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Evaluation of Eco-economy Harmony and Spatial Evolution of the Urban Agglomeration Area in The Great Pearl River Delta

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Abstract. Based on the land use data of the study area during 1990 to 2016, the coordination between ecological environment and economy was estimated according to the ESV (ecosystem services value) and EEH (eco-economy harmony) index. The results showed that large amount of farmland and forests were changed to construction land in the study area, due to the rapid urbanization and industrialization. The ESV showed an overall downward trend, the ESV in per hectare was decreased from 1554,000Yuan to 14513,000Yuan. The economic development speed was decreased from 1990 to 2016, the area with high GDP growth rate is changed from the core area of the pearl river delta to the periphery area. The ecology-economy relation in the study area experienced a transformation of “low grade coordination-low grade conflict -further conflict”. Shenzhen, Dongguan, Huizhou, Jiangmen, the central city of Foshan and Guangzhou became the most high-grade conflict areas.

1. Introduction
The ecosystem services value means the products and services provided by the ecosystem directly or indirectly [1]. With the development of industrialization and urbanization, large amount of farmland, forest, grassland and water area were occupied, which resulted to the damage of ecosystem service function. As an important index of if the economic and ecosystem is balanced, the ecological economic harmony evaluation has been hotspot in the area of sustainable development research[2]. At present, the main method of ecosystem evaluation included energy analysis[3-6], footprint analysis[7-9], input-output analysis[10], value estimating method[11-16]. Combined with the GIS and RS technology, based on the LUCC data, the ecological value equivalent method was used most widely, which was introduced by Costanza et al[17], and amended by Gaodi Xie[18].

2. Overview of the study area
The Great Pearl River Delta located in the longitude between112°22′Eand 115°25′E, latitude between 21°23′N and 24°23′N, including nine cities such as Guangzhou, Foshan, Shenzhen, Zhongshan, Huizhou, Dongguan, Zhuhai, Jiangmen, Zhaoqing, with its catchment area spreading 54764 square kilometers. With 59.98 billion residents, the GDP in Great Pearl River Delta was 67841.85 billion yuan in 2016, and the secondary industry and tertiary industry occupied a percentage of 42.2%and 56.0%. The Pearl River Delta urban agglomeration is one of the most dynamic economic zones in the Asian-Pacific region. It is one of the three regions with the most innovative capacity and the strongest comprehensive strength. Since the reform and opening up, the Pearl River Delta region...
has entered a period of rapid industrialization and urbanization, with rapid changes in land use pattern and threats to regional ecological security. The existing researches focused on the spatial-temporal distribution feature of the ecosystem services value \[^{[19,20]}\], but not on the ecological economic coordination. This paper calculated per unit area ecosystem service value and ecological economic coordination index of 34 districts or counties, analyzed the difference of the ecosystem services value and the ecosystem economic coordination between different area and time, for providing advices for the regional ecological construction and sustainable development.

3. Data resources and Research method

3.1. Date resources
The land use data was from the Satellite Center of MEP. The study area was divided into six categories of land use type, including farmland, forest, grassland, water area, construction land and unused land. The GDP data was from the Guangdong statistical yearbook.

3.2. Land use transition matrix
The land use transition matrix was used to reflect the transfer direction and amount between different land use types. It was realized by the ArcGIS10.1, Arc Toolbox>Analysis Tools > Overlay>Intersect.

3.3. The ecosystem services value
The ecosystem theory of Costanza \[^{[18]}\] and the coefficient of ecosystem service value of Gaodi Xie\[^{[19]}\] was used in this study, as shown in the table1.

\[
ESV = \sum_{k=1}^{n} (A_k \times V C_k)
\]

In the Formula, \(A_k\) is the area of \(k\) type, \(V C_k\) is the coefficient of ecosystem service value of \(k\).

| Forest | Grassland | Farmland | Water area | Unused land |
|--------|-----------|----------|------------|-------------|
| 3097   | 707.9     | 442.4    | 0          | 0           |
| 2389.1 | 796.4     | 787.5    | 407        | 0           |
| 2831.5 | 707.9     | 530.9    | 18033.2    | 26.5        |
| 3450.9 | 1725.5    | 1291.9   | 8.8        | 17.7        |
| 1159.2 | 1159.2    | 1451.2   | 16086.6    | 8.8         |
| 2884.6 | 964.5     | 628.2    | 2203.3     | 300.8       |
| 88.5   | 265.5     | 884.9    | 88.5       | 8.8         |
| 2300.6 | 44.2      | 88.5     | 0          | 0           |
| 1132.6 | 35.4      | 8.8      | 3840.2     | 8.8         |
| 19334  | 6406.5    | 6114.3   | 40676.4    | 371.4       |

3.4. Ecological and economic harmony
The EEH index was used to evaluate the coordination of ecosystem and economic. The formula is as follows.

\[
EEH = \frac{ES_{pr}}{GDP_{pr}}
\]

In the Formula, \(ES_{pr}\) is the rate of change of ESV, \(GDP_{pr}\) is the rate of change of ESV.

Considering the economic development speed in the study area is faster than the most areas in China, this study took the existing related research\[^{[12]}\] as reference, combining with the situation in the study area, the EEH index was divided into six grades, including high coordination (EEH>1) , moderate coordination (0.05< EEH <1), low coordination area (0< EEH<0.05), high conflict zone (EEH<-0.1) , moderate conflict(-0.1< EEH<-0.05) ,low conflict (-0.05< EEH<0).
4. Evaluation results and analysis

4.1. The characteristic of land use transition
From 1990 to 2016, forest was the main type of land in the study area, the percentage was 56.3% to 52%, displayed a decreasing tendency. Similarly, the farmland was decreasing from 29.4% to 21.3%. The construction land area increased from 2944.1 square kilometers to 9412.9 square kilometers, which increased from 5.5% to 17.5%. The area of water is fluctuating.

Table 2. The Area of Land Use Types in the Study Area during 1990 to 2016(km²)

| Year | Farmland  | Forest   | Grassland | Water area | Construction land | Unused land |
|------|-----------|----------|-----------|------------|-------------------|-------------|
| 1990 | 15805.96  | 30312.61 | 1118.14   | 3590.96    | 2946.23           | 17.58       |
| 2000 | 14337.11  | 30031.53 | 1071.36   | 4127.61    | 4206.57           | 17.35       |
| 2010 | 12586.75  | 29477.08 | 963.3     | 3929.28    | 6821.97           | 13.16       |
| 2016 | 11450.06  | 27977.22 | 874.25    | 4071.10    | 9412.91           | 6.00        |

From 1990 to 2000, the main transfer land type was farmland and forest changed to construction land, and farmland changed to water area. The conversion of farmland to construction land mainly occurred in Guangzhou, Foshan, Dongguan. The transformation of forest to construction land is mainly distributed in Dongguan, Shenzhen, and farmland to water area occurred in Foshan, Jiangmen, Zhongshan.

From 2000 to 2010, the main transfer land type was farmland, forest and water area changed to construction land. The conversion of farmland and forest to construction land mainly occurred in Guangzhou, Dongguan, Huizhou. Water area which transferred to construction land mainly distributed in Foshan, Zhongshan, Dongguan.

4.2. The evolution characteristics of ecosystem service value
As a result of large amount of farmland and forest changed to construction land, the ESV showed an overall downward trend from 1990 to 2016, the ESV in per hectare was decreased from 1554,000 Yuan to 14513,000 Yuan. From 1990 to 2010, the ecosystem value has increased in some areas, mainly because the farmland changed to water area in these areas.

In the four years, the high-value area of unit area ecosystem service is distributed in the Fengkai, Huaiji, Guangning, Deqing, et al, mainly due to the high percentage of forest. Besides, the service value of per unit of Shunde and Sanshui are also high, mainly due to its water area ratio was high. The area of ecosystem service value of per hectare lower than 130 × 104 Yuan were expanding, Shenzhen - Dongguan - Huizhou city is the most obvious expansion area.

From 1990 to 2016, among the 34 districts or counties, only Xinhui, Gaoming, Sihui, Panyu, Taishan, Zuhai, Sanshui showed an upward trend of ecosystem service value. The ecosystem service value of per hectare decreased by 86.4 × 104 and 84.5 × 104 yuan in the central city of Foshan and Baoan district, and Shunde, Dongguan, Longgang decreased by 46.4 ~ 60.6 × 104 yuan per hectare, central city of Jiangmen, central city of Shenzhen, Huiyang, Nanhai, central city of Guangzhou and Huizhou decreased by 20-25 × 104 yuan per hectare.
4.3. The characteristics of economic development

From 1990 to 2000, the GDPpr were 0.9% to 15.3% among the 34 districts or counties, the central city of Shenzhen, Longgang District, Baoan District had the fastest speed of economic development, which are all above 15%. The GDPpr in Huadu District, Zengcheng District, Huiyang, central city of Huizhou are all higher than 10%. The counties and districts in Zhuhai-Zhongshan-Jiangmen city cluster developed in a lower speed, the GDPpr are about 0.9~2.9%.

During 2000 to 2010, the GDPpr are 0.9% to 7.6% among the 34 areas, which is obviously lower than the first period. Dongguan, Sanshui, Gaoming, central city of Foshan had the GDPpr above 5.5%. At the outskirts of the Pearl River Delta, Huaiji, Fengkai, Deqing, Gaoyao, Enping, Kaiping, Taishan and other districts and counties have a GDP change rate of 0.9~1.6.

From 2010 to 2016, the GDPpr are 0.4% to 1.8% among the 34 areas, which is obviously lower than the first and second period. The areas which had the highest GDPpr are Panyu District, Longmen, Sihui, Huidong. Nanhai, Shunde, central city of Foshan, central city of Jiangmen, Xinhui, Kaiping had the lowest GDPpr. Overall, different from the first and second period, the GDP growth rate in the periphery of the Pearl River Delta is higher than that of the core area.
4.4. The analysis of Ecological and economic harmony

During 1990 to 2000, 19 districts or counties were at low grade coordination, 13 districts or counties were at low grade conflict, central city of Jiangmen and Xinhui district were at moderate coordination.

From 2000 to 2010, 24 districts or counties were at low grade conflict, 8 districts or counties were at low grade coordination, Dongguan and central city of Foshan were at moderate conflict.

In the period of 2010 to 2016, 12 districts or counties were at low grade conflict, 6 districts or counties were at high grade conflict, Zhongshan, Zhuhai, Sanshui were at high grade coordination, Gaoming and Panyu were at moderate coordination.

Overall, the ecological-economic relation in the study area experienced a transformation of “low grade coordination-low grade conflict -further conflict”. Shenzhen, Dongguan, Huizhou, Jiangmen, the central city of Foshan and Guangzhou became the most high-grade conflict areas.

Table 3 EEH Classification and Quantity in the study area during 1990 to 2016

| classification | high grade coordination | moderate coordination | low grade coordination | low grade conflict | moderate conflict | high grade conflict |
|----------------|-------------------------|-----------------------|------------------------|-------------------|------------------|---------------------|
| 1990-2000      | 0                       | 2                     | 19                     | 13                | 0                | 0                   |
| 2000-2010      | 0                       | 0                     | 8                      | 24                | 2                | 0                   |
| 2010-2016      | 3                       | 2                     | 0                      | 12                | 6                | 11                  |

Figure 2. The Spatial Distribution of GDPpr in different period (%)
5. Conclusion

From 1990 to 2016, the urbanization and industrialization in the study area resulted in the rapid expansion of urban construction land, a large amount of farmland, forest land and water areas were occupied. The ESV showed an overall downward trend from 1990 to 2016, the ESV in per hectare was decreased from 1554,000 Yuan to 14513,000 Yuan. From 1990 to 2010, the ecosystem value has increased in Foshan, Jiangmen, Zhongshan, mainly because industrialization of agriculture lead to the transformation from farmland to water areas, compensated the loss of ESV caused by the reduction of farmland and forest.

The area with the highest ecological service value is Shunde district in the year of 1990, 2000 and 2010, respectively $2.49 \times 10^4$, $2.64 \times 10^4$, $2.14 \times 10^4$ yuan per hectare. Sanshui District had the highest ecological service value in 2016, mainly due to the high proportion of water areas in Shunde and Sanshui. This conclusion is consistent with the results of Changsheng Ye [19]. In the four years, the ecosystem service value are also high in the area of Zhaoqing, such as Huaiji, Guangning, Deqing, mainly due to the high proportion of forest in these areas. The areas with the lowest service value per unit area are central city of Shenzhen and Guangzhou, Dongguan, Baoan district. From 1990 to 2016, only the ecosystem service value in Xinhui, Gaoming, Sihui, Panyu, Taishan, Zhuhai and Sanshui increased, and the area with the largest decline of ecosystem value per unit area are mainly concentrated in Shenzhen, Foshan, Huizhou and central city of Guangzhou.

Overall, the ecology-economy relation in the study area experienced a transformation of “low grade coordination-low grade conflict -further conflict”. Shenzhen, Dongguan, Huizhou, Jiangmen, the central city of Foshan and Guangzhou became the most high-grade conflict areas.
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