The selection of ecological source of Changjiang County based on granularity inverse method and principal component analysis

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Abstract. This paper took Changjiang County as the study district. The selection of ecological source were analyzed by using GIS technology, granularity inverse method and principal component analysis. The result of the granularity inverse method and principal component analysis was that the optimal landscape composition structure of Changjiang County had a particle size of 600 m; there were 14 ecological sources aggregately, and 23 pieces of ecological landscape patches needed to increase newly. Besides, the distribution trend of ecological source was characterized by a large quantity but small scale in the central section and small quantity but large scale in the southeast and northwest, which was mainly influenced by human disturbance.

1. Introduction
The rapid development of society brings us serious environmental problems, such as environmental pollution, ecological degradation, habitat atrophy, and so on, which has threaten the sustainable development of human society (Fischer et al, 2007; Zhou L et al, 2016). However, the sustainable development of society is dependant on the sustainable ecosystem, the result of the interaction between man and nature, spatially appears as regional heterogeneous landscape pattern composed of continuous mosaic of landscape patches (Wang M Y et al,2015). Landscape ecology believes that different landscape types have different mechanisms of action on ecological process, and different hindering functions for ecological flow operation, thereby impact the ecological process(Forman, 1995; Xu J F et al, 2016).Therefore, a reasonable landscape pattern is the basis for achieving sustainable development (Chen Y et al,2016;Wang X Y et al,2016).

What kind of landscape pattern is optimal is the primary problem that landscape pattern optimization should solve (Lu Y et al, 2015). Ecological source is the foundation of the optimization of the landscape pattern, so the optimality of the landscape pattern depends largely on whether the selected ecological source is reasonable. The granularity inverse method uses the back-pushing idea combining with the landscape pattern index to construct an evaluation system, which can objectively and effectively indicate the characteristics of the ecological landscape components. PCA can achieve the comparison of the objects of study by comprehensive consideration of measurement indicators. The combination of the two methods provides an effective way for scientific and objective selection of ecological sources.
2. Materials and methods

2.1. Overview of the research area
Located in the northwest of hainan coastal, Changjiang County is between 108°38′42″E—109°37′33″E, 18°52′48″N—19°30′ 35″N. Danzhou city and Baisha county are connected to Changjiang County in the northeast, Ledong Li Autonomous County in the south and Dongfang city in the southwest. The total area is 161,952.11 hm\(^2\). The topography of Changjiang County is mainly plain in the northwest and hilly in the southeast, high in the southeast and low in the northwest. The climate is tropical monsoon climate. There is no winter in the whole year. Rain and heat are over the same period, the annual average temperature is 24.3 °C, the annual rainfall is 1676 mm. From southeast to northwest along the southern edge Changhua river flows into the sea. For the plentiful water supply and fertile land, Changjiang are rather advantageous to develop highly efficient tropical agriculture for famous and excellent fruits, melons and vegetables out of season and so on. Changjiang County has 8 townships including Shilu Town and Changhua Town, including 75 administrative villages, 2 state-owned farms, and a resident population of 240,000. Arable land and woodland are the main land-use-types, accounting for 26.19% and 65.27% of the total area respectively.

2.2. Data source and processing
The basic data of this study are as follows: Changjiang Class II survey of forest resources in 2010; map scaled at 1:10000, DEM digital elevation model; Level 18 Google Earth remote sensing image data on September 15, 2015 (resolution 1.07m, scale 1:3000) and DEM data. The remote sensing image data were registered by reference to topographic map in Beijing 54 coordinate system. Remote sensing interpretation marks were constructed by field investigation, and the Class II survey of forest resources data were calibrated and adjusted. Changjiang County landscape types are divided into 7 types: forest land, garden land, arable land, grassland, water area, unused land and construction land (Lu Y et al, 2015; Pan X et al, 2016).

2.3. Granularity inverse method
According to the counter-evidence, at first, granularity inverse method assumes that the ecological landscape of the study area has multiple landscape component structures. Then, it determines the optimal landscape component structure through overall connectivity analysis, and selects the ecological source (Lu Y et al, 2015). In the light of the idea of landscape ecology, ecosystems with better structure and larger scales are more likely to achieve regional sustainable development. At the same time, it will also have a dominant impact on the development of ecological processes (Ferreira et al., 2008). Granularity inverse method reflects the change of of landscape component structure, analyzes and determines the ecological source from the perspective of landscape component scale.

2.4. Principal component analysis (PCA)
Principal component analysis is an approach that uses the idea of dimensionality reduction to transform multiple indicators into a few comprehensive indicators (Li S Y et al., 2013). This method preserves the characteristics of the original data, thus simplifying complex research while ensuring accuracy (Liu X et al.,2015). According to the obtained cumulative contribution rate and eigenvalues, based on the standardized data, PCA can construct a comprehensive evaluation function, and then evaluate the research object to obtain a comprehensive score (Zhang Z L et al., 2013). Combining granularity inverse method and the principal component analysis method, we can objectively evaluate and analyze different landscape component structures: firstly, the main components of the landscape component structure evaluation are obtained, and then the weights and scores of each principal component are calculated. Finally, the comprehensive scores of different landscape component structures are obtained according to the weights and scores, and the optimal landscape component structure is selected according to the score.
3. The selection of Ecological source
According to the land use status of Changjiang County, forest land, water area and grassland were extracted to generate 16 landscape composition structures of 50~800 m, and the landscape pattern index of landscape component structure was calculated in Fragstats. The results are shown in Table 1.

Table 1. The statistical table of landscape pattern indexes of different granularity of landscape components structure

| granularity | Number of components | Maximum number of component patches | Connection degree/% | Percentage increase in connectivity /% | Degree of polymerization /% | Cohesion /% | Resolution /% | Adjacent ratio /% | Average proximity /m |
|-------------|----------------------|------------------------------------|--------------------|----------------------------------------|---------------------------|------------|--------------|-------------------|--------------------|
| 50          | 1652                 | 8819                               | 0.0381             | 0                                      | 94.5283                   | 0.5565     | 94.3864       | 5199.187          |
| 100         | 861                  | 8111                               | 0.097              | 154.5932                               | 91.2424                   | 0.5608     | 90.9684       | 1548.992          |
| 150         | 511                  | 7653                               | 0.1873             | 93.09278                               | 89.0634                   | 0.5243     | 88.6621       | 1017.418          |
| 200         | 309                  | 7576                               | 0.3236             | 72.77096                               | 87.6732                   | 0.533      | 87.1453       | 659.856           |
| 250         | 205                  | 7482                               | 0.4878             | 50.74166                               | 86.2864                   | 0.5608     | 85.6356       | 502.5756          |
| 300         | 138                  | 6912                               | 0.7722             | 58.30258                               | 89.4301                   | 0.5243     | 85.0988       | 443.9601          |
| 350         | 84                   | 8149                               | 1.2335             | 59.73841                               | 99.4789                   | 0.533      | 85.4045       | 350.0482          |
| 400         | 69                   | 7422                               | 2.0034             | 62.41589                               | 99.7283                   | 0.5565     | 84.3864       | 277.6449          |
| 450         | 52                   | 7587                               | 2.2624             | 12.92802                               | 99.2878                   | 0.5565     | 84.0445       | 263.0048          |
| 500         | 53                   | 7973                               | 3.2656             | 44.34229                               | 99.1083                   | 0.5565     | 83.7284       | 250.7783          |
| 550         | 52                   | 8016                               | 3.0166             | -7.62494                               | 98.4372                   | 0.5565     | 83.1474       | 241.1161          |
| 600         | 23                   | 7664                               | 6.3241             | 109.6433                               | 98.7977                   | 0.5565     | 82.5098       | 187.4527          |
| 650         | 37                   | 6866                               | 4.955              | -21.6489                               | 97.9284                   | 0.5565     | 82.0191       | 155.6771          |
| 700         | 34                   | 6666                               | 4.4565             | -10.0646                               | 97.5114                   | 0.5565     | 81.2062       | 126.0048          |
| 750         | 24                   | 6909                               | 5.1594             | -6.66248                               | 97.0762                   | 0.5565     | 80.6772       | 96.1324           |
| 800         | 19                   | 7134                               | 4.4327             | -17.4713                               | 97.5114                   | 0.5565     | 78.029        | 109.0526          |

Considering the comparability of data, the measurement indicators need to be standardized first. In the landscape pattern index, the number of components cannot reflect the advantages and disadvantages of the landscape component structure, so it cannot be an indicator when executing the principal component analysis. The greater the separation and the average proximity distance are, the worse the overall connectivity of the ecosystem is, so take the opposite and keep the measured indicators consistent. Therefore, the opposite number is taken to keep the measured indicators pointing in the same direction. Principal component analysis was used to analyze the measured indicators, and two principal components were extracted according to the principle of cumulative contribution rate >80% (Table 2).

Table 2. The statistical table of total variance explained

| Component | Initial eigenvalue | % of Variance | Cumulative% | Extraction Sums of Squared Loadings | Total | % of Variance | Cumulative% |
|-----------|-------------------|---------------|-------------|------------------------------------|-------|---------------|-------------|
| 1         | 4.868             | 60.846        | 60.846      |                                    |       |               |             |
| 2         | 1.606             | 20.075        | 80.921      |                                    |       |               |             |
| 3         | 0.891             | 11.140        | 92.062      |                                    |       |               |             |
| 4         | 0.407             | 5.084         | 97.145      |                                    |       |               |             |
| 5         | 0.147             | 1.842         | 98.987      |                                    | 4.868 | 60.846        | 60.846      |
| 6         | 0.064             | 0.804         | 99.791      |                                    | 1.606 | 20.075        | 80.921      |
| 7         | 0.017             | 0.209         | 100.000     |                                    |       |               |             |
| 8         | 2.382E-5          | 0.000         | 100.000     |                                    |       |               |             |

The eigenvector of the principal component was calculated by dividing the load factor by the square root of the eigenvalue, and multiplied it with a standardized data matrix to obtain the principal component. The expression is as follows:

\[ Z_1=0.350X_1-0.384X_2+0.245X_3+0.446X_4+0.348X_5+0.448X_7+0.054X_8 \quad (1) \]

\[ Z_2=0.051X_1+0.223X_2+0.512X_3+0.061X_4+0.431X_5+0.687X_6+0.148X_8 \quad (2) \]
When the data was substituted into the above equations (1) and (2), the score of the measured index on the principal component was obtained. The score is multiplied by the variance contribution rate of the corresponding principal component, and the comprehensive score of the landscape component structure of each granularity was obtained (Fig. 1). The overall trend of the composite score is decreasing as the granularity increases. The main reason of it is as follows: with the increase of the granularity, the smaller ecological patches are continuously removed and merged, which increases the distance between the components and the fragmentation of the landscape component structure, so the score is gradually reduced. Since the changes in the structure of the landscape components can change the overall characteristics, there is a local trend change in the overall decline trend, which is pretty obvious in the granularity of 600m. The comprehensive score of the landscape component structure of 600m granularity is significantly higher than the surrounding granularity, which approaches the highest score. From the characteristics of granularity inverse method and landscape pattern analysis, when the granularity is small, the landscape components are more and close to each other. But it is too close to the current status of land use, which cannot indicate the core components of the ecosystem. Therefore, it cannot be used as a foundation of the ecological source selection. As the granularity increases, the structure of the landscape component changes qualitatively due to the quantitative change, and a distinct peak appears at a granularity of 600 m. It means that this granularity is a qualitative change point that is conducive to the development of ecosystems.

![Fig.1 Synthesis score of landscape components structure](image)

In summary, the landscape component structure of 600 m granularity has strong overall connectivity, which is the optimal landscape component structure in Changjiang County. The ecological source should be selected with reference to the landscape composition of 600 m granularity. Main landscape components extracted from the composition of the landscape, ecological patches extracted from the map of land use status, ecological patches to be added based on the connection characteristics of the landscape components, all of these constitute an ecological source. There are 23 main components in the landscape component structure, which indicates the existence of 23 large-scale ecological sources. Among them, 9 landscape components are connected with other landscape components in the land use status map, so these landscape components were merged. Finally, 14 large-scale ecological sources were obtained. According to the spatial distribution of the landscape components, the ecological patches that are separated but close to each other were determined, and the non-ecological landscape patches that are separated were converted into ecological landscapes to realize the connection of ecological components and form an ecological source. These new-added ecological patches are a total of 23, including 20 arable land with area of 23.38 hectares, 3 construction land with area of 3.55 hectares.

The ecological source areas in the northwest and southeast of Changjiang County are large in scale, and in the central part is small in scale, which is basically consistent with the topography of Changjiang
County. The central part of Changjiang County is mainly plain, with an altitude of 0~200 m. The flat topography provides favorable development conditions for agriculture. Large areas of arable land locate in this area and are the main agricultural development area of Changjiang County. Because the arable land is strongly interfered by humans, the economic benefits are higher than the ecological land. The types of ecological landscapes in the territory have been nibbled away and separated from each other in space, so the scale is small and the number is large. This also indicates the necessity of local optimization of landscape pattern. The southeastern part of Changjiang County is the remnant of Wuzhi Mountain, the Middle East is Baomeiling Nature Reserve, and the southeast is Bawangling National Forest Park. The terrain is undulating, most areas are well protected, and the forest landscapes are interconnected to form the largest ecological source. The northwest coastal areas are mainly low hills with an altitude of about 400 m. The area includes Changhua Forest Farm and a large area of state-owned reserve land. Vegetation is mainly mixed forest, shrub and eucalyptus. It is subject to less human interference, so there are a large scale of ecological sources. The total area of ecological sources is 104,759.57 hm2, accounting for 64.69% of the total area of Changjiang County. A large amount of ecological land can play an ecological role as the ecological core of western Hainan. The largest ecological source area is 79,945.34 hm2. Most of them are natural mixed forests, which often play a leading role in the ecosystem and should be special protected. The smallest ecological source area is 162.44 hm2. The vegetation type of it is rubber forest. The edge of the ecological source is regular. This shows that it is deeply affected by the planning and the human-made interference. The difference in scale reflects the difference in ecological succession mechanisms. They should be treated differently in ecological construction.

4. Conclusion

Combining the particle size back-calculation method and principal component analysis, this paper obtains the optimal landscape component structure of Changjiang County and realizes the objective selection of ecological source. The 600m-grained ecological landscape component has high overall connectivity and is the optimal landscape component structure of Changjiang County, which is a suitable reference for the selection of ecological source sites. There are 14 ecological source sites in Changjiang County, and the central region is large in number and small in scale, southeastern and northwestern coastal areas are small in number and large in scale. There is a significant correlation between the distribution characteristics of ecological sources and human disturbances. Topography is the main factor affecting its spatial distribution. Changjiang County needs to convert 23 non-ecological landscape patches into ecological landscapes with a total area of 26.93 hectare, forming an ecological source by combining the separated ecological landscape components.

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