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Ecological Research on Natural Resource Management based on Entropy Theory and Hopfield Network

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Abstract

Because of the size and complexity of CHANS (also known as human-environment, human-nature, or social-ecological systems) at regional and global scales, researchers interested in their management are continuously searching for indicators of the state and trajectory of these systems relative to sustainability targets, e.g., indicators such as a system's resilience to perturbations. The sustainable utilization of natural resources is the theme of global economic and social development future. The introduction of information entropy and the application of entropy law make entropy into the field of sustainable development. Every process of exploitation and utilization of natural resources can be regarded as the process of the transformation of the latent entropy into negative entropy capital through human labor. Through the analysis of the management of natural resources from the perspective of system theory, the Hopfield network is used to put the negative entropy in the nature of natural resource management. The establishment in the minimization of entropy increase based on natural resources management of the objective function and constraints, and optimize energy function through the Hopfield, and draw relevant conclusions.

Keywords: natural resources management, entropy, Hopfield network, social-ecological systems

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INTRODUCTION

Natural resources are the most basic material and energy basis for the survival and development of human society. Every major progress and transformation of human society is closely related to the revolutionary changes in the recognition, development and utilization of natural resources. It is a development history of human society for the development and management of natural resources. Sustainable development has been put on the agenda of world development. It became the center and theme of people's research which reasonably develop and utilize natural resources to ensure sustainable development of economy and society. The research on sustainable development and utilization of natural resources involves all aspects of the management of natural resources, such as the effect of natural resources exhaustion (Simon 2000), economic evaluation for natural resources, natural resources carrying capacity (Harbin 1986), the state is highly centralized in the management of natural resources, and privatization of natural resources. Especially when information entropy extends entropy from thermodynamics concept to other areas, entropy law applies an additional directional constraint to all natural processes, which is not only reflected by conservation. However, there is a lack of a reasonable and effective way to guide the practice of the management of natural resource. Considering the characteristics of natural resource management under Entropy constraints, the Hopfield network is introduced in this paper to make an attempt to solve this problem.

In the process of natural resources being utilized by mankind, natural resources system and human economic system are combined into a more complex system through the transformation of material flow, information flow and energy flow. Therefore, it is effective that the management of natural resources is placed under the environment of system. In accordance with the relevant national standards, administrative, economic, legal, scientific and technological, and educational means can be used to manage natural resource, activities planning, adjustment and supervision to achieve resource management which coordinates the relationship between economic development and environmental protection, to prevent environmental pollution, control damage ratio and maintain the ecological balance (Zhu and Zhao 2004). With the increasing prominent problems of global resources and environment, the sustainable utilization

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of natural resources and the sustained and coordinated development of social economy become the core of natural resource management. According to system theory, natural resource management should be regarded as a complex system with self-organizing and dissipative structure, which is composed of natural resources system and human economic system. In view of the complexity of management objects, the management of natural resources needs to embody system principle, dynamic principle and benefit principle from the perspective of system theory. From the dynamic change of system, we should pursue the maximization of ecological, economic and social benefits.

ENTROPY THEORY ANALYSIS OF NATURAL RESOURCE MANAGEMENT

Entropy Related Theory

Entropy is a concept in thermodynamics which is defined by Clausius (Benny Chris and Prigogine 1992) as follows:

$$V_i = S - S_0 = \int_{P_u}^{P} \frac{dQ_{Reversible}}{T} \quad (1)$$

P_0 stands for initial state and P stands for final state system, S_0 is the entropy corresponding to Po, S is the entropy corresponding to P, T is the absolute temperature, Q represents heat, ΔS stands for change in entropy. Entropy is a state function of the system, which is only related to the initial and final state of the system.

Boltzmann discussed the uncertainty of the distribution of neutron system in thermodynamic system. Entropy can be defined as the logarithm of the Boltzmann constant multiplied by the number of States of the system molecule. This formula is the central concept of statistics. It is as follows:

$$S = K_g \ln W \quad (2)$$

Where Kg is a Boltzmann constant, and W indicates the number of microscopic states that the system can exist under the macro state.

The generalization of the concept of entropy took place after the concept of information entropy of C.E. Shannon in 1948. Information entropy is also called generalized entropy, which is generally expressed as:

$$S = -K \sum_i p_i linp_i \quad (3)$$

The ratio coefficient K is the Boltzmann constant and the probability of Pi is I (Chen and Liu 2004). This concept paved the way for entropy from thermodynamics into the information, biological, economic and social fields.

Entropy, as a measure of energy, represents the amount of useful energy that can be turned into a useless energy (the energy that can not be used anymore), so entropy is also called "energy exhaustion". It is to reveal the inherent law of entropy, "for-economic-activity" phenomenon law. The expression of the second law of thermodynamics is $ds \geq \frac{dQ}{T}$. Clausius suggested in 1850 : Entropy never decreases in isolated systems or adiabatic system, unchanged for the reversible process of entropy, then ds=0, the irreversible entropy always increases, then DS ≥0.

The Management of Natural Resources under the Description of Negative Entropy Theory

The entropy law shows that the isolated system will be increasing entropy, finally tends to chaos and disorder. Based on this theory, the thermal silence of the universe is proposed that the universe finally arrive to be heat stillness. But this is not true, so the "negative entropy" theory is put forward to explain the phenomenon. In 1929, Tsirad first put forward the concept of negative entropy. After 1944, Erwin Schrödinger further perfected the theory, and he pointed out: it is the only way that a living organism stay away from death - what is to draw negative entropy from the environment. He also asserts that life is fed by negative entropy flow. The negative entropy is the symbol of evolution; theory suggests that the increase of negative entropy means things are developing in a stable and orderly direction.

From the negative entropy theory, the conclusion we can draw is that: human society (or economic system) continuously absorb negative entropy from the environmental system to counteract the degree of disorder generated in the process of evolution and this is why human society (or economic system) evolves in a complex and orderly way. The exchange of material, energy and information between the human and the environment is concentrated on the development and utilization of natural resources. In the process of natural resources being used by people, the material, energy and information of the environment enter into the system from the outside of the system, and forming a cumulative process of negative entropy flow.

Using the theory of negative entropy to study the utilization of natural resources, it can be expressed as that low entropy resources and energy can be converted

to products through the transformation of industrial system, and at the same time, high entropy waste heat and waste are discharged into the external environment. In this process, the economic system through entropy exchange with the external natural environment and utilization of natural resources, plenty of negative entropy, maintaining the orderly structure of single internal system and dynamic balance, and the emission of high entropy wastes must to the outside environment, the whole system composed of natural resources and economic system and the negative impact some negatives. The natural resource system and the economic system itself, as well as the large systems they make up, are the dissipative structures with the nature of self-organization. When the irreversible process of entropy is transferred to the environment in the system, the system can decompose the high entropy waste discharged, and ecological environment will be in a stable state, however, if the industrial production exceeded the entropy of the ecosystem regulation ability, it will lead to the destruction and imbalance of ecological environment system.

Objective Function and Constraint Conditions for the Optimization of Natural Resource Management

By using the theory of dissipative structure, the whole process of natural resources with material flow, information flow and entropy flow, can be expressed as:

$$D_s = ds_e + ds_i \quad (4)$$

Where D_S is the entropy change of open system, in *dt* time (including the negative entropy flow, high entropy discharge, high entropy waste decomposition), DS_e is entropy change caused by material and energy exchange between the outside and the system, DS_i is entropy change caused by system for internal irreversible process. Entropy principle shows: $\frac{ds_i}{dt} > 0$, but $\frac{ds_e}{dt}$ may be positive and negative, may be zero.

When $\frac{ds}{dt} = \frac{ds_e}{dt} + \frac{ds_i}{dt} > 0$, it illustrate that if the order degree of the whole system is reduced, then the management of natural resources is not successful; when $\frac{ds}{dt} = \frac{ds_e}{dt} + \frac{ds_i}{dt} = 0$, it shows that the order degree invariant of the whole system, natural resources management is successful; when $\frac{ds}{dt} = \frac{ds_e}{dt} + \frac{ds_i}{dt} < 0$, it means $DS_i < ds_e$, it illustrate that system entropy become low because of material and energy exchange between the system and the environment, and there appear low entropy new ordered structure, which increase the degree of order of the whole system, hence, the management of natural resources is very successful.

According to the theory of dissipative structure, in order to maintain the ordered structure of the system, the negative entropy, which actually need to provide the irreversible process of the system flow of the thermodynamic system through the energy exchange with the outside world. Open thermodynamic system with dynamic equilibrium can maintain its advanced ordered structure only when the entropy flow term is negative, so that it will not go into extinction.

Using the negative entropy theory to evaluate natural resources management may take equation (4). When $ds = ds_e + ds_i \leq 0$, natural resource management is successful, otherwise, the natural resource exploitation process induce a large number of high entropy into the system of the whole environment, to destroy the ecological environment, this means that natural resources management is not successful. Therefore, the objective function of natural resource management based on the negative entropy theory, which can be derived from the equation (4) and the combined equation (2) and equation (3), as follows:

$$\min f(x) = -\sum_i v_i linv_i = -\sum_j v_j linv_j \quad (5)$$

The momentum constraints at all levels are as follows:

$$\sum_{i=1}^{n} g_{ri} p_i + \sum_{j=1}^{k} g_{rj} p_j = a_r, r = 1,2,\ldots,m \quad (6)$$

g_{ri}, g_{rj} and a_r are known constants, and m is the number of constraints.

HOPFIELD NETWORK ANALYSIS OF NATURAL RESOURCE MANAGEMENT BASED ON NEGATIVE ENTROPY

Hopfield Neural Network

Hopfield neural network (HNN) is a mono-layer fully interconnected neural network model. The connections between neurons are bidirectional, and the output of each neuron in the network is fed back to the inputs of other neurons at the same level. People pay more attention to it because of its realization of associative memory and optimization problem solving. As long as the neural network, which is determined by the algorithm and the coupling coefficient of neurons in the right state, has not reached the stable state, then it will keep changing all the time. Only in the appropriate

given excited mode, that the state would have been changed, which must reduce the energy function until a predefined minimum value, to reach the state stable and no longer changes (Ann 2004). Considering the above principles of HNN and the application of negative entropy theory in natural resource management, Hopfield network analysis based on negative entropy will be a very effective method of natural resource management.

There are discrete Hopfield neural network (DHNN) and continuous Hopfield neural network in Hopfield neural network (CHNN). CHNN is closer to the biological neural network than DHNN, because it uses each neuron parallel in parallel, imagination, real-time, distributed storage, collaborative etc. Considering the particularity of this research object, CHNN neural network model is used to analyze it.

Hopfield Optimization of Natural Resource Management

Using Hopfield network to analyze the problems studied must construct energy function on the basis of correctly expressing the research questions, so that the minimum value corresponds to the optimal solution can solve the problem. The object of this paper is to measure the quality of natural resource management based on the theory of negative entropy. Considering the objective function and constraint conditions of the research object (equation (5), equation (6)), we will use external penalty function method to construct the objective function.

The external penalty function method (also known as the exterior point method), the iterative point of the method generally moves outside the feasible area, it adds penalty to the objective function in violation of the constraint point, and does not punish the feasible point (Shi and Dong 1999). In the outer point method, equality constraint problem as follow:

$$\begin{cases} \min f(x) \\ s.t.\, h_j(x) = 0 \end{cases}$$

Defining auxiliary functions:

$$F_L = (x, \sigma) = f(x) + \sigma \sum_{j=L}^{L} h_j^2 j(x) \qquad (7)$$

There, σ is the penalty factor.

then order

$$J_r = \sum_{i=L}^{n} g_{ri} p_i + \sum_{j=L}^{k} g_{rj} p_j - a_r, r = 1,2, \ldots, m \qquad (8)$$

The equality constraint problem in this paper can be obtained by the combination of equation (5) and equation (8).

$$\begin{cases} \min f(x) = -\sum_{i} v_i linv_i - \sum_{j} v_j linv_j \\ J_r = \sum_{i=L}^{n} g_{ri} p_i + \sum_{j=L}^{k} g_{rj} p_j - a_r, r = I, L, m \end{cases} \qquad (9)$$

The energy function of the type (9) application type (7) can be obtained as follows:

$$E = -A\left(\sum_{i=1}^{n} v_i linv_i + \sum_{j=1}^{n} v_j linv_j\right) + \sum_{r=1}^{m} \lambda_r \left(\sum_{i=L}^{n} g_{ri} p_i + \sum_{j=L}^{k} g_{rj} p_j - a_r\right)^2 \qquad (10)$$

CONCLUSION

Our understanding developed at multiple scales across multiple dimensions (local to global; ecological, social, and economic). The concept of negative entropy is introduced into the management of natural resources, we can draw the following conclusion: It is the optimal choice for the minimization of increasing entropy, which realize the sustainable utilization of resources and steady state evolution of ecosystems. In order to achieve the minimization of entropy increase, the negative entropy flow should be changed, the quality of the environment should be improved through efforts, some times, compensation and orderly regulation of environmental system according to the laws of nature is continued evolution for achieving environmental system (Miao and Yan 2006).

In addition, cleaner production and self-organization mechanism of human economic system should be promoted, and also strengthen its own feedback regulation function, and the orderly transformation of material and energy between subsystems of the economic system, so as to improve the negative entropy flow of human system. Of course, adjusting and optimizing the internal structure of the system may hold by strengthening macroeconomic regulation and control policies and laws, and establish an ecological economic regulation and early warning system. In order to make the system a dissipative structure which is sensitive to benign fluctuations, we must make a good combination of material cycle, energy flow, information transmission and value increment, so as to achieve optimal output of the system.

Natural resource management is a combinatorial problem, and also a NP-Hard puzzle: it not only meets the demand of the economic system for resources, but also satisfies all kinds of momentum constraints, so as to ensure the entropy change of the whole open system in minimum time. Because of its complexity, the solution is more difficult than the general combinatorial optimization problem. Choosing an appropriate Hopfield neural network method is an effective solution in managing resources, and makes the output neurons correspond to each other, then building network energy function under certain conditions, which induce the minimum of energy corresponding to resources in the most balanced state. This is the most feasible way for solving this problem.

Of course, Hopfield is a gradient system which will inevitably fall into the local value. With the complexity of the energy function, the more the local value minimizes or the pseudo attractor exists, the more difficult the network is to achieve the optimal solution. It is difficult to directly obtain the initial network structure to meet the stability condition especially in the practical application, and the energy function in the initial design is not stable; it can't get legal solution even if it is stable. However, legal solution is not the optimal solution. In order to get a satisfactory solution, some design techniques are needed and the integration of its global optimal method is considered. In view of the fact, this is only a preliminary idealistic proposal on natural resource management and the negative entropy based on Hopfield network. Further research is necessary for the improvement of more complex and specific problems.

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