Evaluation of ecological environment of Songshan scenic area based on GF-1 data

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Abstract. Songshan scenic area is a national-level scenic spot in Henan Province and has important economic and social value. The use of remote sensing technology can quickly evaluate the ecological environment and provide an important reference for the ecological environment management department of scenic spots. In this paper, GF-1 satellite imagery is mainly used to comprehensively consider the climate, topography, type of landforms and impact of human activities. The AHP method is used to evaluate the ecological environment of Songshan scenic area from 2013 to 2017. The evaluation results show that: in 2013, 2015, and 2017, the average values of the eco-environmental quality index were 78.9659, 81.2519, and 82.4581. The ecological environment status showed an improvement trend, and the reduction of land use intensity and the increase of vegetation coverage were the main factors for improving the ecological environment of the scenic spot. The areas with deteriorating ecological environment are mainly distributed in areas such as Shaolin Temple, Tallinn area and Songyang college.

1. Introduction
Scenic areas are national natural and cultural heritage protection areas established by country. In recent years, because of the urbanization, phenomenon of artificiality, and commercialization, the scenic areas’ environment become increasingly serious. Evaluation of ecological protection of scenic areas has positive significance [1-2]. With the development of remote sensing and geographic information technology, methods for assessing the regional ecological environment quality have also been continuously improved. Wang Shiyuan et al. [3] used remote sensing data to extract four indicators of greenness, humidity, heat and dryness, the evaluation results can be better spatial visualization. Li Ruoning et al. [4] used the tomographic analysis method to comprehensively evaluate the 18 indicators affecting the ecology of Yuntai mountain in the research. Lin Meizhen et al. [5] applied the fuzzy comprehensive evaluation method and the analytic hierarchy process to the quantitative assessment of the ecological environment of the Baiyun mountain scenic area in the study. At present, most of the studies on the ecological environment of Songshan scenic area use field surveys, sampling, and other methods, such as soil quality, vegetation, and tourism activities, for a single fact [6-9]. However, the study of comprehensive ecological environment assessment and change analysis for the entire Songshan scenic area is not a lot. This paper uses GF-1 data, combined with other data sources such as Landsat8, comprehensively considers the four aspects of climate, topography, land type, and human activity impact, established an environmental assessment ecological model.
2. Study areas and data
Songshan (112°45′48″-113°11′55″, 34°23′28″-34°35′40″) scenic area is located in the west of Henan province, and it is in the northwest of Dengfeng city. It stretches for more than 60 kilometers east and west, with an altitude of 400 to 1500 meters. Songshan scenic area belongs to the continental monsoon humid climate, with four distinct seasons, mild climate, annual average temperature of 14.3°C, annual rainfall of 500-600 mm, and summer precipitation accounts for 53% of annual precipitation. The research area for Songshan scenic area is shown in Figure 1.

The data was used in this paper includes: remote sensing satellite data, topographic data and survey statistics data. Remote sensing satellite data includes GF-1 and landsat8 image data and topographic data is DEM data. The survey statistics include the location data of public toilets, hotels, restaurants and the planning materials, statistical bulletins, etc. in recent years in Songshan.

3. Research methods
In this paper, applying remote sensing and geographic information technology construct an ecological environment quality assessment model for the Songshan scenic area, determines the weights based on the AHP method, and completes the comprehensive assessment of the ecological environment quality of the Songshan in 2013, 2015 and 2017.

3.1. Construction of remote sensing ecological index
Based on the results of research and analysis of predecessors' numerous research results, combined with the opinions of many experts, the ecological environment evaluation index system was constructed, including vegetation coverage, slope, elevation, soil erosion intensity, land use intensity, density of pollution sources, temperature vegetation drought index. The calculation methods of selected factors are as follows:

1) Vegetation coverage
Vegetation coverage refers to the percentage of the vertical slide area of the vegetation (including leaves, stems and branches) on the ground to the statistical area. In this paper, normalized vegetation index method is used to achieve the calculation of vegetation coverage. According to the calculated NDVI data, the NDVI values with cumulative probability of 5% and 95% were taken as $NDVI_{low}$ and $NDVI_{high}$, respectively.
The vegetation coverage formula is shown below: \[ F_C = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \] (1)

2. Slope.
Higher slopes are not conducive to affecting the growth of vegetation, the accumulation of water, and even increase the potential erosion intensity of the soil. In this paper, the DEM data with a resolution of 30m is selected and calculated using the slope calculation tool in Arcgis 10.2.

3. Soil erosion intensity.
Soil erosion is an important cause of ecological damage, and it is also an important indicator of ecological environmental quality assessment. The actual soil and water loss module is difficult to obtain, so this paper uses ground slope, vegetation coverage, and land use intensity type factors to classify soil erosion intensity.

| Slope(°) | Land type | 5-8 | 8-15 | 15-25 | 25-35 | >35 |
|----------|-----------|-----|------|-------|-------|-----|
| 60-75    | mild      | mild | mild | moderate | moderate | moderate |
| 45-60    | mild      | mild | moderate | moderate | strong |
| 30-45    | mild      | moderate | moderate | strong | very strong |
| <30      | moderate  | moderate | strong | very strong | severe |

4. Land use intensity.
According to the degree of impact of land use type on the ecological environment of the scenic area, different values are assigned to the traffic land, construction land, bare soil, cultivated land, grassland, forest land and water area, reflecting the intensity of land use intensity.

5. Elevation.
Topography has an important impact on biomass. Human activities are frequent in Songshan scenic area. In the low-altitude area, most of the land has been opened up as farmland. In high altitude areas, due to less human activities, vegetation is flourishing and the ecological environment is better.

6. Pollution source density.
In the area of public toilets, hotels, restaurants, and roads around the scenic area, there are a large number of human activities involved, leading to a deterioration of the local ecological environment. Use the Arcgis density analysis tool to do density analysis in scenic area.

7. Temperature vegetation drought index (TVDI).
TVDI is a comprehensive index based on vegetation index and land surface temperature. The combination of the two can highlight the available water in vegetation and is a sensitive indicator of soil moisture and vegetation moisture in a region. The formula for the temperature vegetation drought index is: \[ TVDI = \frac{T_S - T_{S_{min}}}{T_{S_{max}} - T_{S_{min}}} \] (2)

3.2 Evaluation factor standardized processing
In this paper, the dimensions between the various factors are not uniform, so they cannot be directly used for environmental assessment. It is necessary to construct a unified standard to reflect the degree of impact on the environment. The indicators that are positively related in this paper (elevation, vegetation coverage) adopt the following formula, and the values are distributed between 0 and 100:

\[ T_y = 100 \times \frac{T_y(0) - T_y(\text{min})}{T_y(\text{max}) - T_y(\text{min})} \] (3)
In this paper, negatively correlated indicators (TVDI, slope, land-use intensity, soil erosion intensity, pollution source density) adopt the following formula:

$$T_y = 100 - 100 \times \frac{T_y(0) - T_y(\text{min})}{T_y(\text{max}) - T_y(\text{min})}$$

(4)

3.3. Weight calculation

In this paper, vegetation coverage, slope, elevation, soil and water loss intensity, land use intensity, pollution source density, and temperature vegetation drought index were selected as evaluation factors of ecological environment. Build a hierarchical hierarchy model and use the 1–9 scale method to perform a pairwise comparison. According to expert opinion and field survey and other methods, determine the relative importance of selected factors, and finally assign corresponding scores. In order to verify whether the weight setting is reasonable, this paper refers to random agreement. The sexual indicators were verified and CR = 0.0269 < 0.1 was calculated, therefore, the judgment matrix has consistency, the weights are set reasonably, and the weight distribution of each factor finally calculated (Table 2).

| First-level indicators | Secondary indicators | Correlation | Weight |
|------------------------|----------------------|-------------|--------|
| climate                | TVDI                 | -           | 0.0295 |
|                        | Slope index          | -           | 0.0295 |
| topography             | Elevation            | +           | 0.066  |
| Feature Type           | Soil erosion intensity | -         | 0.1117 |
|                        | Land use intensity   | -           | 0.2117 |
| human activity         | Vegetation coverage  | +           | 0.1117 |
|                        | Pollution source density | -   | 0.4337 |

3.4. Scenic ecological index calculation

The eco-environmental index of Songshan scenery area is calculated using the quality index method, which is the weighted sum of all standardized evaluation factors. The formula is as shown in formula (5):

$$EI = \sum_{j=1}^{n} I_j W_j$$

(5)

4. Results and analysis

4.1. Eco-environmental evaluation result

Based on the above evaluation methods, the distribution maps of eco-environmental quality indices for 2013, 2015, and 2017 (Figure 3) were calculated.

Table 3. Mean index and EI mean statistics

| Year | Pollution source density | Slope | Elevation | Vegetation coverage | Soil erosion intensity | TVDI | land use intensity | EI |
|------|--------------------------|-------|-----------|---------------------|------------------------|------|-------------------|----|
| 2013 | 93.2631                  | 74.2902| 70.758    | 68.9594             | 88.77                  | 59.8651| 66.4366             | 81.1574 |

Figure 2. EI distribution map of Songshan scenic area from 2015 to 2017.
4.2. Analysis of Eco-environmental evaluation results

4.2.1. Overall analysis of ecological environment quality
The average EI values of the Songshan in 2013, 2015, and 2017 were 78.9659, 81.2519, and 82.4581, showing an increasing trend year by year, indicating that the ecological environment in the area has been improving year by year in the last five years. From 2013 to 2017, except for the decrease of the pollution source density index, the vegetation coverage index, soil erosion intensity index, TVDI index, and land use intensity index increased by 13.8105, 0.5404, 6.0404, and 7.8595, indicating that the ecological environment became better. Combined with the weights of the indicators, the vegetation coverage index, soil erosion intensity index, TVDI index, and land use intensity were calculated. The contribution of the index to the eco-environment reached 1.5426, 0.063, 0.1781, and 1.7110, indicating that the decrease in land-use intensity and the increase in vegetation coverage are the main factors that make the eco-environment in the Songshan scenery area become better.

4.2.2. Grading and change detection

4.2.2.1. Ecological environmental quality classification
In order to better analyze the distribution of the ecological environment in Songshan area, according to the results of the field survey and in accordance with the standards for the classification of ecological environment in nature reserves [15], the EI is divided into 5 levels: worst (0 ≤ EI < 50), poor (50 ≤ EI < 65), medium (65 ≤ EI < 75), good (75 ≤ EI < 85), excellent (85 ≤ EI < 100) five grades (Figure 3).

![Figure 3. Distribution of EI quality grades in Songshan scenic area from 2013 to 2017](image)

4.2.2.2. Detection of changes in Eco-environmental quality
In order to better analyze the temporal and spatial changes, the EI was tested for the difference detection between 2013 and 2017. According to the differential sign is negative, 0, positive, divided into worse, unchanged, better three categories.
Figure 4. EI change detection chart from 2013 to 2017

The areas with better quality of ecological environment are mainly distributed on the eastern edge of the scenic area. This part of the area is dominated by residential areas and sloping cultivated land. As a result of strict account control measures in recent years, the area has strictly controlled the population and gradually reduced the size of the population. The residents inside the scenic spot migrated outwards and gradually reduced the negative impact of the residents' living on the environment in the scenic area.

The areas with poor quality of ecological environment are mainly distributed in the four core scenic spots within Shaolin Temple and Tallinn area, Songyangyang college area. The human disturbance caused by tourism activities exceeds its maximum environmental capacity, which in turn affects the structure and function of the plant community, which leads to the deterioration of the quality of the ecological environment in the core scenic area.

The areas with constant ecological environment are mainly concentrated in the eastern and western. These areas have abundant forest resources, high altitude, few tourists and no ecological environment damage. Therefore, the quality of ecological environment in these areas has not changed much.

5. Conclusions

This paper used multi-source remote sensing data to construct an ecological environment assessment model of Songshan scenic area, completed the calculation of the eco-environmental index from 2013 to 2017, and analyzed their spatio-temporal changes. The conclusions are as follows:

1) The average eco-environmental quality index of the Songshan scenic area during the three periods of 2013, 2015 and 2017 were 78.9659, 81.2519, and 82.4581, showing an upward trend. The reduction of land-use intensity and the increase of vegetation coverage were main ecological factors that make the environment better in Songshan.

2) The proportion of the eco-environmental index of the scenic spots from 2013 to 2017 were 12.24%, 62.16%, and 25.4%. The overall ecological environment quality gradually improved. In recent years, Dengfeng city has attached great importance to environmental protection work, the return of farmland to forests, the implementation of energy-saving emission reduction measures, has played a positive role in the protection of the ecological environment.

3) The areas with deteriorated ecological environment are mainly four core scenic spots within the scenic area of Shaoishishan mountain, Shaolin temple, Tallin area and Songyang college area. This is mainly due to the large number of tourists visiting in recent years, the human disturbance caused by tourism activities exceeds the environmental capacity, which affects the structure and function of the plant community, leading to the continuous deterioration of the ecological environment quality of these core scenic spots.
Acknowledgments
This research is supported by the project 152102210044, 162102310192 and 152300410189 of the Henan Province Science and Technology Research Project.

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