(1):51—55.

Ge F, Ding Y Q, 1996. Analysis of the features of the energy flow in cotton agroecosystem[J]. Acta Ecologica Sinica, 16(3):225—231.

Grumbine R E, 1997. Reflections on "what is ecosystem management"[J]. Conservation Biology, 11(1):41—47.

Guo Z W, Li D M, 1993. Loop analysis for the combination of food Chains in ecological engineering[J]. Acta Ecologica Sinica, 13(4):342—347.

Han B P, 1993. Progesses on the analysis of econetwork[J]. Chinese Journal of Ecology, 12(6):41—45.

Han B P, 1995. The time chain analysis of matter and energy flow in econetworks[J]. Acta Ecologica Sinica, 15:163—168.

Jørgensen S E, Henning Mejer, Søren Nors Nielsen, 1998. Ecosystem as self-organizing critical systems[J]. Ecological Modelling, 111:261—268.

Liu T B, Qi C X, Han C R, 1992. A sturdy on development model of an typical agroecosystem in Heilonggang Region[J]. Acta Ecologica Sinica, 12(3):247—256.

Ma S J, Wang R S, 1984. The social-economic-natural complex ecosystem[J]. Acta Ecologica Sinica, 4(1):1—9.

Ma S J, Wang R S, 1995. Social-economic-natural complex ecosystem(SENCE) and sustainable development[M](Tom Hutao, Tongbin Chen ed.). Sustainable Development in China: from Concepts to action. 2—8.

Ouyang B, 1994. Transient-state analysis on biotic energy flow in forest ecosystem[J]. Chinese Journal of Ecology, 13(6):55-61.

Patten B C, Higashi Masahiko, 1995. First passage flows in ecological networks: measurement by input-output flow analysis[J]. Ecological Modelling, 79:67—74.

Søren Nors Nielsen, 1995. Optimization of exergy in a structural dynamic model[J]. Ecological Modlelling, 77:111—122.

Tyler G, Miller Jr, 1992. Living in the environment(7th Edition)[M]. Belmont, CA: Wadsworth Publishing Company.

Xu M, Pan X L, 1995. Stability and dynamics of the energy flow of the PUWA agro-ecosystem[J]. Acta Ecologica Sinica, 15(1):72-78.

Yang S H, 1997. Urban ecological environment[M]. Beijing: Science Press. 6.

Yuan X M, Han W X, 1998. The coordination of complex systems and sustainable development[J]. Chinese Population, Resources and Environment, 8(2):51—55.

Yue T X, Ma S J, 1991. Ecosystem stability and its analysing model[J]. Acta Ecologica Sinica, 11(4):361—366.

Zhao J Z, 1992. Population and sustainable development of social-economic-natural complex ecosystem: system analysis and regulation strategies of the population of Yichun City[J]. Acta Ecologica Sinica, 12(1):77—83.

Zhao J Z, 1995. Theoretical analysis on the measurement of sustainable development of social-economic-natural complex ecosystem[J]. Acta Ecologica Sinica, 15(3):327—330.

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