For office use only
T1 ________________
T2 ________________
T3 ________________
T4 ________________

Team Control Number
1900406

Problem Chosen
E

For office use only
F1 ________________
F2 ________________
F3 ________________
F4 ________________

2019
MCM/ICM
Summary Sheet
(Your team's summary should be included as the first page of your electronic submission.)
Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

Ecosystem Service Valuation Model:

Exploring the Real Economic Costs of Land-Use Projects

Traditionally, most land use projects do not consider the impact of ecosystem services — the many benefits and assets that humans receive freely from our natural environment and a fully functioning ecosystem. However, when we promote land development projects, we do limit or remove ecosystem services provided by lands. Therefore, with the increasingly scarce resources and deteriorating environment, it is necessary to put a value on the environmental cost of land use development projects.

To understand the real economic costs of land-use projects when consider ecosystem services, we first develop an ecosystem service valuation model, in which the ecosystem service consists mainly of three parts — product service, regulatory service, cultural service, and each of the three can be valued by certain measurement indicators. For example, the value of regulatory service can be determined by indicators of eight aspects: soil conservation, carbon fixation, oxygen production, water conservation, flood storage, air purification, water purification, climate regulation. The sum of the values corresponding to each indicator is the ecosystem service value we are searching for.

Next, we divided the land into six categories of forest, grassland, farmland, wetlands, rivers and lakes, deserts, and obtained a table of ecosystem service values per unit area of each land type respectively, in order to help identify the true economic costs of land-use projects in the next part.

Then we take a small community and another large national project as examples, to conduct specific cost-benefit analysis, and use the mathematical model we have developed to figure out the ecological cost corresponding to the two projects. In addition, based on the above analysis, we provide the project planners and managers with some feasibility recommendations for land use projects.

Finally, we evaluated the validity and limitations of our model. And since some parameters tend to increase or decrease with time, the possibility of the model changing over time should be considered. Therefore, we made a modification about how the basic ecosystem service valuation model changes with time.

Contents

1 Introduction

1.1 Background

The biosphere provides many natural processes to maintain a healthy and sustainable environment for human life, which are known as ecosystem services — the many benefits and assets that humans receive freely from our natural environment and a fully functioning ecosystem.

Ecosystem services consists mainly of three parts. First, diverse kinds of final products provided by ecosystem, like water and mineral resources. Second, many ecosystem regulation processes beneficial to human beings, for example, turning waste into food, water filtration, growing food, pollinating plants, and converting carbon dioxide into oxygen. Third, the ornamental services provided the environment, such as scenic spot, nature reserve, geological park and forest park, etc.

Traditionally, most land use projects do not consider the impact of, or account for changes to, ecosystem services. However, when we promote land development projects, we do limit or remove ecosystem services provided by lands. Therefore, with the increasingly scarce resources and deteriorating environment, it is necessary to put a value on the environmental cost of land use development projects.

1.2 Restatement of the Problem

To understand the true economic costs of land use projects when ecosystem services are considered, we are required to complete the following tasks:

- **Task 1**: Establish an ecosystem services valuation model to identify the value of ecosystem services of different kinds of lands.
- **Task 2**: Apply the ecosystem services valuation model to varying sizes of projects, and conduct a cost benefit analysis of these projects.
- **Task 3**: Evaluate the validity of the model summarize its advantages and limitations.
- **Task 4**: Based on the above analysis, put forward feasible recommendations for land use project planners and managers.
- **Task 5**: Explain whether the model changes over time, and if so, how it changes with time.

1.3 Overview of Our Work

First, we constructed an ecosystem service assessment model to analyze the real economic costs of land-use projects considering the value of ecosystem services, which consists mainly of three parts: product service, regulatory service and cultural service. Each of the three can be valued by a certain number of measurement indicators, and the sum of the values corresponding to each indicator is the ecosystem service value we are seeking.

Next, we divided the land into six categories of forest, grassland, farmland, wetlands, rivers and lakes and deserts, and obtained a table of ecosystem service values per unit area corresponding to each land type.

Then we selected a small community project and a large national project for specific analysis, and used the mathematical model we built to find the ecological cost corresponding to the two projects. In addition, based on the above model analysis, we provide project planners and managers with some feasibility suggestions for land use projects.

Finally, we evaluated the validity and limitations of our model and made a modification to the time changes.

More details will be explained in the following pages.

1.4 Assumptions

- Assumption I: Currently, this is a peaceful and independent world. There will be no large-scale military or political conflicts which have universal affects in a short period.
- Assumption II: Ecosystems in all regions have reached a stable state of both structure and function, and are continuing to operate normally. There is no ecological crisis that cannot be solved in a short time.
- Assumption III: The land per unit involved in this paper refers to one and only specific type, so it is impossible that one unit of land belongs to two types or does not belong to any of the land types mentioned below.
- Assumption IV: In order to simplify the calculation and identify the practicability of the model under average level, this paper uses the average value obtained from the annual data of China in 2015 as the standard to estimate the value of ecological services. This will be explained in detail at Section 3.2.
- Assumption V: This model is only applicable to the cost of ecological services in China. If it is needed to calculate the projects in other countries, the equivalent conversion shall be made according to the local price of corresponding products.

2 Ecosystem Services Valuation Model

Generally speaking, ecosystem services include product services, regulatory services, cultural services. Based on this, we establish an ecosystem services valuation model.

2.1 Valuation of Product Services

The product services of ecosystem refer to all kinds of final products provided by ecosystem for human beings, whose value is determined by the output of various products and their prices. That is

$$V_p = \sum_j W_j \cdot P_j$$

where V_p is the value of product services (RMB); W_j are the output of products; P_j are the prices of the corresponding product.

2.2 Valuation of Regulatory Services

The regulatory services of ecosystem mainly include eight aspects: soil conservation, carbon fixation, oxygen production, water conservation, flood storage, air purification, water purification, climate regulation.

2.2.1 Soil Conservation

The soil conservation function of ecosystem services is evaluated from two aspects: maintaining soil fertility and alleviating sediment deposition disasters. Amount of soil conservation is calculated by the difference between potential soil erosion and actual soil erosion. Amount of soil nutrient retention was estimated based on the amount of soil conservation and the contents of nitrogen (N), phosphorus (P), potassium (K) in the lost soil.

The value of soil fertility conservation is estimated as follow

$$E_f = \sum_i A_c \cdot C_i \cdot P_i \quad (i = N、P、K)$$

where E_f is the value of soil fertility conservation (RMB); A_c is the amount of soil conservation (m^3); C_i are the contents of nitrogen (N), phosphorus (P), potassium (K) in the lost soil (kg/m^3); P_i are the prices of fertilizers (RMB/kg).

Sediment deposition often leads to natural disasters such as floods, so the economic benefits of alleviating sediment deposition disasters can be calculated according to the cost of building reservoirs. The formula is showed below

$$E_n = k \cdot A_c \cdot P_d$$

where E_n is the value of alleviating sediment deposition disasters (RMB); k is the proportion of sediment deposited in reservoirs, rivers and lakes due to soil erosion; A_c is the amount of soil conservation (m^3); P_d is the construction cost per unit volume of reservoir capacity (RMB/m^3).

Therefore, the total value of soil conservation function is

$$V_1 = E_f + E_n$$

where V_1 is the total value of soil conservation function (RMB); E_f is the value of soil fertility conservation (RMB); E_n is the value of alleviating sediment deposition disasters (RMB).

2.2.2 Carbon Fixation

According to the photosynthesis equation

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$$

It can be seen that 264g carbon dioxide can be absorbed by plant when 162g glucose is produced, that is to say, when producing 1g glucose, 1.63g carbon dioxide can be absorbed. Thus, the value of carbon fixation function is

$$V_2 = W_d \cdot P_c$$

where V_2 is the value of carbon fixation function (RMB); W_d is the total amount of dry matter in ecosystem (kg); P_c is the price of is the price of carbon (RMB/kg), which can be determined by the price of carbon trading on the international market.

2.2.3 Oxygen production

According to the photosynthesis equation, 162g glucose can absorb 264g carbon dioxide and release 192g oxygen, that is to say, 1 g glucose can absorb 1.63g carbon dioxide and release 1.19g oxygen. Thus, the value of oxygen production function is

$$V_3 = W_d \cdot P_o$$

where V_3 is the value of oxygen production function (RMB); W_d is the total amount of dry matter in ecosystem (kg); P_o is the price of oxygen (RMB/kg), which can be calculated according to the price of industrial oxygen production.

2.2.4 Water Conservation

The total amount of water conserved by ecosystems each year is calculated as follows

$$W_f = R + I_w - E_r - O_w$$

where W_f is the total amount of water conservation in a region (m^3); R is annual precipitation (m^3); I_w is annual inbound water volume (m^3); E_r is annual evaporation (m^3); O_w is annual outbound water volume (m^3).

The value of water conservation function is

$$V_4 = W_f \cdot P_d$$

where V_4 is the total value of water conservation function (RMB); W_f is the total amount of water conservation in a region (m^3); P_d is the construction cost per unit volume of reservoir capacity (RMB/m^3), which can be determined according to the Specifications for Assessment of Forest Ecosystem Services in China.

2.2.5 Flood Storage

Reservoirs, lakes, rivers and other wetlands play an important role in flood storage, flood discharge and peak reduction, which is instrumental to mitigate and prevent flood hazards.

For lakes, their flood storage capacity can be determined by the following formula

$$L_p = 134.83 \cdot exp(0.927 \cdot L_a)$$

where L_p is the amount of water that a lake can store (10^4 m^3); L_a is the surface area of the lake (km^2).

For reservoirs, their flood storage capacity can be calculated by the difference between the total reservoir capacity and the amount of water storage at the reservoir in dry season. The formula is

$$R_p = T_v - S_v$$

where R_p is the amount of water that a reservoir can store (10^4 m^3); T_v is the total reservoir capacity (10^4 m^3); S_v is the amount of water storage at the reservoir in dry season (10^4 m^3).

The flood storage value of ecosystem can be calculated by multiplying the storage capacity of lakes and reservoirs by the cost of reservoir capacity of reservoir construction unit, as follows

$$V_5 = (L_p + R_p) \cdot P_d$$

where V_5 is the value of flood storage function (10^4 RMB); P_d is the construction cost per unit volume of reservoir capacity (RMB/m^3).

2.2.6 Air Purification

This paper mainly considers the air purification function of ecosystem to sulfur dioxide (SO_2), smoke and industrial dust, and the value of air purification is given by

$$V_6 = \sum_i k_i \cdot E_i \cdot C_i \quad (i = SO_2、Smoke、Dust)$$

where V_6 is the total value of air purification function (RMB); k_i is the proportion of ecosystem purification to total industrial emissions (%); E_i are the amount of emissions of sulfur dioxide (SO_2), smoke and industrial dust (m^3); C_i are the processing costs of per unit emission of sulfur dioxide (SO_2), smoke and industrial dust (RMB/m^3), which can be determined by the Specifications for Assessment of Forest Ecosystem Services in China.

2.2.7 Water Conservation

We mainly consider the water purification function of COD (Chemical Oxygen Demand) and ammonia nitrogen by ecosystem.

$$V_7 = \sum_i k_i \cdot E_i \cdot C_i \quad (i = COD、\text{Ammonia nitrogen})$$

where V_7 is the total value of water purification function (RMB); k_i is the proportion of ecosystem purification to total industrial emissions (%); E_i are the amount of emissions of COD and ammonia nitrogen (m^3); C_i is are the processing costs of per unit emission of COD and ammonia nitrogen (RMB/m^3), which can be determined by the Specifications for Assessment of Forest Ecosystem Services in China.

2.2.8 Climate Regulation

The value of climate regulation function of ecosystem is mainly reflected in the value of heat absorption and cooling of ecosystem, including plant transpiration and water surface evaporation.

The transpiration is mainly carried out by green space, including forests and grasslands. The transpiration of one hectare green space in summer can absorb 81.1×10^3kJ of heat. The corresponding value of transpiration can be calculated according to the electricity consumption and electricity price that can achieve the same goal, which is given by

$$E_v = (F_a + G_a) \cdot H_a \cdot \rho \cdot P_e$$

where E_v is the value of transpiration (RMB); F_a is forest area (km^2); G_a is grassland area (km^2); H_a is the amount of heat absorbed per unit green area (kJ/km^2); ρ is a constant, 1kWh/3600kJ; P_e is the electricity price (RMB/kWh).

The evaporation value of water surface can be calculated according to the area of water surface and the amount of electricity required to evaporate the same amount of water, which is given by

$$E_w = W_a \cdot E_p \cdot \beta \cdot P_e$$

where E_p is the value of evaporation (RMB); W_a is the water surface area (m^2); E_p is annual average evaporation (m); β is the amount of heat consumption of water per unit volume of evaporation (kJ/m^3); P_e is the electricity price (RMB/kWh).

Thus, the value of climate regulation function is

$$V_8 = E_v + E_w$$

where V_8 is the total value of climate regulation function (RMB); E_v is the value of transpiration (RMB); E_p is the value of evaporation (RMB).

2.2.9 Value of Regulatory Services

The value of regulatory services is determined by

$$V_r = \sum_{i=1}^{8} V_i$$

where V_r is the value of regulatory services (RMB); V_i are the values of the above eight functions respectively (RMB).

2.3 Valuation of Cultural Services

The cultural services of ecosystem refer to the ornamental services provided by scenic spot, nature reserve, geological park and forest park, etc., whose value has a linear relationship with tourism income, that is

$$V_c = k_c \cdot I_t + \mathrm{b}_c$$

where V_c is the value of cultural services (RMB); I_t is the tourism income of one region (RMB); k_c is the slope and b_c is the intercept, which can be determined by linear regression model.

Now we show the process of getting k_c and b_c by regression. After surveying and analyzing 8 different tourist attractions in China, the value of cultural service of each tourist attraction and the corresponding tourism income were obtained. Using SPSS to perform regression analysis on two variables, we can get the estimator of the parameter k_c and b_c, and then we can get the estimated formula of cultural service value as follows:

$$V_c = -19.1280 + 0.2614 \cdot I_t$$

$$R^2 = 0.7878, \quad SER = 27.0819$$

Some information related to the regression model are given below.

Table 1 Estimates and other information of the regression model

	Coefficients	Standard error	t Stat	P-value
Intercept	-19.1280	20.7395	-0.9223	0.3919
Tourism Income	0.2614	0.0554	4.7186	0.0033

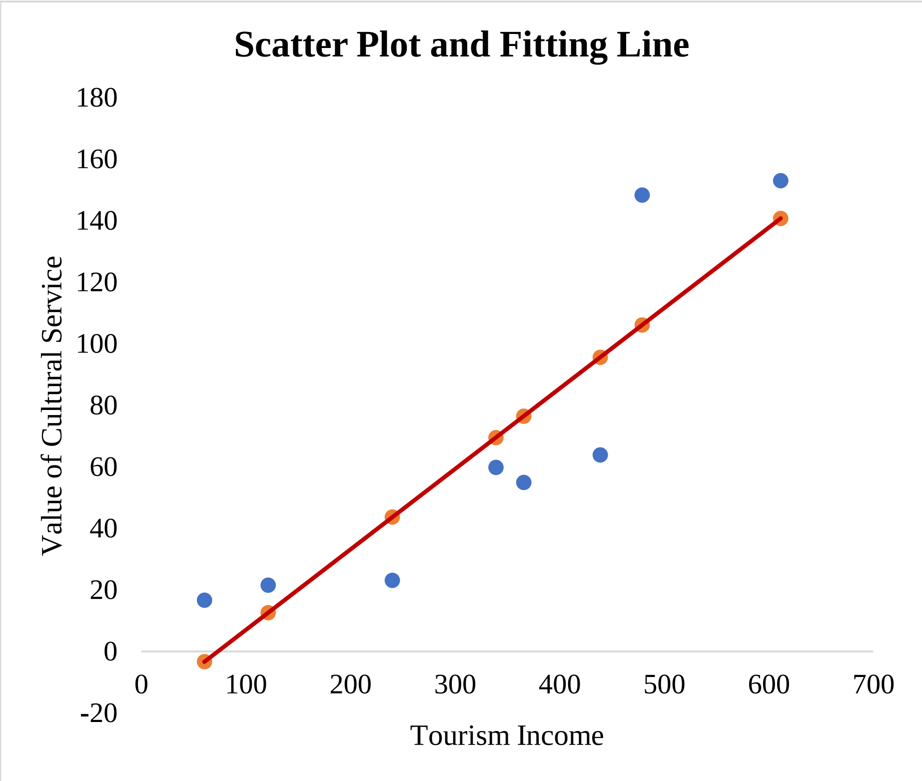

Figure 1 Scatter Plot and Fitting Line of the regression model

2.4 Valuation of Ecosystem Services

The value of ecosystem services is determined by

$$V_e = V_p + V_r + V_c$$

where V_e is the value of ecosystem services (RMB); V_p is the value of product services (RMB); V_r is the value of regulatory services (RMB); V_c is the value of cultural services (RMB).

3 Cost Benefit Analysis of Land Use Projects

Based on the three types of ecosystem services, land can be divided into six categories: forests , grassland, farmland, wetlands, rivers and lakes, and deserts. The ecosystem services cost of these six land types is showed below.

3.1 Ecosystem Services Value of Different Types of Lands

3.1.1 Forest

1. Product services

The supply of products provided by forests mainly includes food production and raw material production. According to the basic classification, special types of planted forests (removing the value of pest control functions due to a single species of trees) and land mainly for agricultural and urban uses are not included here. Since China's forest ecosystem is part of forestry management, its products include forest cultivation, collection of forest products and production of forest harvesting products such as wood, rubber, turpentine and other product types.

2. Regulatory services

As the largest terrestrial ecosystem on the earth, forest is an important part of the biosphere. It has many functions such as soil conservation, carbon fixation, and energy storage, which plays a vital role in maintaining ecological balance. Due to its large vegetation density, the forest system has a strong soil conservation function. Good tree height and canopy coverage make the forest have strong carbon fixation and oxygen production. At the same time, because most of the forests develop for a long time, they can form huge underground roots and can effectively conserve water. In addition, the forest can effectively purify the atmospheric environment and the water environment, such as dust retention and ammonia nitrogen purification. Finally, due to the transpiration of trees, forests also have the function of absorbing heat and cooling to regulate the climate.

3. Cultural service

As a comprehensive ecosystem with biodiversity, the forest itself has a high value of ornamental and cultural services.

3.1.2 Grassland

1. Product services

As an important animal feed source, grassland is closely related to the aquaculture industry. Its products mainly include animal feeding and product and quality of grazing.

2. Regulatory services

Based on vegetation coverage, grassland can effectively maintain soil fertility and reduce soil erosion to a certain extent, thereby maintaining soil. Although it is relatively weak in terms of its impact on water sources, it is similar to forests, and it also has a carbon-fixing function and an oxygen-producing function based on plants. Compared with the strict conditions of forests, grassland can not only be used as a large-scale pasture, but also can be used as an urban greening to improve the environment. Therefore, its atmospheric environment purification function cannot be ignored. At the same time, plant transpiration can also effectively improve the regional climate.

3. Cultural service

The grassland itself is also highly ornamental, with additional cultural service value.

3.1.3 Farmland

1. Product services

The existence of farmland is to meet the needs of agricultural products for population and socio-economic development in a certain period. The most basic main function is the production of agricultural products, covering a wide range, including crop products and production, grain, cotton, oil, Sugar, tobacco, vegetables, herbs, melons and other crop products, as well as tea gardens, mulberry gardens, orchards.

2. Regulatory services

Since the cultivation of crops affects the amount of soil nutrients and soil erosion, for example, continuous planting reduces soil fertility, so soil retention is not considered here. At the same time, based on the particularity of large-scale planting of single crops, this type of vegetation does not have obvious carbon sequestration, oxygen production and water conservation. However, it should be noted that large-scale crop cover can produce considerable vegetation transpiration, so as to effectively regulate the temperature and humidity while purifying the atmosphere.

3. Cultural service

Farmland, as a functional land with agricultural products as its basic output, does not have an aesthetic landscape in the usual sense and therefore does not have ornamental and cultural service value.

3.1.4 Wetland

1. Product services

Wetlands are defined as the intersection of land and water, with water levels close to or from the surface of the earth, or shallow water. Therefore, wetlands are rich in underground freshwater resources. Moreover, wetlands are rich in species diversity, and there are abundant wetland plant species, among which lotus root, alfalfa, glutinous rice and water chestnut are all edible agricultural products; reed and cattail are also important raw materials for papermaking and weaving, which have high economic value.

2. Regulatory services

As one of the most important ecosystems in the world, wetlands are called “the kidney of the world”. It plays an important role in the ecological regulation of the surrounding environment. The plant community in the wetland can absorb carbon dioxide and some harmful gases in the air, release oxygen, and purify the atmospheric environment. The plants grow densely and the grass root layer is loose and porous in the wetland, so it can strongly conserve water source. At the same time, the plant transpiration and evaporation of water increase the humidity of the air and regulate the environmental climate. In addition, swamp wetlands can slow down the flow of water, help the precipitation of poisons and impurities (pesticides, domestic sewage and industrial emissions). Some plants growing in the wetlands can also decompose and purify environmental pollutants, and play a role in water purification.

3. Cultural service

The species diversity of wetlands also constitutes a variety of natural landscapes with high cultural service value.

3.1.5 River and Lake

1. Product services

Rivers and lakes are widely distributed in various provinces and cities in China. The large amount of fresh water resources contained therein constitutes the main source of living, industrial production water and agricultural irrigation water for the surrounding residents. The various aquatic animals grown in rivers and lakes, such as freshwater fish, crabs, shrimps, and oysters, constitute the main products of fishery production. In addition, the water potential energy caused by the difference in ground potential at both ends of the water flow can also be converted into clean and sustainable electric energy by the hydropower station, which plays an important role in human life production.

2. Regulatory services

The strong water storage capacity of rivers and lakes makes it necessary to store floods, discharge floods and reduce flood peaks, which is of great significance for mitigating flood disasters. At the same time, the exchange of water between the rivers and lakes and the atmosphere also helps to achieve natural circulation of water and regulate the environmental climate. In addition, the slow flow rate of the river contributes to the precipitation of poisons and impurities and acts as a water environment purification.

3. Cultural service

The beautiful natural landscapes of rivers and lakes also provide a high level of ornamental and aesthetic value for humans.

3.1.6 Desert

1. Product services

Deserts usually refer to areas with dry climate, poor vegetation, and desolate environments due to scarce precipitation or large evaporation. Because of the poor natural environment of the desert, only a small number of plants can survive, so the production value of the desert can be neglected.

2. Regulatory services

Since a small number of plants in the desert survive, the photosynthesis of plants can achieve the absorption of carbon dioxide and the release of oxygen. Therefore, it can be considered that the desert has a limited purification function of the atmospheric environment. In addition, the root system of desert plants is developed and the water storage capacity is strong. However, because the natural environment of the desert is very dry and the water evaporates quickly, it can only be considered to have extremely limited water conservation functions.

3. Cultural service

The unique natural landscape of the desert also provides some ornamental and aesthetic value to humans.

3.1.7 Ecosystem Services Values

Taking the 2015 national annual data of China as an example, we calculate the ecological services value per unit of different types of land based on the above analysis. The results are shown in the tables below, which will be used in the calculation of the following programs.

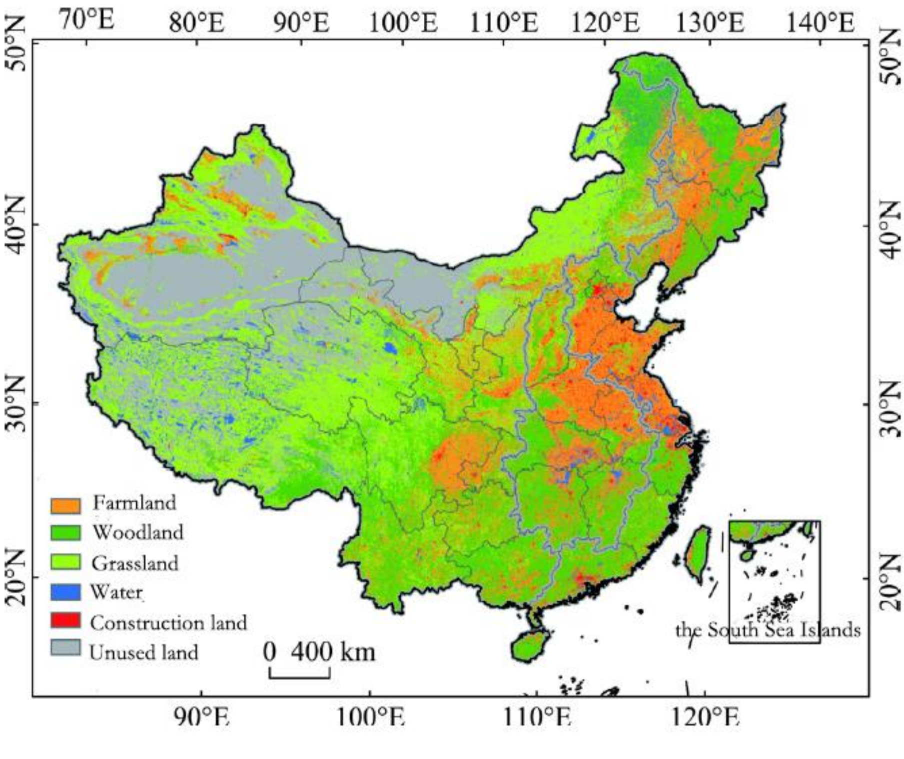

Figure 2 China Topographic Satellite Map 2015

Table 2 Land classification of China in 2015

	Woodland	Grassland	Farmland	Wetlands	Water	Desert
Area (10^4 hm^2)	312600	39280	17300	3446	2706	121

Table 3 Gross value of production of China in 2015

		Woodland	Grassland	Farmland	Wetlands	Water	Desert
Product services value (10^8 RMB)	Agricultural products	4436.4	29780.4	48062.2	9573.6	10880.6	--
	Water resources (2.19 RMB / ton)	--	--	--	16841.5	58105.7	--
	Hydroelectric power (0.689 RMB/kWh)	--	--	--	1542.1	5320.3	--
Adjustment services value (10^8 RMB)	Soil conservation	5643.6	3951.5	--	--	--	--
	Carbon sequestration (267 RMB / ton)	6185.5	2369.5	--	--	--	--
	Oxygen production (1245 RMB / ton)	21055.2	8065.7	--	--	--	--
	Water conservation	17697.8	--	--	1950.9	--	68.5
	Flood regulation	--	--	--	--	24325.8	--
	Air purification	6064.7	2646.1	559.4	373.0	--	0
	Water purification	2414.7	--	--	2228.5	1804.7	--
	Climate regulating	38.6	48.5	21.3	4.3	203580.4	--
Cultural services value (10^8 RMB)		2920.1	1534.7	--	725.8	539.6	1.2
Total (10^8 RMB)		66456.6	48396.4	48642.9	33239.7	304557.1	69.7

Table 4 Value per unit of China in 2015

	Woodland	Grassland	Farmland	Wetlands	Water	Desert
Value per unit (10^4 RMB / hm^2)	21259.31	12320.88	28117.28	96458.79	1125488.00	5760.33

In addition, residential land and construction land should also be taken into consideration. The value factors for these types are similar to the above land classifications, but the ecological services value is usually negative due to little greenbelt and dense population, thus generally lower air quality than the vegetation-covered areas. Pollution from life and industry also make things worse. The only exception is the water conservancy facilities usage. It has proximity to water and is far away from heavy industry, and therefore its ecological services value is positive.

The average ecological service value can be obtained by similar calculation as follows:

Table 5 Ecological service value of other types of lands

	Residential land	Industry and mineral land	Transportation facilities land	Water conservancy facilities land
Value per unit ($10^4\ RMB\ /\ hm^2$)	-31058	-133929	-744	5733

3.2 Cost Benefit Analysis of Projects

In this part, we will take two specific projects as examples to carry out cost-benefit analysis. All the data we use come from China Statistical Yearbook and the Specifications for Assessment of Forest Ecosystem Services in China.

3.2.1 Applications on Small-Scale Projects

First, take the small-scale local project as an example and use the above model for evaluation.

According to relevant reports, in 2015, Shanghai Volkswagen Changsha Automobile Factory was completed and put into operation in Changsha Economic and Technological Development Zone, with a total area of 1.38 million square meters and a vehicle production capacity of 300,000 units per year. The project belongs to the acquisition of unused land and changes it to industrial construction land. Therefore, the ecosystem service value of the area after the change is as follows:

$$-133929 \times 10^4 \times 138 \times 10^4 \times 10^{-4} = -1.8482202 \times 10^{11}$$

Since there is no consumption and output of unused land, the ecosystem service value here is 0 by default. Therefore, the actual ecosystem service value of the project is -18,482,200,000 RMB. From the perspective of ecological services, over-exploitation of construction land will not only reduce the coverage of vegetation, but also affect its multiple adjustment functions for the environment and climate, while also generating dust and waste gas, adding to the burden of existing ecosystems, which is apparently not advisable.

If considering the benefits, according to the average market price, the unit price of each Volkswagen is 279,800 RMB per vehicle, so its revenue in the next one year is about

$$27.98 \times 10^4 \times 30 \times 10^4 = 8.394 \times 10^{10}$$

Then the actual value of the project within 3 years should be

$$-1.8482202 \times 10^{11} + 8.394 \times 10^{10} \times 3 \approx 669.98 \times 10^{8}$$

Considering the long-term use of the factory, its revenue creation ability is sustainable, and it can effectively promote regional economic development in the long run. If the local government can effectively use some of the economic benefits to optimize land use types and rationally control pollution, the project has certain investment value in both ecological and economic sense.

3.2.2 Applications on Large-Scale Projects

The above model also has certain application value for larger projects. Taking China's South-to-North Water Transfer Project as an example, the construction of the project in Shaanxi Province is also called the “Water diversion from Han River to Wei River” cross-basin water transfer project. It is a national-level water conservancy construction project. From the perspective of ecosystem services, the project has an impact on the vegetation and residents along the water source area and the transportation line. The specific impact area is shown in the following table:

Table 6 The specific impact area of China's South-to-North Water Transfer Project

Area /hm^2	Forest	Grassland	Farmland	Waters	Residential land	Water conservancy facility land
Water source area	-42.20	--	-50.53	+107.26	-16.06	+62.01
Water line	-23.78	-0.27	-26.05	+1.53	--	+0.63
Total	-65.98	-0.27	-76.58	+108.79	-16.06	+62.64

Then, the ecological service value of the project can be calculated:

Table 7 Ecological service value of China's South-to-North Water Transfer Project

Land type	Forest	Grassland	Farmland	Waters	Residential land	Water conservancy facility land
Area（hm^2）	-65.98	-0.27	-76.58	108.79	-16.06	62.64
Unit area value（10^4 RMB /hm^2）	21259.31	12320.88	28117.28	1125488	-31058	5733
Value（10^4 RMB）	-1402689.3	-3326.64	-2153221	122441839.5	498791.5	359115.1
Total value（10^4 RMB）	119740508.9					

From the above results, the ecological services value of the project in 2015 is 119740508900 RMB. Although the water conservancy project has flooded parts of the woodland and farmland, it is still with great investment value since it significantly increases the water area and thus the gain of the whole ecosystem exceeds the loss. Moreover, the water conservancy facilities effectively relieve the crisis of water shortage region, improve the regional water environment by reforming agricultural irrigation desert, and is conducive to crop growth and promote industrial structure adjustment. Resulting in considerable economic benefits, this water transfer project is of great social significance. However, there are still some problems. The inundation of residential land will lead to relocation of inhabitants to other lands, and the relocation process as well as the new accommodations will still bring costs to some extent.

4 Model Evaluation and Suggestions

4.1 Model Evaluation

4.1.1 Advantages

1. The model is simple and easy to implement

This model mainly uses the linear relationship between independent variables and dependent variables. Thanks to its normal form, it will greatly simplify the complexity of calculation in practical application, thus improve the efficiency of simulation.

2. Comprehensive coverage and universality

The model analyzes the land ecosystem service costs both directly and indirectly from three perspectives consisting of products, ecological regulation and cultural services. At the same time, there are segments of each point of view, which fully consider all the factors related to ecological services, so as to make the simulation more reliable and precise, which will have reference to some extent, and can be applied to most of the region.

3. Reasonably quantify the value

The quantification of ecological services has always been a controversial problem due to its involvement of biological activities and environmental regulation, which are difficult to be digitized. This model uses the alternative cost method to flexibly describe the ecological value by using specific indexes that can be inquired and their related functions, such as using the linear function of ticket income of scenic spots to describe the cultural services value of the region, thus making the model more practical.

4.1.2 Disadvantages

1. Some quantitative indicators are not suitable

In the model of calculating the value of ecosystem services, for each value indicator, a corresponding quantifiable and observable variable value must be chosen to replace the value. Therefore, for some value indicators, the value of the alternative observation variables we choose may not reflect the corresponding ecological value correctly and completely.

2. Land type classification is not specific enough

In the above mathematical model, we divide the land types into six categories in a general way, and find the ecosystem service value per unit area corresponding to each type of land. In fact, for the same type of land, the soil nutrient content, animal and plant species, soil erosion, etc. are not the same. Therefore, there will be differences in the corresponding ecosystem service value per unit area.

3. Ignore the influence of geographical location, climate and other factors

In different geographical locations, the species of animals and plants living on the same type of land are different, so their corresponding production service value, ecological adjustment value and cultural service value are different. In addition, different climates will also affect the living conditions of plants and animals. For example, the transpiration of plants living in areas with higher temperatures will be stronger, which will also bias the corresponding ecosystem service value.

4. Actual project analysis did not take into account changes in time

In the above model calculation, we first obtained a table of ecosystem service value per unit area corresponding to different land types using the data of various indicators in China in 2015. However, in the specific case analysis afterwards, we did not make certain adjustments to the value table according to the actual implementation time of the project, which made the final result may have a certain deviation from the facts.

4.2 Suggestions

Based on the feasibility analysis of the above model, we provide some following suggestions for the land use planners and managers.

1. Project location

The ecological services values are different among several land types. Additionally, because of the particularity of scarce vegetation, the ecological services value of residential land or construction land is often negative. Therefore, if the site of program is selected without caution, the ecological value of the land will easily decline, which will lead to the collapse of the ecosystem and thereafter irreversible environmental loss. So we suggest that when selecting project location, especially industrial or residential land, areas with low ecological services value should be chosen preferentially, such as wasteland, while the occupation of land with high ecological value is supposed to be minimized, such as forest and water area, which is vital for ecological balance.

2. Ecological services cost compensation

If the completion of the project requires excessive expropriation of land with high ecological services value, it is necessary to give some compensation. Under normal circumstances, the constructed urban land has sustainable economic benefits, thus we suggest a certain proportion of such profits which should be allocated to pollution control and ecological and biological system recovery on a regular basis, so as to alleviate the loss caused by the cost of ecological services of the project.

3. Optimize the project facilities

The development of science and technology makes it possible to balance human activities and ecological operation. For example, the existing urban "sponge" surface structure can effectively conserve water, and the design of skyscrapers reduces the occupation. The optimization of project facilities, such as optimizing construction materials, can reduce the impact on local ecology as much as possible ensuring the effectiveness of project at the same time, thus reducing the cost of ecological services.

5 Modification of the Model

According to the ecosystem service value model constructed above, for a piece of land, the ecosystem service value is equal to the product of the ecosystem service value per unit area corresponding to the land type and the area of the land type. Therefore, for the above model, the land area is an observable specific variable, and the corresponding unit area ecological service value is a parameter that changes with time. The specific changes are as follows.

5.1 Valuation of Product Services

For an ecosystem with a stable structure and function, the number of producers in the whole system will maintain a dynamic balance with the number of consumers and decomposers. If the surrounding climate does not change drastically, the output of the entire ecosystem will maintain a relatively stable output in the same time interval. Therefore, in general, the value of a product's product service does not change with time.

5.2 Valuation of Regulatory Services

Since the number of plants in a stable ecosystem generally does not change over time, soil retention, carbon sequestration, oxygen production, water conservation, and flood storage functions remain generally unchanged for the ecosystem. However, due to the expansion of human living environment and the need for industrial production, the air pollutant content and water pollution emissions have also increased dramatically. Therefore, the atmospheric environment purification function and water environment purification function of the ecosystem will also increase. It grows over time until it reaches the limits of the ecosystem's ability to purify air and water pollution. In addition, as the greenhouse effect continues to accumulate, the global average temperature continues to rise, which also accelerates the transpiration of plants and the evaporation of water surface, making the climate regulation function of ecosystems grow with time.

5.3 Valuation of Cultural Services

With the continuous improvement of people's income level and the gradual improvement of material quality of life, the proportion of cultural consumption in people's lives has also increased, and holiday tourism has become a popular way of leisure and consumption. The amount of consumption provided by people for the ornamental value and aesthetic value of natural landscapes has also increased, which has led to an increase in the value of cultural services in natural landscapes.

Reference

[1] Mar á R. Felipe-Lucia, Francisco A. Com ń, Javier Escalera-Reyes, A Framework for the Social Valuation of Ecosystem Services, Ambio, Vol. 44, No. 4 (May 2015)

[2] SHI Yangyang, LÜ Xiao, HUANG Xianjin, YU Miao, Arable Land Use Transitions and Its Response of Ecosystem Services Value Change in Jiangsu Coastal Areas. Journal of Natural Resources. J. Vol.32. No.6, Jun..,2017

[3] DONG Jiahua, SHU Tingfei, XIE Hui, BAO Cunkuan, Calculative Method for Ecosystem Services Values of Urban Constructive Lands and Its Application. Journal of Tong Ji University (Natural Science). J. Vol.35, No.5, May.,2007;

[4] OUYANG Zhiyun, ZHU Chunquan, YANG Guangbin, XU Weihua, ZHENG Hua, Zhangyan, Xiaoyi, Gross Ecosystem Product: Concept, Accounting Framework and Case Study. Acta Ecologica Sinica. J. Vol.33, N o.21, Nov.,2013;

[5] CAO Yingui, ZHOU Wei, YUAN Chun, Regional Ecosystem Service Value Based on Landuse Change. Bulletin of Soiland Water Conservation. J. Vol.30, No.4, Aug.,2010

[6] XIE Gaodi, ZHANG Caixia, ZHANG Changsun, XIAO Yu, LU Chunxia, The Value of Ecosystem Services in China. Resource Science. J. Vol.37, No.9, Sept.,2015

[7] XIE Gaodi, LU Chunxia, CHENG Shengkui, Progress in Evaluating the Global Ecosystem Services. Resource Science. J. Vol.23, No.6, Nov.,2001

[8] XIE Gaodi, ZHEN Lin, LU Chunxia, XIAO Yu, CHEN Cao, Expert Knowledge Based Valuation Method of Ecosystem Services in China. Journal of Natural Resources. J. Vol.23. No.5, Sept.,2008

[9] GUO Lingxia, ZHAO Wei, WANG Lina, ZHANG Lili, Study on Regional Ecological Service Value Change Based on the Pattern of Land Consolidation: A Case of Hubei Province. Areal Research and Development. J. Vol.31, No.6, Dec.,2012

[10] PENG Wenfu, ZHOU Jieming, YANG Cunjian, ZHAO Jingfeng, LUO Huailiang, Reserch on Ecosystem Service Values Based on Landuse Change in Sichuan Province.Resources and Environment in the Yangtze Basin. J. Vol.23, No.7, Jul., 2014

[11] LIU Jinzhen, Reaserchs on Impact Asssesment of Interbasin Transfer Projects on Terrestiral Environment – In the Aase of Hanjiang-to-Weihe River Project. M. Wuhan: Central China Normal University, 2009

[12] http://www.stats.gov.cn/tjsj/ndsj/

[13] http://data.stats.gov.cn/easyquery.htm?cn=C01