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T3 ________________	Problem Chosen	F3 ________________
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Summary Sheet.

Emergy: The Bridge between Ecosystem Services and Currency

With the development of economy, the impact of land use projects on ecosystem services has been widely concerned. The traditional economic system can no longer satisfy the evaluation of ecosystem services. In this context, this paper create an ecological services valuation model to understand the true economic costs of land use projects when ecosystem services are considered.

In task1, we refer to previous studies such as The Millennium Ecosystem Assessment (MA) and The Economics of Ecosystems and Biodiversity (TEEB) select 12 indicators from four categories of ecosystem services and study five basic ecosystems: forest, grassland, cropland, desert and wetland. Then, according to the principle formula of emergy valuation, we get the emergy calculation model of 12 indicators, and connect the non-monetary and monetary accounting systems through the emergy to money ratio, and get the real economic cost calculation model of ecosystem services.

In task2, we choose Guangdong province and Zhanjiang Mangrove as large project and small project for research. We use our emergy calculation model to calculate the total emergy of each indicator of Guangdong province and Zhanjiang Mangrove. Then the real economic cost per unit area of the five basic ecosystems is obtained using fuzzy comprehensive evaluation (FCE) method, and we analyze the ecological degradation of Zhanjiang mangrove forest caused by the newly built Maoming-Zhanjiang railway.

In task3 and 4, through the analysis and evaluation of a mangrove project In Guangdong and Zhanjiang, we calculate the cost of ecosystem degradation and test the actual effectiveness of our model, land use project planners and managers can obtain some suggestions from our results.

In task5, we assume that the emergy to money ratio and transformity need to be changed over time. Meanwhile, the experts' comments on five ecological values in expert judgment matrix need to be updated over time.

Finally, we analyze the sensitivity of our model by testing the fluctuation of the energy indicator in Guangdong, and discuss the strengths and weaknesses of our model.

Key words: emergy, emergy valuation, ecosystem services

Contents

1 Introduction

1.1 Background

With the rapid development of economy, many human behaviors are changing the ecosystem, which may limit or remove the ecosystem services. Ecosystem services are the many benefits and assets that humans receive freely from our natural environment and a fully functioning ecosystem. The Millennium Ecosystem Assessment (MA) delineated the four categories of ecosystem services: provisioning, regulating, supporting and cultural. [1] When humans alter ecosystems through behavior, such as changing land-use patterns, these effects may seem trivial, but they add up to impacts on biodiversity and environmental degradation.

At present, economic theory tends to ignore its impact on the biosphere, and most land use projects do not consider the impact of, or account for changes to, ecosystem services. But the environment is facing the terrible consequences of degradation, such as soil erosion, soil salinization, Water degradation, Biodiversity loss and so on.

In order to analyze the cost-benefit of land use development projects, and to enable the land use project planners and managers to make correct decisions, we need to include ecosystem services in the cost of land use projects to understand the real economic cost of land use projects.

1.2 Our work

- In order to calculate the degradation cost of the ecosystem, we establish an ecological value assessment model based an ecological services valuation model. To simplify the model, we select five major ecosystems and 12 important indicators for emergy calculation, and then estimated the emergy of the entire ecosystem. When we consider the land development project, we can calculate the cost of the degradation of the ecosystem by the difference in emergy before and after land development.
- After that, we apply our model to Guangdong and Zhanjiang, and found that both of them were roughly consistent with the actual situation, which showed that our model was reasonable.
- Then, we conclude that for land use project planners and managers, if the economic benefits brought by the project are much larger than the cost of environmental degradation, the project can be considered to implement.
- Finally, we have carried on the sensitivity analysis and the Strengths and Weaknesses summary to our model, and has the clear direction to the future consummation and the optimization.

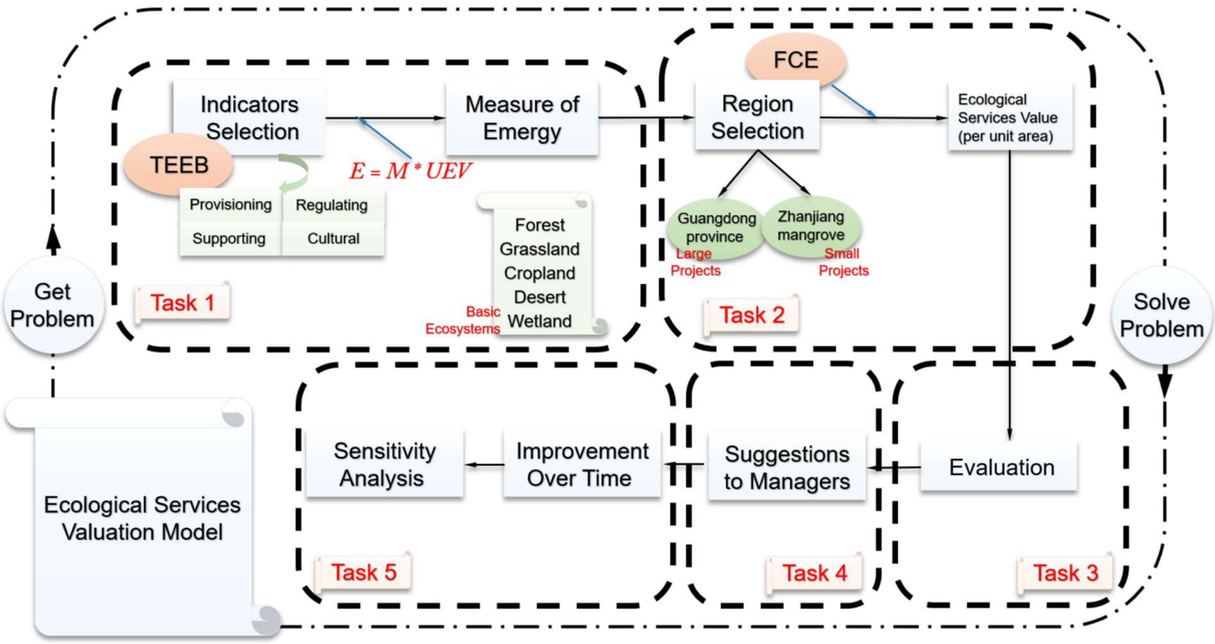

Fig.1 Technology route for the creation of our paper

2 Assumption and Symbol Explanation

2.1 Assumption

In order to simplify the complex situation of real life, we made the following assumptions before establishing the model.

- The ecosystem we study has limited resources.
- Before the implementation of large projects or small projects, the ecosystem has been in a stable state without significant disaster impact and significant ecosystem evolution.
- The ecosystem service valuation of each indicators within the same ecosystem is uniform, that is, when calculating the total emergy of the same ecosystem, we only consider the area or volume occupied by the indicator.
- The emergy to money ratio is constant over a short period of time.

2.2 Symbol Explanation

We list the symbols used in this paper in Table 1.

Tab.1 Symbol explanation

Symbol	Definition
E_{pf}	Emergy of food
E_{pw}	Emergy of water
E_{pe}	Emergy of energy
E_{rwr}	Emergy of water regulation
E_{rwp}	Emergy of water purification
E_{rap}	Emergy of air purification
E_{rmsf}	Emergy of maintaining soil fertility
E_{rep}	Emergy of erosion prevention
E_{scn}	Emergy of carbon sequestration & NPP
E_{sb}	Emergy of biodiversity
E_{cre}	Emergy of recreation and eco-tourism

3 Ecosystem services

Based on our assumptions, we follow the general classification criteria of The Economics of Ecosystems and Biodiversity (TEEB), but combined with the actual situation made some adjustments[2]. We selecte 12 suitable ecosystem service indicators from the four major categories of provisioning, regulating, supporting and cultural. As is shown in figure 1.

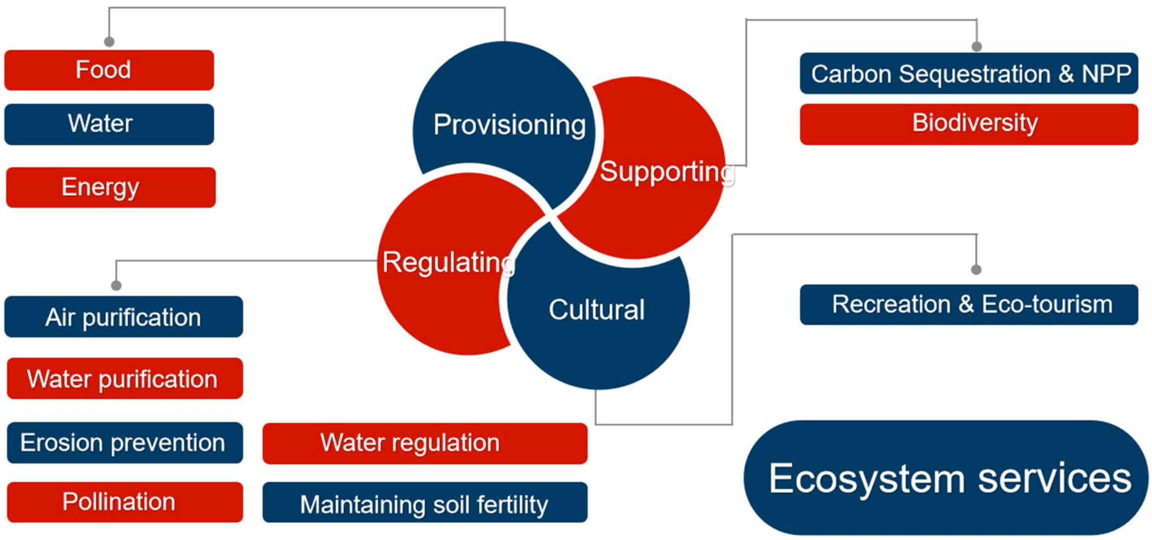

Fig.2 The 12 indicators of ecosystem services

An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system.

According to the 12 indicators above, we select five major natural ecosystems for research, then construct an ecosystem service classification system. These natural ecosystems are forest, grassland, cropland, wetland and desert.

These ecosystems and their corresponding ecosystem services are shown in table 2.

Tab.2 The five ecosystems and their corresponding indicators

		Forest	Grassland	Cropland	Desert	Wetland
Provisioning	Food			√		
	Water					√
	Energy					√
Regulating	Air purification	√	√	√		√
	Water conservation	√	√		√	√
	Water purification	√	√			√
	Erosion prevention	√	√			√
	Maintaining soil fertility	√	√	√		
	Pollination	√	√	√		
Supporting	Carbon Sequestration & NPP	√	√		√	√
	Biodiversity	√	√	√	√	√
Cultural	Recreation & Eco-tourism	√	√	√	√	√

Referring to previous research, we decide to use the emergy valuation. Here we explain some nouns relating to emergy.

- The definition of **emergy**[3]

Amount of energy of one form that is used in transformations directly and indirectly to make a product or service. The unit of emergy is the emjoule or emergy joule. Using emergy, sunlight, fuel, electricity, and human service can be put on a common basis by expressing each of them in the emjoules of solar energy that is required to produce them. If solar emergy is the baseline, then the results are solar emjoules (abbreviated sej). Although other baselines have been used, such as coal emjoules or electrical emjoules, in most cases emergy data are given in solar emjoules.

- The definition of **emergy valuation**

Emergy valuation takes energy quality as the measurement standard, with the help of transformity, converts different types and different qualities of energy in social economic system or ecological environment system into energy value of unified standard scale, so as to measure and analyze the real value and contribution to the whole system by comprehensive analysis. [4] The starting point of the emergy valuation is to regard the system as a continuous input of various energy and substances from the outside to maintain the system. The quantity and mass of various energy or substances from the outside can be converted into a unified emergy unit solar emjoules (sej) through the transformity. Then the system is described and analyzed with the emergy as the common unit. Therefore, emergy valuation is a method based on the evaluation of various inputs of the system, which is called donor side. [5]

- The definition of **transformity**

Emergy input per unit of available energy output. The solar transformity of the sunlight absorbed by the earth is 1.0 by definition.

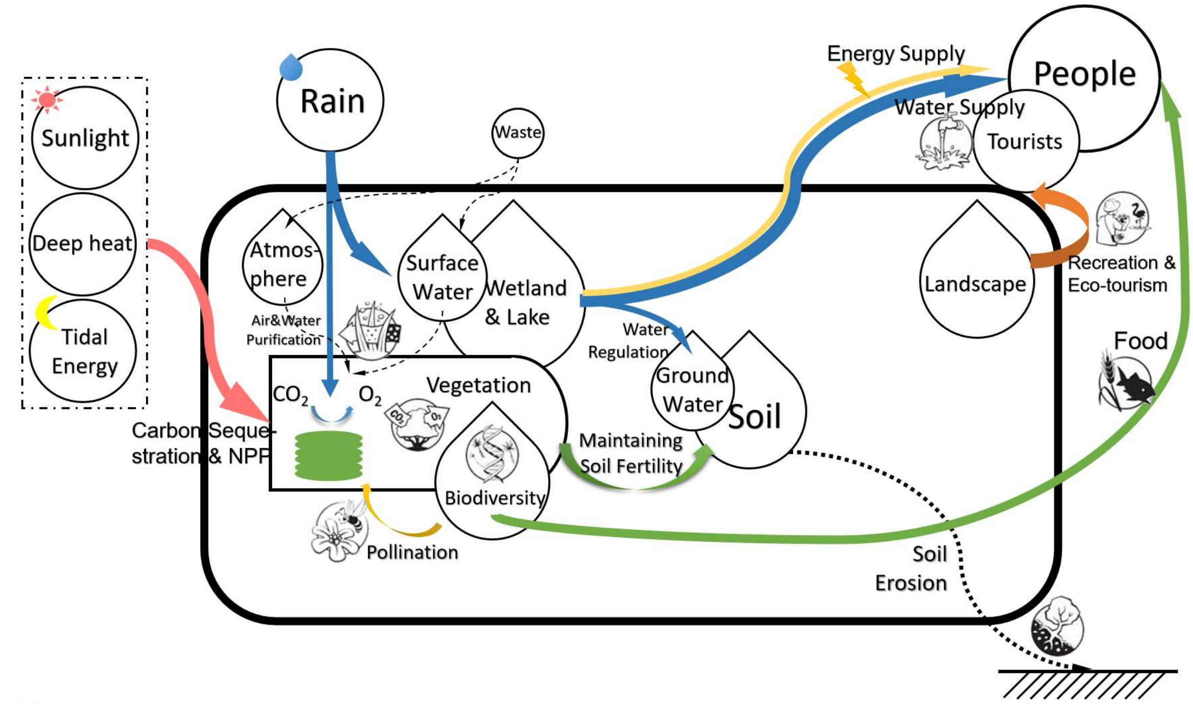

Fig.3 The emergy diagram of various ecosystem services

By calculating the emergy of the 12 indicator our given s, we calculate the sum of the emergy and calculate the monetary value of the emergy by **the emergy to money ratio**, which can be used to measure the value of ecosystem services in a region.

The principle of the emergy valuation is[6]:

$$E = Q \cdot UEV \tag{1}$$

In formula (1), E represents the emergy of an indicator, Q represents the quality of the indicator, and UEV represents the transformity.

Drawing on previous studies, we simplify some of these indicators based on our assumptions, and evaluate the ecosystem services valuation of the indicators we selected.

3.1 Provisioning services

3.1.1 Emergy of food

Ecosystems provide the conditions for growing food, mainly from cropland.

$$E_{pf} = S \cdot Y \cdot UEV_f \tag{2}$$

In formula (2), S represents the total area of cropland(hm2), Y represents the yield per unit area of cropland(kg), UEV_f represents the specific emergy of food supply (sej/g).

3.1.2 Emergy of water

Ecosystems play an important role in the global water cycle, regulating runoff and purifying water. Wetland and forests can increase the amount of water available. Ecosystems provide the conditions for growing food, mainly from cropland.

$$E_{pw} = M \cdot \rho \cdot UEV_w \tag{3}$$

In formula (3), M represents the total ecosystem water supply (m3), ρ represents the density of water (kg/m3) , UEV_w represents the specific emergy of water supply (sej/g).

3.1.3 Emergy of energy

Wetlands in the ecosystem can develop hydropower.

$$E_{pe} = H \cdot UEV_{\hbar} \tag{4}$$

In formula (4), H represents the total hydropower generation in this region (kWh), $UEV_{\hbar}$ represents is the specific emergy of energy supply (sej/kWh)

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3.2 Regulating services

3.2.1 Emergy of water regulation

The vegetation in the ecosystem can intercept rainwater, the dead branches and leaves can absorb water, and the soil can store precipitation.

$$E_{rwr} = R \cdot \rho \cdot \mathrm{S} \cdot \mathrm{k} \cdot UEV_{gw} \tag{5}$$

In formula (5), R represents the total precipitation in this region (mm), ρ represents the density of water (kg·m-3), S represents the total area of this ecosystem (km2), k represents the infiltration coefficient of the region, UEV_{gw} represents the specific emergy of groundwater(sej·g-1).

3.2.2 Emergy of water purification

The root system of aquatic plants in the ecological system is developed and grows fast. It can absorb harmful substances in water, filter microorganisms, release oxygen and minerals, so as to improve water and purify water.

$$E_{rwp} = A \cdot M \cdot DALY_w \cdot \tau \tag{6}$$

In formula (6), E_{rwp} represents the emergy required to reduce harmful effects on human health (sej), A represents the ability to absorb water pollutants, M represents the water storage of this region (kg), $DALY_w$ represents the disability adjusted life year of one individual caused by water pollutant (cap yr/kg), τ represents the total area emergy used per capicity (sej/cap).

3.2.3 Emergy of air purification

Green plants in an ecosystem can stop dust, absorb carbon dioxide and release oxygen through photosynthesis, and absorb some of the toxic gases in the air.

$$E_{rap} = A \cdot M \cdot DALY_a \cdot \tau \tag{7}$$

In formula (7), E_{rap} represents the emergy required to reduce harmful effects on human health (sej), A represents the ability to absorb air pollutants, M represents the air volume of this region (l), $DALY_w$ represents the disability adjusted life year of one individual caused by air pollutant (cap yr/kg), τ represents the total area emergy used per capicity (sej/cap).

3.2.4 Emergy of maintaining soil fertility

In an ecosystem, vegetation cover prevents soil erosion, and a well-functioning ecosystem provides the soil with the nutrients it needs to support plant growth and increase soil fertility.

$$E_{rmsf} = E_{mRE} \cdot k_1 \cdot k_2 \tag{8}$$

In formula (8), E_{mRE} represents the emergy required by soil organic matter increase (sej), k_1 represents the ratio of forest litter to the biomass (g/g, %), k_2 represents the proportion of litter containing carbon to litter (g/g, %).

3.2.5 Emergy of erosion prevention

In the ecosystem, the surface vegetation cover can reduce the soil erosion, and some plants can use their developed root system to protect the soil against wind and rain erosion.

$$E_{rep} = G \cdot UEV_s \tag{9}$$

In formula (9), G represents the soil retention due to forest cover (g). UEV_s represents the transformity of soil (sej/g).

3.3 Supporting services

3.3.1 Emergy of carbon sequestration & NPP

Ecosystems regulate the global climate by storing and sequestering greenhouse gases.As plants grow, they absorb carbon dioxide from the atmosphere and effectively trap it in their tissues. Carbon is stored this way.

NPP refers to the amount of energy fixed by plant photosynthesis, which can be used for plant growth and reproduction after deducting the part consumed by plant respiration. To avoid double counting, we only use sunlight, tidal energy and deep heat.

$$E_{scn} = E_{sun} + E_{tidal} + E_{heat} \tag{10}$$

In formula (10), E_{scn} represents the emergy required by NPP increase in this region (sej), E_{sun} represents the sunlight, E_{tidal} represents the tidal energy, E_{he} represents the deep heat.

3.3.2 Emergy of biodiversity

The ecosystem provides a variety of living environments for animals and plants to adapt to the habitat of different species. Species depend on each other and restrict each other.

$$E_{sb} = GEB_d \cdot T \cdot S \cdot \frac{N_1}{N_0} \tag{11}$$

In formula (11), E_{sb} represents the emergy required by biodiversity conservation (sej), GEB_d represents the geobiosphere emergy baseline (GEB) (sej/yr), T represents the average turnover time of species (yr), S represents the area of this region (hm2). N_1 represents the species density in this region (No./ha), N_0 represents the number of global species.

3.4 Cultural services

3.4.1 Emergy of recreation and eco-tourism

Some unique landscapes in the ecosystem play an important role in tourism, which can provide considerable economic benefits.

$$E_{cre} = I_T \cdot E_m R \tag{12}$$

In formula (12), E_{cre} represents the emergy required by recreation and eco-tourism (sej), I_T represents the income brought by recreation and eco-tourism ($), $E_m R$ represents the emergy to money ratio (sej/$).

4 Applications in different size areas

4.1 Application in Guangdong

Guangdong province, located in the south of the Chinese mainland and the east Asian monsoon region, is one of the regions with the most abundant light, heat and water resources in China. The main ecosystems of Guangdong province are forests, grasslands, cropland and wetland.

Fig.4 The geographical location of Guangdong province

4.1.1 The emergy of each indictor

By applying our model to Guangdong province, China, we can calculate the corresponding emergy of 12 indicators in the ecosystem of Guangdong, as shown in table 3.

Tab.3 Emergy analysis of ecosystem services value in Guangdong

Item		Raw data	UEV[11] (sej • unit^{-1})	Total emergy (sej • a^{-1})
Provisioning	Food	Grain output[7] 440898t		1.22×10^{19}
	Water	The amount of food supply[8] $V=4.35\times10^{14}m^3$	7.01×10^{3}	5.72×10^{20}
	Energy	Hydropower generation $H=1.11\times10^{17}J$	6.28×10^{4}	8.94×10^{21}
Regulating	Air purification	Disability-adjusted life years $DALY_A=7.00\times10^{-4}$		1.73×10^{21}
	Water regulation	Rainfall precipitation 2357.6mm	2.23×10^{5}	5.65×10^{19}
		Permeability $k=1.50\times10^{-3}cm/s$[9]		
	Water purification	Disability-adjusted life years $DALY_W=2.88\times10^{-1}$		1.94×10^{21}
		Average turnaround time 12.5years		
	Erosion prevention	Natural erosion area[10] $14781.05cm^2$	4.42×10^{6}	1.91×10^{20}
	Maintaining soil fertility	Average plant litter $3.62mg \cdot hm^{-2} \cdot year^{-1}$ $k_1=25$, $k_2=50$		1.04×10^{20}
Supporting	Carbon Sequestration & NPP	Sunlight $1.60\times10^{18}J$	1	4.98×10^{18}
		Deep heat $2.07\times10^{4}J$	4.90×10^{3}	
		Tidal energy $7.56\times10^{13}J$	3.09×10^{4}	
	Biodiversity			4.80×10^{20}
Cultural	Recreation & Eco-tourism	Total output value $1.29\times10^{11}$$		2.68×10^{20}

Then, we use the pie chart to intuitively show the proportion of emergy corresponding to the 12 indicators, as shown in figure 5.

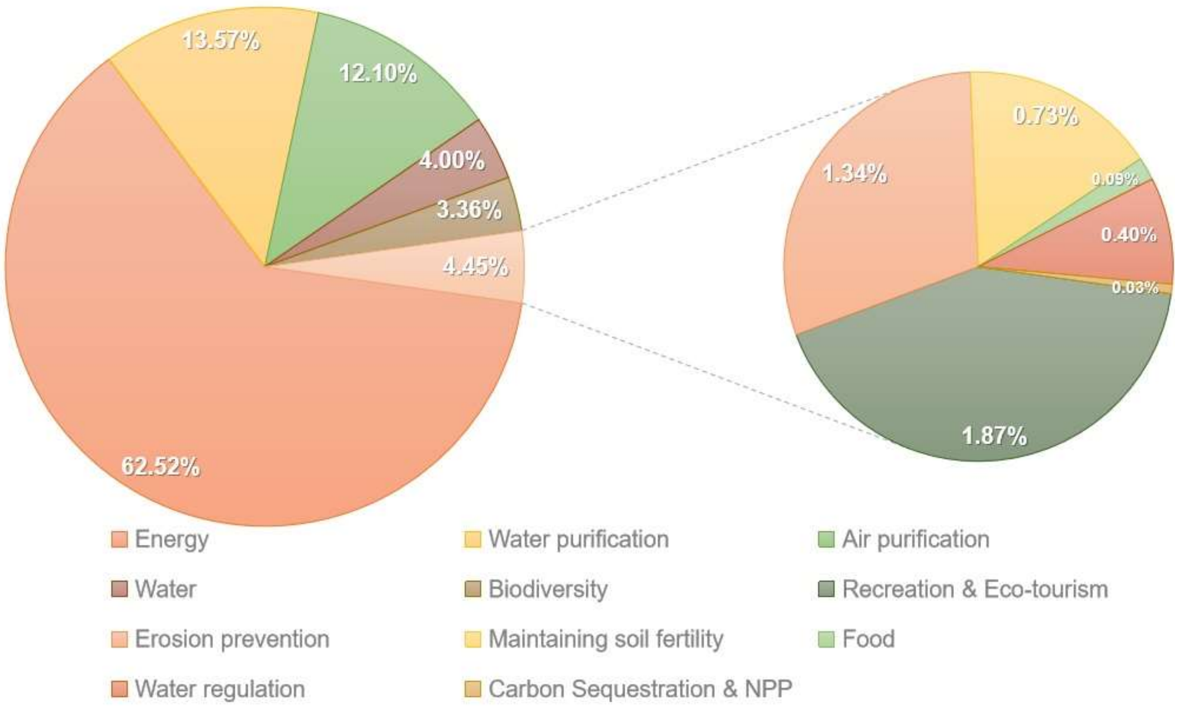

Fig.5 The emergy proportion of the 12 indicators in Guangdong

According to figure 5, we can find that energy supply contributes the most to the ecosystem service value of Guangdong province, accounting for 62%, followed by water purification and air purification, accounting for 25%.

Energy supply accounts for a large proportion, because Guangdong has a large population and a high level of economic development, so the demand for electricity is very high. In addition, Guangdong is one of the regions with the most abundant light, heat and water resources in China and is committed to developing clean energy, which requires the services provided by the ecosystem.

Guangdong province is located in the east Asian monsoon region, and its climate is mainly subtropical monsoon climate and temperate monsoon climate. Wetlands and forests account for a large proportion of its total area, and the energy value per unit area of the wetland ecosystem is large. Therefore, among the value of ecosystem services, the value of services provided by wetlands is relatively large.

4.1.2 The economic value of ecological services per unit area of each ecosystem

We use fuzzy comprehensive evaluation (FCE) method[12] to evaluate the unit value of four ecosystem services in Guangdong province. According to the emergy of the 12 indicators calculated in table 2, and considering the actual situation, we obtained the expert judgment matrix of four ecological services, and assigned weights to the ecological types corresponding to each indicator.

We first gain factor set U = {forest, grassland and cropland, wetland}.

Then we get a set of comments for each ecological service, which constitutes the expert judgment matrix R.

According to the emergy data of each indicators obtained previously, the energy value set A of the unit area of the ecosystem is obtained, and the energy value data of the unit area of the four major ecosystems (sej/hm2) is calculated by substituting the fuzzy matrix judgment formula.

First of all, we analyze Criteria Judging matrix of the regulating services.

$$A_1 = (3.7598 \quad 4.0001 \quad 2.2543 \quad 1.6526 \quad 1.0475\ )^T * 10^{13}$$

$$R_{1=} \begin{pmatrix} 0.7 & 0.1 & 0.1 & 0.1 \\ 0.3 & 0.2 & 0 & 0.5 \\ 0.3 & 0.1 & 0 & 0.6 \\ 0.3 & 0.6 & 0 & 0.1 \\ 0.4 & 0.3 & 0.3 & 0 \end{pmatrix}$$

Second, we analyze Criteria Judging matrix of the supporting services.

$$A_2 = (0.9915 \quad 0.5036)^T * 10^{13}$$

$$R_{2=} \begin{pmatrix} 0.5 & 0.2 & 0.1 & 0.2 \\ 0.5 & 0.1 & 0.1 & 0.3 \end{pmatrix}$$

Finally, we analyze Criteria Judging matrix of the cultural services.

$$A_3 = 0.0029 * 10^{13}$$

$$R_{2=}(0.3\ 0.2\ \ 0.2\ 0.3)$$

We get the economic value of ecological services per unit area of each ecosystem through the emergy to money ratio, as shown in table 4.

Tab.4 The economic value of ecological services per unit area of each ecosystem

	Forest	Grassland	Cropland	Wetland
Food	$0	$0	$2,288	$0
Water	$0	$0	$0	$564,735
Energy	$0	$0	$0	$8,883,714
Air purification	$412,549	$58,936	$58,936	$58,936
Water regulation	$7,052	$4,705	$0	$11,757
Water purification	$242,232	$80,744	$0	$484,465
Erosion prevention	$23,849	$47,698	$0	$7,951
Maintaining soil fertility	$14,174	$10,628	$10,628	$0
Carbon Sequestration & NPP	$1,036	$413	$206	$413
Biodiversity	$81,772	$16,355	$16,355	$49,061
Recreation & Eco-tourism	$27,392	$18,261	$18,261	$27,392
Total	$810,162	$237,768	$106,688	$10,090,242

In order to more intuitively show the proportion of unit value of each different ecological service indicator in the four ecosystems, we have drawn the following four pie charts.

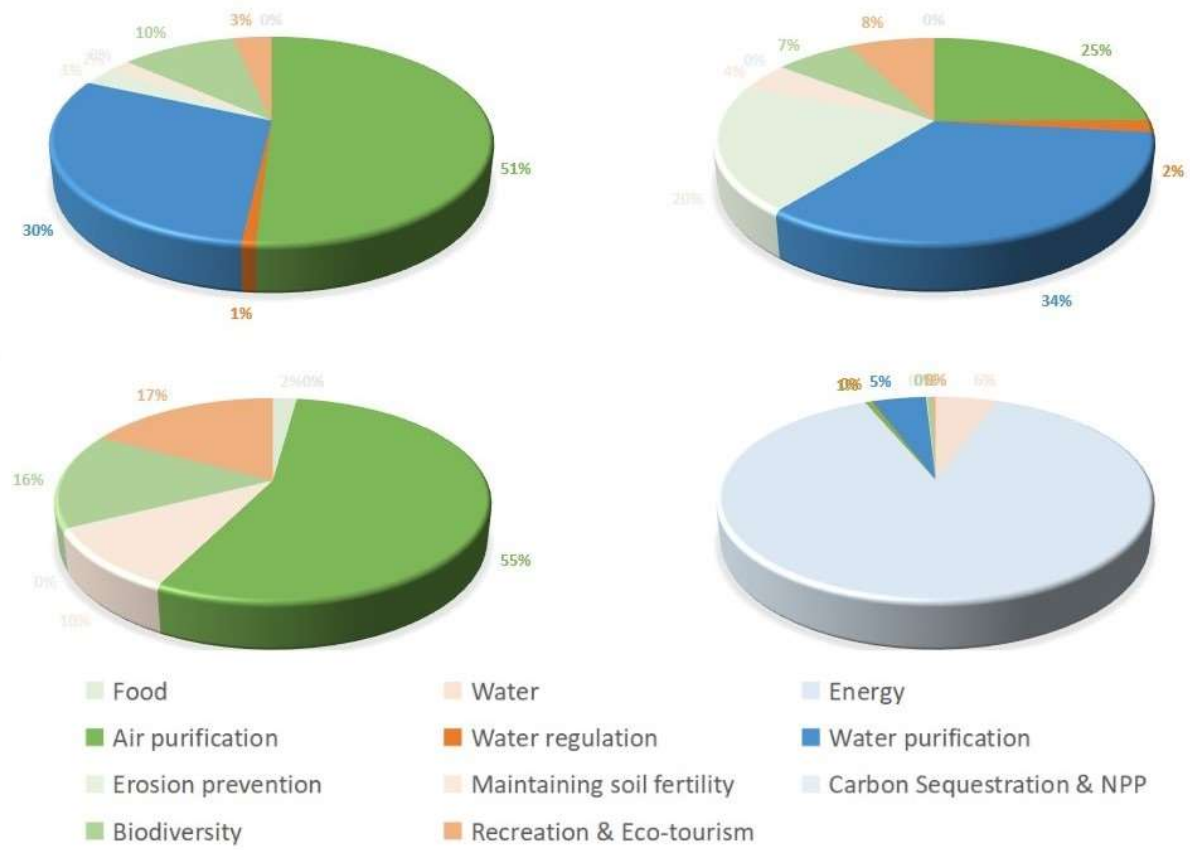

Fig.6 The proportion of unit value of each indicator in the four ecosystems

We analyze figure 6 as follows.

- Forest, grassland and cropland take up a large proportion of the value generated by air purification, among which forest takes up the largest proportion. This is because there are most plants in the forest, which can prevent dust, absorb carbon dioxide and release oxygen through photosynthesis, and also absorb some toxic gases in the air.
- Forest and grassland also account for a large proportion of the value of water purification, because the root system of some plants can absorb harmful substances in water, filter microorganisms, release oxygen and minerals, so as to improve the water body and play a role in water purification.
- The most important ecosystem service value of wetlands comes from energy, which is provided by hydroelectric power. Compared with the remaining three ecosystems, the other value that wetlands can provide is small.

4.2 Application in Zhanjiang

Zhanjiang mangrove forest, located in the southernmost part of the Chinese mainland, is a national nature reserve in China. Zhanjiang is located in the transition zone from the tropical monsoon zone to the subtropical monsoon zone, which is greatly affected by the monsoon climate and Marine climate. The peninsula where Zhanjiang is located is relatively flat with complicated coastline, numerous offshore islands and abundant natural resources.

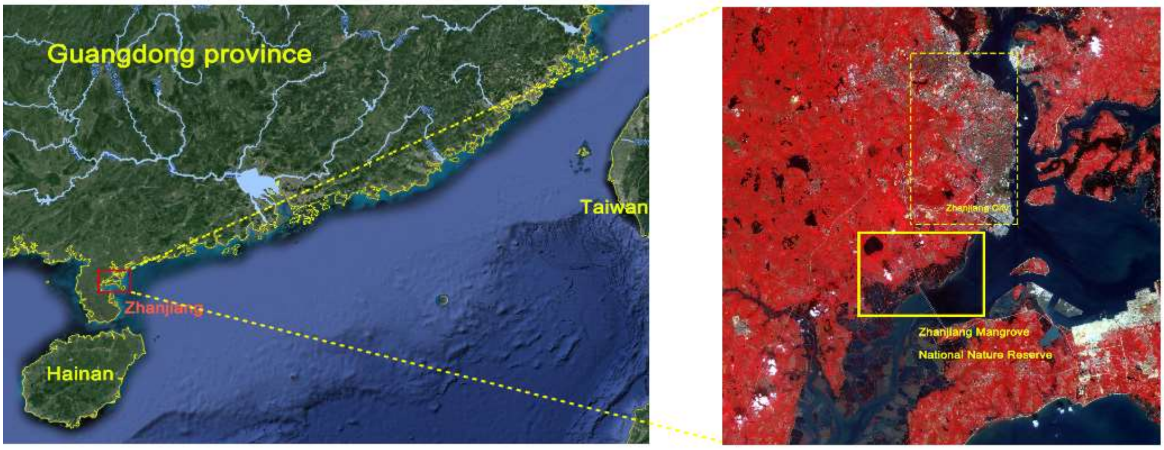

Fig.7 The geographical location of Zhanjiang Mangrove National Nature Reserve[13][14]

4.2.1 The emergy of each indictor

Similar to the calculation method of ecosystem service emergy in Guangdong province, we collect relevant data from Zhanjiang statistical yearbook and various literature, then calculate emergy shown in table 5.

Tab.5 The emergy of each indicator in Zhanjiang[15]

Indicators	Emergy
Food	1.39×10^{16}
Water purification	1.20×10^{16}
Water regulation	6.08×10^{15}
Biodiversity	5.42×10^{15}
Recreation & Eco-tourism	4.72×10^{15}
Carbon Sequestration & NPP	2.66×10^{15}
Water	1.95×10^{15}
Air purification	1.51×10^{15}
Maintaining soil fertility	1.17×10^{15}
Energy	7.26×10^{14}
Erosion prevention	4.13×10^{12}

In order to more intuitively show the proportion of emergy of each indicator, we draw figure 8.

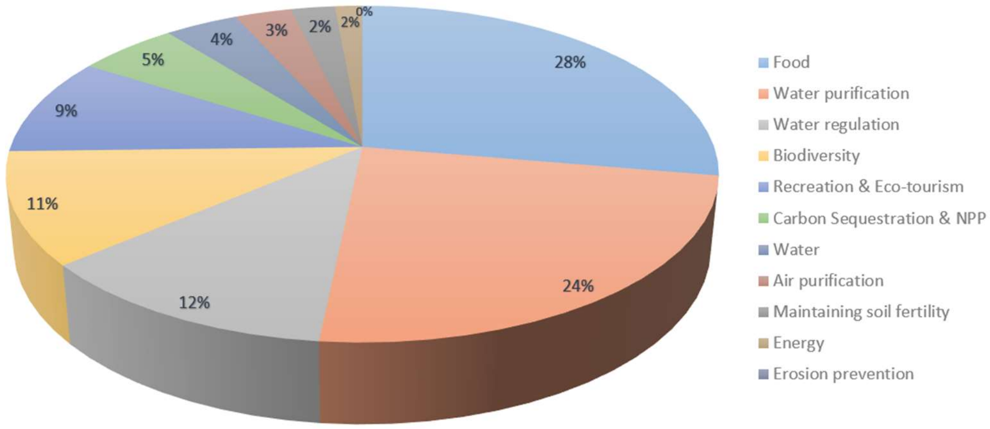

Fig.8 The proportion of emergy of each indicator

We analyze figure 7 as follows.

- Zhanjiang mangrove swamps originate from natural coastal swamps and provide a lot of food for human beings and other living things through the development of agriculture and fishery.
- Mangrove swamps play an important role in water storage, river runoff regulation, groundwater recharge and regional water balance.
- Marsh wetland can slow down the flow of water, help the precipitation and removal of toxins and impurities, some of the aquatic plants can effectively absorb toxic substances in water, purification water quality.
- Mangrove swamp not only has mangrove this precious rare plant, and plankton is rich, habitat for a large number of fish, but also for wild animals, especially some rare or endangered wild animals such as black-faced spoonbill provides a good habitat.
- It is the breeding, habitat, migration and wintering place of birds and amphibians, which plays an important role in protecting biodiversity.

4.2.2 The cost of Zhanjiang ecosystem degradation

$$T_C = A \cdot U \tag{13}$$

In formula (13), U represents the cost per unit area, (the data of U comes from table 5, A represents the total area of the ecosystem, T_C represents the total cost of ecosystem degradation.

According to formula (13), we can calculate the total cost of the destruction of Zhanjiang Mangrove National Nature Reserve by building the railway, is also the ecological cost of Zhanjiang Mangrove National Nature Reserve. As shown in table 1.

Tab.6 The cost of Zhanjiang ecosystem degradation

Total area of Zhanjiang Mangrove National Nature Reserve	9258 hm^2
Unit land price of Zhanjiang ecological wetland	2659.75 dollars/hm^2
The area damaged by railway construction	9100 m^3
Ecological cost	$24203.62

The construction of the railway in Zhanjiang will indeed have an impact on the local ecology, but it will also greatly promote the development of transportation, thus facilitating more tourists to visit the mangrove forest in Zhanjiang, increasing the number of tourists and improving the value brought by tourism to Zhanjiang.

Therefore, even though the construction of railway in Zhanjiang will have a certain impact on the ecosystem, this impact is very small. According to our model, the cost is $24203.62, indicating that the impact is indeed very small.

The project land will destroy the vegetation near the surface of the protected area, so it will affect the biodiversity, water purification capacity and other emergy.

The railway in the Zhanjiang mangrove nature reserve is not a habitat or breeding area for birds. Therefore, no matter during the construction or operation of the railway, there is no serious impact on the biological activities and the overall environment of the reserve.

The construction of the railway will damage the natural landscape to a certain extent, but after the railway is completed, more tourists will be able to enjoy the local landscape and attract more tourists to visit, which will bring more value than the cost of the mangrove ecological degradation in Zhanjiang.[16]

5 Evaluation of our model

We apply our model to Guangdong province. If we plan a big project in Guangdong province, it will be a big project.

For example, we expropriate 1000 hm^2 of forest land, 200 hm^2 of farmland land, 300 hm^2 of grassland land and 50 hm^2 of wetland land in Guangdong province.

$$T_C = A_f \cdot U_f + A_g \cdot U_g + A_c \cdot U_c + A_w \cdot U_w \tag{14}$$

In formula (14), U represents the cost per unit area, (the data of U comes from table 3, A represents the total area of the ecosystem, T_C represents the total cost of ecosystem degradation.

According to formula (14), we can get the impact of land acquisition on the ecology, that is, the cost of ecosystem degradation is \$1.39×109. As shown in table 7

Tab.7 The cost of ecosystem degradation

Ecosystem	U(dollars/hm^2)	A(hm^2)	Total cost(dollars)
Forest	8.10×10^5	1000	8.10×10^8
Grassland	2.38×10^5	200	4.76×10^7
Cropland	1.07×10^5	300	3.21×10^7
Wetland	1.01×10^7	50	5.05×10^8

Based on our model, we can calculate the general ecological cost, so land use project planners and managers such as mayor, land and resources bureau chief, they can reference for land development project decision-making using our model calculated the ecological degradation of costs, combined with the expected return on the project, considering whether to put into the project.

If the benefits of the project are much greater than the costs of ecosystem degradation, for example, the difference of one order of magnitude or more, then the project can be considered for implementation. If the difference is not particularly large, then it is inappropriate.

Because the indicators we consider are not comprehensive, and the emergy of some indicators will constantly change, and some data are not particularly accurate, but we have referred to a lot of literature and data, and the indicators we consider are very important and occupy a very large proportion, so they are of certain reference value for planners and managers.

6 Improvement of our model over time

Based on previous assumptions, the emergy to money ratio and transformity of some indicators are constant in a short time, but the transformity of each indicator will change with time and the change of ecosystem in the coming decades.

According to the current social development trend, with the gradual development and use of clean energy and the low-carbon economic transformation in recent years through consultation and cooperation among various countries, we predict that the emergy to money ratio of developed countries and some developing countries will gradually decrease.

At the same time, the ecological environmental value will be higher and higher in the future, which is reflected in our model that the transformation of each indicator will increase, so that the calculated ecosystem value per unit area will also increase. So what we need to do is adjust the transformation so that the calculated ecosystem valuation will be realistic.

Last but not least, with the passage of time, the ecosystem service ability and the physical properties of ecosystem may have a little change, reaction in our model, the fuzzy comprehensive evaluation method of expert judgment matrix, the experts' comments on five ecological index between may fluctuate over time, which affects us to five basic ecosystem value per unit area of empowerment.

7 Sensitivity test

We test the sensitivity of our model by estimating the fluctuation of the energy indicator.

We assume that the power generating capacity of hydropower stations in Guangdong province 1% of fluctuation, put it into the original model to analysis, we find that, after adjusting for the economic valuation of a unit area of the wetland ecosystem has also had a certain fluctuation, because energy release is more intense, it swings a little obvious, but the range will not affect our models and data results, our model sensitivity is wonderful.

As shown in table 8, it is the sensitivity analysis table after the fluctuation of the energy indicator.

Tab.8 Test our model in energy

Energy	Wetland unit area value	Proportion of each ecosystem
1%	0.8762%	0.0893%

8 Conclusion

We refer to the previous research, reference the MA and TEEB estimates the ecological value classification method of ecosystem services from four categories of chose 12 indicators, using emergy to estimate the ecosystem service value and studying the ecosystem service value of forest, grassland, cropland, desert and wetland.

Firstly, we selected Guangdong province for the study and calculated the proportion of total emergy of each ecosystem in the total ecosystem of Guangdong province. Based on the four distribution of ecosystem in Guangdong province, we calculated the various ecosystems emergy per unit area, due to the various indicators in various system of different proportion, we used fuzzy comprehensive evaluation(FCE) method to calculate the each indications proportion in the ecosystem, and connecting with the actual results to us fully analyzed and proved that our results with the actual situation of Guangdong province is more close to. We hypothesized that if we were to carry out a large land development project in Guangdong, we could use our model to calculate the cost of ecosystem degradation.

After that, we used emergy valuation on this small ecosystem of Zhanjiang Mangrove National Nature Reserve. By calculating the cost of the local environmental damage caused by the construction of the railway near the protected area, we found that the damage to the ecosystem caused by the construction of the railway in the mangrove ecological protection area of Zhanjiang is not very great, it is far less than the other economic benefits it brings, so the cost of environmental degradation is relatively low.

9 Strengths and Weaknesses

9.1 Strengths

- We use the emergy valuation, has the more obvious superiority. It is able to convert all the different categories of energy, resources, products and even such incomparable and difficult items as services and services into a unified dimension. We constantly optimize our model to make it as perfect as possible.
- We use the fuzzy comprehensive evaluation (FCE) method, so that the applicability of the model is strong, from small community-based projects to large national projects can be reasonably estimated. Our model is based on time. We can not only analyze the data in the past, but also predict the future.
- Our paper is very visual. All our calculations are graphed so that one can understand them at a glance.

9.2 Weaknesses

- We simplified the model quite a bit, so a lot of the indicators we didn't take into account, there's a big cost missing here.
- Of the 12 indicators we considered, we were unable to calculate the cost of pollination due to a lack of data.

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