The Application of the Tiangong-2 Wide-band Imaging Spectrometer Data in the Ecological Environment Evaluation: A Case Study of Kunming

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Abstract: As a new type of remote sensing data source, the Tiangong-2 image data have several advantages and can be applied in various fields, of which one application is the ecological environment evaluation. In this study, the ecological environment status in Kunming, a major city of "The belt and Road Initiative", is performed using data provided by the wide-band imaging spectrometer on Tiangong-2. The ecological environment evaluation system is established based on The Criterion for Ecosystem Status Evaluation, in which the vegetation coverage index, soil index and slope are used as the evaluation indicator. The ecological environment status in Kunming is evaluated and classified into four grades including excellent, good, medium and poor based on the "3S Technology". The result shows that the ecological environment in Kunming is good, of which 62.75% is excellent or good grade and distributed in the area with high vegetation coverage, 30.84% is medium grade and distributed in the mountainous areas or the Dian Lake, and 6.40% is poor grade and distributed in the north of Dian Lake or other built areas. Strengthening the ecological protection and restoration of Dian Lake and its surrounding areas will help to improve the overall ecological environment quality of Kunming.

1 INTRODUCTION

Tiangong-2 was launched in September 15, 2016, carrying three earth observation loads, of which one is the wide-band imaging spectrometer (MWI) (Yang et al., 2017; Wen, 2016). So far a lot of ground observation data have been obtained by MWI. The data be used to monitor large-scale, medium and large objects in ocean, land, and air. It can be applied in various fields, such as land and resources, agriculture and forestry applications, hydrology and water resources, marine and coastal research, etc. One important application of these data in the field of ecological environment is the ecological environment evaluation.

The ecological environment is the basis of all living beings and human existence, providing material support and ecological services for human society (Zhao et al., 2013). The quality of ecological environment is closely related to the sustainable development of social economy (Chen, 2012; Zhao et al., 2009) With the city development, the contradiction between economic development and ecological environment quality will be highlighted. For example, the degradation of forest and grassland is serious, soil erosion is aggravated, natural disasters occur frequently, pollution is aggravated, and the ecological environment is deteriorating (He et al., 2017; Deng et al., 2016; Li et al., 2016; Song and Xue, 2016). Considering the above situation, ecological environment evaluation is very important. The ecological environment evaluation is a quantitative description and evaluation of the advantages and disadvantages of the ecological environment, which more accurately reflect the status of the ecological environment and expose the main environmental problems. It provides scientific basis for the ecological protection and restoration measures, the formulation of ecological environment planning and the countermeasures of environment management and control (Zhao et al., 2013; Cheng et al., 2012). Ecological environment evaluation is of great significance to the effective management and sustainable development of regional ecological

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environment (He et al., 2017; Wang and Zhao, 2016)There are many methods of ecological environment evaluation, which can be divided into qualitative and quantitative evaluation. Quantitative evaluation includes vulnerability calculation method, distance calculation method, ecological footprint method and comprehensive index method (Guo and Li, 2007; Rees, 1992; Bi and Hong, 2001). At present, the comprehensive index method is widely used and it refers to the reasonable evaluation of the research area by selecting the appropriate evaluation index and evaluation model. There are great differences in the selection of the index system or the weight distribution of the same index in the understanding of the ecological environment or the purpose of the study, which leads to differences in the evaluation results of the same ecological environment. As a result, different evaluations cannot be directly compared. Adopting standardized method, such as Technical Criterion for Ecosystem Status Evaluation (HJ192-2015), can enhance the comparability between results from various researches. HJ192-2015 uses the comprehensive index (Ecological index, EI) to describe the overall state of the regional ecological environment. It provides for the evaluation index system of ecological environment status and the calculation method of each index, which is suitable for evaluating the status and changes of the ecological environment of the county, provincial and ecological areas. However, the indexes are difficult to obtain and the data acquisition cycle is long. Besides, the data sources are mostly obtained based on the administrative area, which is difficult to meet the requirements of the timeliness and refinement of the evaluation unit. GIS and RS technology are used to evaluate the ecological environment condition, to process the remote sensing image data of the evaluation area and extract the index data of the evaluation, greatly saving the time and energy of the data collection and management, improving the timeliness of the evaluation results, increasing the visibility of the results, and providing technical support for the ecological environment evaluation. Many researchers use remote sensing data to evaluate ecological environment. For example, researches are carried out on ecological environment evaluation in the Quanzhou Bay area, Kunming Chenggong District, Yanhe watershed and Longkou, respectively (He et al., 2017; Li et al., 2016; Wang and Zhao, 2016; Gan et al., 2016). With the growing maturity of remote sensing (RS), the EI index can be relatively easy to obtain and the result can be well visualized (Song and Xue, 2016; Li et al., 2007; Gupta et al., 2012; Yan, 2017).

In this paper, Tiangong-2 MWI image, as a new domestic remote sensing data source, is used for the ecological environment evaluation in Kunming. Referring to Technical Criterion for Ecosystem Status Evaluation (HJ192-2015) (Rees, 1992), and combining the characteristics of Kunming's eco-environment, the evaluation factors are extracted with RS and EI is calculated to evaluate of the ecological environment condition in Kunming. This paper quantitatively analyses and evaluates the ecological environment in Kunming, which can provide the basis for the scientific ecological protection and restoration of this city, as well as promote the "The Belt and Road Initiative" ecological construction.

2 MATERIALS AND METHODS

2.1 Study Area

Kunming (102°10 'E~103°40' E, 24°23 'N~26°22' N) is located in the central area of the lake basin group in the central Yunnan Province, which is in the central part of Yungui Plateau in Southwest China. Kunming is south to Dian Lake and is surrounded by mountains on three sides. It is dominated by Plateau hilly landforms (Tang, 2017; Yang et al., 2001).

Kunming is a frontier and portal of China facing Southeastern Asia, Southern Asia, the Middle East, southern Europe and Africa. As an important city along the Belt and Road, Kunming has a unique geographical advantage, connecting to the coastal areas through Guizhou Province on the East, to India and Pakistan through Myanmar on the west, to the Central Plains of the China through Sichuan Province and Chongqing on the north, and to Thailand and Cambodia through Vietnam and Laos on the south.

Kunming is dominated by low north latitude subtropical-plateau monsoon climate, with the average annual temperature of 14.7 Celsius degree and the average annual precipitation of 1011.2mm (Zhao et al., 2013). It has jurisdiction over 7 municipal districts, 1 county-level city, 3 counties and 3 autonomous counties. Its permanent population is 6.728 million. There are three main lakes, which is the Dian Lake, the Yangzonghai Lake and the Qingshuihai Lake. Kunming’s vegetation type is the Evergreen broad-leaved forest in the Northern Subtropical Zone and it has significant characteristics of biodiversity (Zhao et al., 2013).

2.2 Data Source and Data Preprocessing

In this paper, a new generation of domestic remote sensing image data, Tiangong-2 Wide-band Imaging Spectrometer (MWI) images, are used as the data source. As a new generation of wide band remote sensor, the Wide-band Imaging Spectrometer on Tiangong-2 has a wide FOV (Field of View) and combination of image and spectrum. It integrates visible and near infrared, short wavelength infrared and thermal infrared spectrums in one instrument. Detailed data descriptions are listed below in Table 1.

In this study, MWI images and ASTER GDEM (90m) are selected as data source. The remote sensing image of Kunming in March 22, 2017(Figure 1, data source: Space application data promoting service platform for china Manned Space Engineering, http://www.msadc.cn/) is selected as the data source and the vegetation coverage index and soil index are extracted. The slop is extracted using ASTER GDEM (90m) data (Data source:NASA).

2.3 Evaluation Method

In this study, the Technical Criterion for Ecosystem Status Evaluation (HJ192-2015) is taken as a reference (Rees, 1992). In accordance with the principle of representativeness, simplicity and applicability, as the basic elements of vegetation, soil and topography, the data of vegetation coverage, bare soil vegetation index (GRABS) (Yang et al., 2001) proposed by Yang Cunjian et al. and slop are selected as the key factors. After the normalization of these factors, the EI(Ecological Index, 0~100)was obtained through weight calculation. Finally, according to the EI, the ecological environment of Kunming was evaluated and analyzed.

Firstly, the FLAASH atmospheric correction for Tiangong-2 MWI is performed with the help of ENVI and the image is cut using the vector boundary of Kunming.

Table 1: Data index of Tiangong-2 MWI.

Index	Visible Near Infrared	Short Wavelength Infrared	Thermal Infrared
spectral range(μm)	0.4~1.0	1~1.7	8~10
numbers of channels	14	2	2
Channel range(μm)	V1:0.970~0.990 V2:0.930~0.950 V3:0.895~0.915 V4:0.845~0.885 V5:0.810~0.830 V6:0.740~0.760 V7:0.6775~0.6875 V8:0.655~0.675 V9:0.610~0.630 V10:0.555~0.575 V11:0.510~0.530 V12:0.480~0.500 V13:0.433~0.453 V14:0.403~0.423	S1:1.23～1.25 S2:1.63～1.65	T1:8.125～8.825 T2:8.925～9.275
spatial resolution(m)	100	200	400
swath(km)	300	300	300

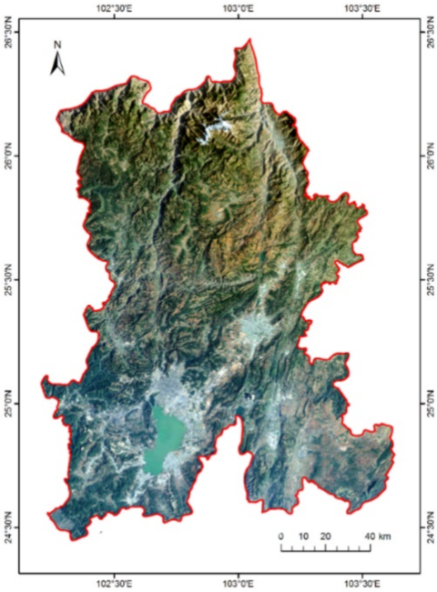

Figure 1: True color synthetic image of Tiangong-2 MWI(RGB=band8/10/12).

Then, benefiting from the IDL Language Programming System, this paper summaries an approach for Tiangong-2 MWI data processing and application in light of the ENVI remote sensing software, which provides a band match instrument to the calculation of VC and NDVI indexes.

The vegetation coverage (VC) was calculated with NDVI:

$$VC = \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \quad (1)$$

$$NDVI = \frac{V_4 - V_8}{V_4 + V_8} \quad (2)$$

NDVI is the normalized difference vegetation index (NDVI). $NDVI_{max}$ and $NDVI_{min}$ is the maximum and minimum NDVI value of the region, respectively. V4 and V8 is band 4 and band 8 of visible near infrared of Tiangong-2 MWI, respectively.

The bare soil vegetation index is calculated as:

$$GRABS = VI - 0.09178 \times BI + 5.58959 \quad (3)$$

VI, BI are the green index and soil brightness index of tasseled cap transformation respectively, which are calculated with the help of Tasseled Cap tools of ENVI5.1.

Based on ASTER GDEM (90m), the splicing and projection are firstly carried out, and the samples are resampled as 100m, which is consistent with the data of MWI. Then, the slop information is extracted with the help of the Topographic Modeling tool of the ENVI5.1.

The EI is calculated through weight and the weights of different factors are determined by Analytic Hierarchy Process (AHP). The evaluation matrix is constructed by using the 1-9 scale method, and the weight values of the indexes are calculated and the consistency of matrix is checked with MATLAB.

Table 2: Judgment matrix.

	Sv	Ss	St	weight
Sv	1	4	6	0.7
Ss	1/4	1	2	0.2
St	1/6	1/2	1	0.1

Consistency test results show that λmax=3.0092 , C.I.=0.0046 , C.R.=0.0088 <0.1, which has satisfactory consistency.

$$EI = W_1 \times S_v + W_2 \times S_s + W_3 \times S_t \quad (4)$$

S_v, S_s and S_t are the vegetation coverage factor, soil factor and topographical factor, respectively. W_1, W_2 and W_3 are corresponding weight coefficients which are set as 0.7, 0.2 and 0.1.

Finally, the EI index results are divided into 4 grades by Natural Breaks with ArcGIS10.0, and the visual display of pixel level is carried out(Zhang, 2014).

3 RESULTS

3.1 Ecological Environment Evaluation in Kunming

Using the RS method, the vegetation factor (vegetation coverage index), soil factor (bare soil index) and topographic factor (slope) were obtained, as shown in Figure 2.

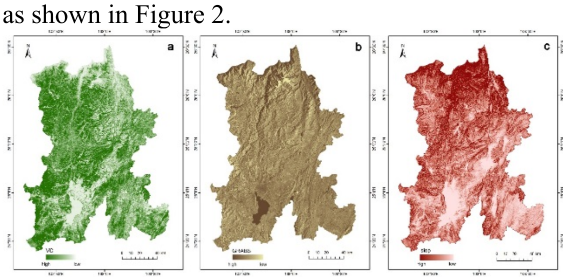

Figure 2: Results of evaluation factor (a. vegetation factor b. soil factor c. topographic factor).

Figure 2-a is the result map of vegetation factor. The higher vegetation coverage is, the better the quality of eco-environment is. The dark color areas

stand for woodland, where the vegetation coverage is high. The light color area in southwestern Kunming is Dian Lake. The light color area to the northeast of Dian Lake is the construction zone， in which the vegetation coverage is low. In the northern light color area, the vegetation coverage is also very low due to snow cover.

Figure 2-b is the result map of soil factor. This index is a linear combination of the greenness index and the soil brightness index. It reflects the soil nude condition well. The higher the degree of soil exposure is, the greater the risk of erosion and degradation would be and the worse the quality of the ecological environment is. The dark color areas of the map are water areas with no vegetation. The darker of the other area means higher the soil exposure and worse the quality of the ecological environment.

Figure 2-c is the result map of the topographical factor. The greater the slop is, the higher the risk of landslide and debris flow would be. The index can reflect the ecological risk in the study area to a certain extent. The dark color area in the northern part of the map is mountainous, where the slop is large, and the light color area in the south is water area, town and so on, where the slop is very small.

Figure 3 is a result map of the ecological environment evaluation of Kunming, which is weight calculated with the normalized vegetation coverage factor, soil factor and topographical factor. The ecological environment status of the study area is divided into four grades: excellent, good, medium and poor. The total area of the excellent grade is 5600 km^2, which is 26.62% of the whole area. These areas are widely distributed in Kunming with high vegetation coverage. The areas with good ecological environment are distributed in areas with lower vegetation coverage or lower slop, whose total area is 7600.58km^2, accounting for 36.13% of Kunming. The region with medium ecological environment covers an area of 6487.02km^2, which contributes to 30.84% of Kunming, mainly distributed to Dian Lake and the northern mountainous region with a relatively low vegetation coverage and high slop. It has a fragile ecological environment and is vulnerable to the rain erosion. The ecologically poor region is mainly distributed in the downtown northeast to the Dian Lake and other human dominant areas with its total area of 1347.03 km^2, which is 6.4% of Kunming.

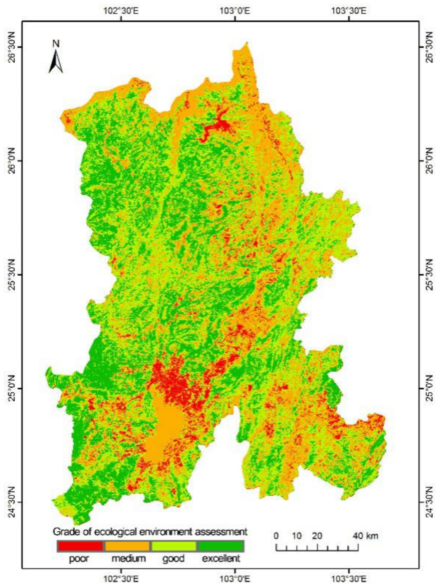

Figure 3: The results of ecological environment evaluation in Kunming

Table 3: Statistics of ecological environment evaluation results

Level	Area/km^2	Percentage/%
Excellent	5600.58	26.62
Good	7600.58	36.13
Medium	6487.02	30.84
Poor	1347.03	6.41

3.2 Ecological Environment Evaluation in Various Counties and Cities of Kunming

There are 14 districts / counties in Kunming. The ecological environment status of 14 districts / counties is statistically analyzed, and the results of ecological environment evaluation of each district / county are obtained (Figure 4). The regions with an excellent ecological environment, whose area is 1671.1km^2, accounting for 29.83% of Kunming, are mainly distributed in Luquan Autonomous County for Yi and Miao Nationality. The regions with good ecological environment are mainly distributed in Luquan Yi and Miao Autonomous County and Xundian Hui Autonomous County, whose area are 1692.26 km^2 and 1524.78 km^2, accounting for 22.26% and 20.06% respectively. The regions with medium ecological environment are located in Xundian Hui and Yi Autonomous County and Dongchuan District, with the area of 1226.71 km^2 and 1048.32 km^2, accounting for 18.91% and 16.16% respectively.

The regions with poor ecological environment are mainly distributed in Guandu district and other central urban areas.

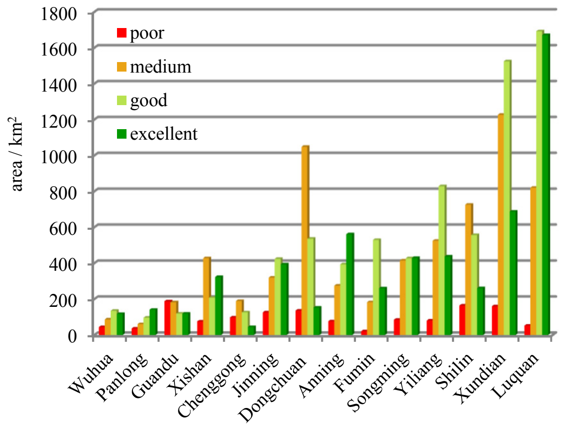

Figure 4: Evaluation results of ecological environment in various districts / counties of Kunming.

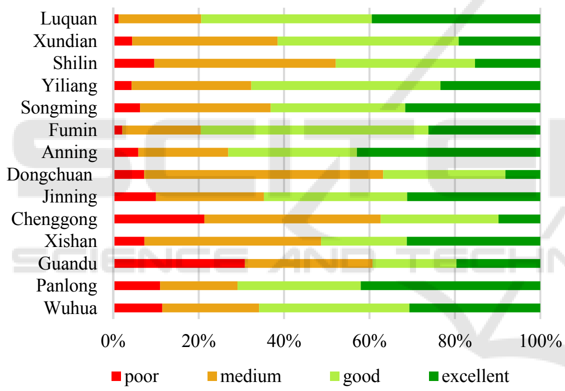

Figure 5: Percentage accumulation chart of ecological environment in various districts / counties of Kunming.

Each district / county was calculated to get the percentage accumulation chart of the ecological environment status (Figure 5). The district / county ecological environment is good as a whole, the numbers of district/county with more than 60% excellent and good ecological environment area is 9. They are Fumin County, Luquan Yi and Miao Autonomous County peace counties, Panlong District, Yiliang County, Wuhua District, Jinning District, Xundian Hui and Yi Chongming County Autonomous County and the proportion were 79.47%, 79.39%, 73.06%, 70.88%, 67.65%, 65.82%, 64.70%, 63.13% and 61.46%, respectively. The ecological environment status of Xishan District, Shilin Yi Autonomous County, Guandu District, Chenggong county and Dongchuan area is relatively poor, and the ratio of excellent and good is less than 60%. Among them, the ecological environment in Guandu and Chenggong is more severe, and the regions with poor ecological status account for 30.85% and 21.36% . Guandu and Chenggong District, as the downtown area of Kunming, have large population density, large proportion of urban construction land, and great difficulty in ecological environment control. Therefore, the ecological environment of the two area is less than the surrounding area / county, ignoring the effect of the different ecological function zoning on the results.

With the "The Belt and Road Initiative" development, bring some pressure to the ecological construction. At the same time of economic development and urban construction, we need to strengthen the control of ecological environment, increase the rate of urban greening, strengthen the management of water bodies, and continue to maintain a good level of ecological environment.

4 DISCUSSION

Tiangong-2 Space Laboratory is the first real laboratory in China (Wen, 2016). A number of cutting-edge science and technology development strategy of high science and application tasks was undertaken in Tiangong-2 Space Laboratory, including a number of scientific experiments and testes, as well as validation system of new technologies(Wen, 2016). Tiangong-2 Space Laboratory has carried out a number of new space applied load equipment and more than ten applications and experiments, which are related to earth observation and space science, space astronomy, microgravity basic physics, microgravity fluid physics, space materials science, space life science, space environment, space physics, etc.(Yang et al., 2017). There are three instruments for the study of earth observation and space science, including Wide-band imaging spectrometer, Three-dimensional imaging microwave altimeter and Multi-band ultraviolet edge imaging spectrometer(Qin et al., 2017; Kong et al., 2017). The Wide-band Imaging Spectrometer data is the first combination of visible and near infrared, shortwave infrared， thermal infrared and polarization push-scan imaging system on the single instrument in the world for the first time, and it can achieve the observation of the ocean, land and atmosphere(Wen, 2016; Yang et al., 2017; Qin et al., 2017). Besides, it has characteristics of wide swath (300km), high time resolution (the same area can be covered once in 2-3 days) and high spectral resolution (18 bands; VNI: 14 bands with the range of 0.4~1.0μm; SWI: 2 bands with the range of 1~1.7μm; INF: 2 bands with the range of 8~10μm). In comparison, Landsat 8 OLI, as a common data source in the field of ecological environment, has a swath of 185km and 11 bands, and its revisit interval is 16 days. The wide-band imaging spectrometer is an important innovation, and the sensed images have been used as data source in some researches about the monitoring of coastal areas (Liu et al., 2017). Its data need to be explored and verified in the other fields, such as ecological environment, lake monitoring, agroforestry, etc. It is the first time for the Wide-band imaging spectrometer data to be used in the ecological environment evaluation and its application potential of the new type of domestic load in the ecological environment is explored.

In this study, three elements of vegetation, soil and terrain were selected to evaluate the ecological environment, and the characteristics of the study area and the availability of data were taken into consideration in the selection of the indexes. The purpose of this paper is to verify the application potential of the new domestic remote sensing data in the field of ecological environment. It is the first time to extract the vegetation index and soil index by using the data of the wide-band images and the extraction results are in good agreement with the actual situation. The follow-up study should study the theory and method of ecological environment evaluation and improve the evaluation system. In addition. Tiangong-2 has high temporal resolution, which can be used for simultaneous observation and evaluation of ecological environment, and monitoring of ecological environment changes.

5 CONCLUSIONS

(1) The ecological environment status of Kunming is good. The regions, with excellent or good ecological environment grade account for 63.29% of the total area of Kunming. The Dian Lake region and the mountainous regions with steep slope cover 31.06% of Kunming, whose ecological environment grade is medium. Regions north to the Dian Lake and other areas' environment status is worse, accounting for 5.65% of the total area in Kunming. It is helpful to improve the overall ecological environment quality of Kunming by strengthening ecological protection and restoration of the Dian Lake and its surrounding areas.

(2) The distribution of ecological environment status in each district / county is different. Fumin County and Luquan Yi and Miao Autonomous County ecological environmental status is relatively good, whose ecological environment excellent of good area ratio are 79.47% and 79.39% respectively. The ecological environment quality of Chenggong area is the worst, of which more than 60% is under poor (21.36%) or medium (41.27%) ecological environment status. The protection of the ecological environment in the central cities should be strengthened to further balance the ecological environment status distribution of different districts/ counties.

(3) This study，the ecological environment evaluation of Kunming, will not only provide the decision for Kunming's "The Belt and Road Initiative" ecological construction, but also help for the official scientific protection and restoration of ecological environment. The image of Tiangong-2 MWI has the advantages of high cutting width, spectral resolution and time resolution, which has great potential for applications in the evaluation of macro ecological environment.

(4) In the follow-up study, the evaluation index system of ecological environment will be improved by adding the indicators of biological abundance, pollution load index and environmental restriction index. Besides, the dynamic evaluation model will be set up to realize the dynamic monitoring and evaluation of the ecological environment in the key areas by combining the remote sensing image data of multi time phase.

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