

EVALUATION OF ECOLOGICAL SERVICES OF JILIN PROVINCE, NORTHEAST CHINA

YU Shu-xia¹, SHANG Jin-cheng², GUO Huai-cheng¹

(1. College of Environmental Sciences, Peking University, Beijing 100871, P. R. China;

2. Department of Environmental Sciences, Northeast Normal University, Changchun 130024, P. R. China)

ABSTRACT: The main purpose of this study is to give evaluation of ecological services of Jilin Province, Northeast China. To take this value into decision-making and GDP accounting system is considered to be one of the economic solutions for ecological problems. The evaluation is based on the methods proposed by COSTANZA *et al.*, and some modifications about unit value of forest and cropland system were made according to the real characters of ecosystem, climate, natural conditions etc., in Jilin Province. Total value of ecosystem services is about 554.404×10^9 yuan(RMB)/a, which is about 4.9 times of GDP of the corresponding period. The results of this study could be used as a fundamental work for the construction of ecological province, which was carried out from 2001, and could provide ecological information for decision-making. Furthermore, the necessities for the further studies on the evaluation of ecological services and natural capital were discussed.

KEY WORDS: ecological services; economic evaluation; sustainable development; strategic decision-making; Jilin Province

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1 INTRODUCTION

Ecosystem services can be divided into two major categories, one is system function, and the other is system services and goods provision, which provide not only materials such as food and medicine, but also support and maintenance of whole system. Ecological services contribute to the whole economic system, both directly and indirectly, and consequently represent parts of the total value of our economy system (COSTANZA *et al.*, 1997; GUO *et al.*, 2001).

Sustainable development requires to pay the same concerns to environment as economic development. In fact, the value of ecological services is seldom considered in policy- and decision-making processes. In the traditional way, ecological services have no economic values, and most of the natural resources and ecological services are cost-free for any purpose. The externality of environment pollution and ecological services consumption is one of the most primary reasons for environmental degradation (OUYANG *et al.*, 1999b). The treatment of environmental pollution does not solve these problems effectively, for it could not pre-

vent environmental pollution and stop resources wasting radically (ZHOU and YAN, 2000).

To take the economic evaluation of ecosystem services and natural capital into the policy-making decisions and accounting system was considered to be a solution to ecological problems (OUYANG *et al.*, 1999a; XUE *et al.*, 1999). Furthermore, it could be used to revise current gross domestic product (GDP) into "green" one (ANNE *et al.*, 1998; HE, 1997). It might also be used as an index in strategic environment assessment, for the quantitative information it provided about natural resources consumption and environment pollution.

During the last few years, the value of ecosystem services, the possibilities and rationalities of evaluating these services attracted interests of many ecologists and economists. COSTANZA *et al.* (1997), DAILY (1997), and OUYANG *et al.* (1999a; 1999b) have summarized the categories of services, which include climate regulation, disturbance regulation, water supply and regulation, erosion control and sediment retention, waste disposal, materials provision, gas regulation, soil formation, genetic resources, etc.

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Biography: YU Shu-xia (1976–), female, a native of Xuchang City of Henan Province, Ph.D. candidate, specialized in environmental management and assessment. E-mail: ysxzh@163.com

The existing studies are often emphasis on specific type of biome. The forest system, especially the rain-forest, is the main object of some studies (BALICK and MENDELSON, 1992; CHOPRA, 1993; GUO *et al.*, 2001; TORRAS, 2000; JIANG and ZHOU, 1999; KREMEN *et al.*, 2000; PETERS *et al.*, 1989). Wetland is another focus because of its unique function (ACHARYA, 2000; MAHAN *et al.*, 2000; BYSTROM *et al.*, 2000), and some researches are carried on grassland (XIE *et al.*, 2001; PIMENTAL *et al.*, 1995). These studies provided much valuable information about ecological services and value of these biomes. However, they could not be used in other circumstance directly, for the specificity of certain biome. When scale and objects of one study change, the corresponding results will change significantly (SEIDL and MORAES, 2000). Therefore, some modifications may be necessary before applying the results into other studies.

Jilin Province lies in the middle of Northeast China. The total area is about $191 \times 10^3 \text{ km}^2$, and the main types of ecosystem are forest, grassland, cropland, wetland, lakes/rivers and desert. The ecosystem conditions are relatively better in Jilin Province when compared with others, while its economic development lags behind. Some strategies have been carried out to activate economic development. How to balance economic development and ecosystem protection is one of the most emergent issues currently. Therefore, the government brought forward the strategy of constructing ecological province in 2001.

The main objective of this study is to give comprehensive and reasonable assessment of the value of ecosystem services in Jilin Province, which would provide scientific basis for environment, ecosystem construction and strategic decisions. The modifications during the evaluation are based on related researches in Jilin Province or related fields, which may make the results closer to the real situations.

2 METHODS

In this study, the evaluation was mainly based on the method proposed by COSTANZA *et al.* (1997) in quantifying the value of worldwide natural capital and ecosystem services. The unit values of forest, water and croplands systems were modified according to characters of the ecosystem and economic development in Jilin Province. By means of geographic information system, the information of area and distribution of each biome was obtained from digital land-use map

of Jilin Province in 2000 on the scale of 1:100 000.

2.1 Function Evaluation for Forest Ecosystem

The main types of forest in Jilin Province are theropencedrymion and secondary forest. Their services, i.e., erosion control, material provision and gas regulation etc., have their characters. Therefore, some modifications about unit value of ecological services according to the real situation in Jilin Province are necessary and reasonable. In this study, those modifications include three main aspects, which are erosion control and sediment retention, water conservation, and material provision.

2.1.1 Erosion control and sediment retention

Soil erosion has many negative influences. Erosion by water and wind adversely affects soil quality and productivity due to reduced infiltration rates, water holding capacity, nutrients, organic matter, soil biota and soil depth (PIMENTAL *et al.*, 1995). At the same time, about 53% of the lost soil will be retained in riverbed (ZHOU and YAN, 2000), lakes or reservoirs. Getting rid of these sediments will cost manpower, which can be used as a substitution to the loss of sediment retention. This evaluation also takes the assumption that the losing of soil erosion are linear correlation with erosion modulus into consideration. The soil erosion modulus of different biomes is taken from YU *et al.* (2001). The cropland's soil erosion modulus is set as zero, for the loss of improper land use by agriculture activity is not deduced in this study. The value of soil erosion prevention and sediment retention can be calculated by using the formula below:

$$V_{si} = (M_0 - M_i) \times P_s \quad (1)$$

where V_{si} is the unit value of soil erosion prevention and sediment retention of the i th type of forest community (yuan (RMB)/(ha·a)); M_0 is cropland's soil erosion modulus (t/(ha·a)); M_i is the average soil erosion modulus of the i th type of forest community (t/(ha·a)); P_s is the unit value of loss of soil erosion (yuan/t); and i refers to different types of forest.

2.1.2 Water conservation

The forest, which is regarded as green reservoir, can keep huge quantity of water and regulate the distribution of water resources in different seasons. Degradation of vegetation could cause decrease of water provision and aggravate flood. WU *et al.* (2000) used water balance method to calculate the quantity of conserved water, and then gave value of water regulation of forest:

$$V_{wi} = (W_{pre} - \sum (W_{fi} + W_{Ei})) \times P_w \quad (2)$$

where V_{wi} is the unit value of water conservation of the

i th type of forest community (yuan/(ha·a)); W_{pre} is average annual precipitation (t/(ha·a)); W_{fi} is average annual runoff of the i th type of forest community (t/(ha·a)); W_{Ei} is average annual evaporation (t/(ha·a)); P_w is water price, expressed by shadow price, the engineering cost of constructing reservoir (yuan/t); and i refers to different types of forest.

2.1.3 Materials provision

Wood provision of forest is considered in this study. Yield and price determine the value of wood provision. The yield of wood refers to the annual amount of growth of stumpage. Furthermore, some recent researches made it clear that wood accounts for 20% of whole materials provided by forest (XUE *et al.*, 1999). Therefore, value of wood provision can be reckoned as follows:

$$\begin{aligned} V_{Mi} &= Y_{fi} \times P_{wood} \\ Y_{fi} &= G_i \times 20\% \end{aligned} \quad (3)$$

where V_{Mi} is the unit value of wood provision of the i th forest community (yuan/(ha·a)); Y_{fi} is annual unit area yield of the i th forest ecosystem (m³/(ha·a)); G_i is the total net primary productivity of the i th forest community (m³/(ha·a)); P_{wood} is market price of wood (yuan/m³) and i refers to different types of forest.

2.2 Function Evaluation for Cropland Ecosystem

According to previous studies (COSTANZA *et al.*, 1997; CHEN and ZHANG, 2000), the unit value of cropland is obviously lower than the real one, since only the function of food production is included. In this study, the value of ecological services of cropland is calculated from food production, raw materials provision, and gas regulation. The value of gas regulation service is evaluated based on the study of OUYANG *et al.* (1999a), and not introduced again here.

2.2.1 Food production

One of the fundamental functions of ecosystem is to synthesize organic matter by a process called photosynthesis, which provides essential support for the whole life system. In the primary production of cropland system, certain parts are provided as food for human beings, i.e., food production. As for Jilin Province, the main crop is corn. Therefore, the unit value of cropland's food production is evaluated with the average yield per unit area and price of corn:

$$V_c = P_c \times Y_c \quad (4)$$

where V_c is unit value of food production of cropland (yuan/(ha·a)); P_c is the price of corn (yuan/t), and Y_c is the average yield per unit area of corn (t/(ha·a)).

2.2.2 Raw materials

Of the primary products of corn, roots, stalk and leaves

may not be used as food, but they could be used as fuel, forage, fertilizer and energy sources. Under this case, the profit got from using them as material of electricity generation is taken for the value of ecological services of raw materials provision:

$$V_{RM} = R_E \times W \times P_E \quad (5)$$

where V_{RM} is the value of raw materials (yuan/(ha·a)); R_E is the unit weight electricity productivity of organic materials (kW/t); W is the weight of raw materials got from unit area corn field (t/(ha·a)) and P_E is the price of electricity (yuan/kW).

3 RESULTS AND DISCUSSION

The results of economic evaluation for ecosystem services and natural capital of Jilin Province are shown in Table 1.

3.1 Value of Ecological Services in Jilin Province

The total value of ecosystem services and natural capital in Jilin Province is about 554.404×10^9 yuan per year, about 4.9 times of its GDP in 2000 (112.902×10^9 yuan). The results demonstrate that ecosystem and its functions and services are better than the average level in both China (CHEN and ZHANG, 2000) and the whole world (COSTANZA *et al.*, 1997). The results also indicate that Jilin Province belongs to an affluent area when taking ecological services as an index. However, it is, in fact, the less developed province in China. The affluence in natural capital and services and consummate in function on one hand, along with its failing behind other provinces in economic development on the other hand, indicate that, in national or even world wide level, the market system for natural capital and ecosystem services does not exist or does not work well.

3.2 Value of Ecological Services of Each Biome

Each of the biome has its own characters and role in maintain the balance of ecosystem in Jilin Province.

3.2.1 Value of ecological services of forest

Of all the biomes, the forest provides the highest amount, about 50.1% of total service value. The forest is one of the most important biome in Jilin Province. Natural or man-made forest with a canopy density above 30% is the primary type of forest that has perfect structure and function for ecological services. The area and values of ecological services of shrubbery or coppice land and open woodland are apparently lower than that of natural or man-made forest with a canopy density above 30%. The amount and composition of

Table 1 Ecological values and components in Jilin Province

Biome	Area ($\times 10^4$ ha)	Unit value ($\times 10^3$ yuan/(ha·a))	Total value ($\times 10^6$ yuan/a)	Percentage of total area (%)	Percentage of total value (%)
21	7221.011	34.462	248849.551	37.79	44.89
22	444.652	21.534	9574.995	2.33	1.73
23	692.454	24.479	16950.919	3.62	3.06
24	114.297	20.231	2312.402	0.60	0.42
31	310.488	10.707	3324.457	1.62	0.60
32	675.111	6.832	4612.642	3.53	0.83
33	65.461	5.018	328.504	0.34	0.06
41	380.987	26.102	9944.656	1.99	1.79
46	498.800	116.937	58328.078	2.61	10.52
51	664.453	—	—	3.48	—
61	735.990	—	—	3.85	—
111	7305.519	27.401	200177.356	38.23	36.11
total	19109.226	29.012	554403.561	—	—

Notes: Symbols of types of biome:

21: Natural or man-made forest with a canopy density > 30%;

22: Shrubbery or coppice land with a canopy density > 40% and height < 2m;

23: Open woodland with a canopy density between 10% and 30%;

24: Other kinds of forest, including nursery, fell-field or orchard;

31: Grassland, including natural or man-made grassland for grazing or mowing, with a canopy density > 50%;

32: Grassland, including natural or man-made grassland for grazing or mowing, with a canopy density between 20% and 50%;

33: Grassland, including natural grassland, with a canopy density between 5% and 20%;

41: Water area, including river, trench, lake, reservoir, and pond;

46: Wetland, including marsh, river and lake;

51: Common land, including land for construction, transport both in city and in country;

61: Unused land, including desert, gobi, saline and bare land;

111: Cropland, including both rainfed farmland and paddy field

the value that forest provide indicates that, in the process of making decisions, special attention should be paid to forest, not only to its area, but also to its structure and function.

The unit value of ecological services of the forest system is a much lower, conservative one when compared with the actual services it provides. During the evaluation, the differences in ecological services caused by various uses of forest, structure of forest, different species and age of stand of forest are not considered. The scale of research will also influence results significantly (SEIDL and MORAES, 2000).

3.2.2 Value of ecological services of cropland

The cropland is another important biome in Jilin Province, which provides about 200.177×10^9 yuan per year, about 36.11% of total value, just lower than that of forest. Agriculture and forestry are the supporting industries for Jilin Province, thus, scientific management and sustainable utilization of these ecosystems should be vital to the entire development of Jilin Province.

The unit value of ecosystem services and natural capital of cropland is higher than that in the study of COSTANZA's *et al.* (1997), for the function of food production, material provision and gas regulation are

considered in this study, rather than only the value of food production in former study.

Besides more services included here, some other factors result in higher unit value of cropland. One is that cropland is highly influenced and managed by human beings, and has characteristics of rapidly material circulation and energy transformation, which are different from forest, grassland and other biomes that are seldom or never influenced by human beings. The other reason is that during the evaluation, the investments that include human power, material and energy consumption are not deducted, and the loss caused by unsuitable land use and irrational cultivation are also not considered. Furthermore, the value of material provision is evaluated according to the gross electricity production, without deducting investment and cost of operation in the power station. Thus, the real value of cropland system may be different from the result that this study got. And it needs further studies.

3.2.3 Value of ecological services of wetland

Because of its unique roles in environmental protection, climate regulation, water regulation and habitation-provider for some rare species (ACHARYA, 2000), the wetland possesses the highest unit value of ecosystem services among all of the biomes. There-

fore, its total value becomes the third highest one, about 58.328×10^9 yuan per year, about 10.52% of the total value, though its smaller area, about 498.8×10^3 ha, only about 2.61% of total area.

3.2.4 Value of ecological services of water area

In Jilin Province, the ecological value of the water area is lower than the average value of whole world (COSTANZA *et al.*, 1997). Jilin Province lies in the North Temperate Zone. Seasonal changes of temperature and precipitation limit the value of services provided by the water area. Because of the low temperature, primary productivity of water area is lower than that in tropic. More than three months of freezing season also impairs the value of ecological services. Furthermore, the serious water pollution due to agriculture and industry development is considered to be another important reason.

3.2.5 Value of ecological services of grassland

Grassland in Jilin Province includes three types according to canopy (Table 1). Of all these three kind of grassland in Jilin Province, grassland with medium coverage has the highest percentage in area compared with the other two types. The lower percentage of grassland with highest coverage indicates that grassland has degenerated in Jilin Province. Ecological value that each kind of grassland provides is varied significantly, from 5.018×10^3 yuan/(ha·a) (with coverage between 5%–20%) to 10.707×10^3 yuan/(ha·a) (with coverage higher than 50%). The differences of unit value demonstrate the obvious effects of degradation, which would impair its value in animal husbandry, bring loss to farmer, and would also decrease the value of ecological services. Grassland is mainly located in west part of Jilin Province. Ecosystem is very fragile there, and is very difficult to be recovered. Exploitations in these areas should be very careful.

3.2.6 Value of ecological services of other biomes

In this study, the ecological services provided by common land, including land used for construction, transport both in city and country, and unused land, which includes desert, gobi, saline and bare land, are not evaluated, whose ecological value is set to zero. These kinds of land use types account for 7.33% of total area, 1.4×10^6 ha. It is another field that need further studies.

3.3 Research Prospect

Because of the complicity and diversity of ecosystem and its services and functions, there still has no universal mode for valuation. The existing methods and demonstrated studies have their limitations, and still

need further study before applying them to other studies. It needs some more detailed and further studies on the relationship between value of ecological services and the natural conditions.

The evaluation of some biomes need further studies, such as the deduction of investment in cropland; relationship between unit value of forest and its scale, species, structure; the ecological value of common land, unused land and so on.

The pollution or resources depletion may have much more indirect or accumulative effects on the value of ecological services. With the aggravation of environmental pollution and resources scarcity, the price of natural resources may exponentially increase. The relationship between environmental pollution and its impair to the value of ecological services is another field that need further studies. In addition, the manners of how to use these results to instruct decisions still need further studies.

4 CONCLUSIONS

Ecological services contribute to the whole economic system, and represent part of the total value of our economy system. To give the reasonable quantity of these services is one of the most fundamental works before taking these services into decision-making process and accounting system. In this paper, the accounting method and related parameters are modified before applying to Jilin Province. The result indicates that the whole system provides about 4.9 times of its GDP in corresponding period, about 554.404×10^9 yuan per year.

Among all the main biomes, the forest provides the highest amount of total service value, and the wetland possesses the highest unit value of ecosystem services among all of the biomes. The unit value of cropland is higher than that in other studies, for considering more functions and some other reasons.

Based on this evaluation, it could be concluded that Jilin Province provides much more ecological contribution to the whole country and even whole life support system, despite its lower development in economy. Now, for Jilin Province, the economic development and the ecological protection are two main tasks. The strategy of constructing ecological province intends to balance and realize these two objects. The evaluation may provide fundamental information about ecological services for the establishment and implementation of the development strategies. It could also help the governor to take ecological factors into considera-

tion for it is quantified and can compare with other economic factors.

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