Asian Agricultural Research 2015, 7(7): 50 – 56, 59

Ecological Benefits Evaluation in Ecological Migration Zone Based on Ecological Green Equivalent: A Case Study of Migration Zone in Yanchi County

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Abstract With four ecological migration zones in Huamachi Town of Yanchi County in Ningxia Autonomous Region as the object of study, we carry out the evaluation of ecological benefits in ecological migration zone. Using the SPOT satellite remote sensing image in 2008 and UAV aerophotographic image in 2013, we first monitor and analyze the land use change over five years in the study area, and then adopt ecological green equivalent evaluation model for the evaluation of ecological benefits in the ecological migration zone. Studies have shown that: (i) from 2008 to 2013, the ecological green equivalent in the study area was increased and the ecological environment was improved; (ii) the ecological green equivalent in the study area was less than 1 in 2008 and 2013, and ecological environment was still fragile in the migration zone; (iii) the forest coverage rate of the study area was 20% less than the minimum forest coverage rate of the United Nations, but 15% higher than the forest coverage rate of the Ministry of Environmental Protection. There is a large gap between the forest coverage rate based on ecological green equivalent and optimal forest coverage rate, suggesting that the land use still needs to be adjusted in study area, and it is necessary to increase efforts to strengthen ecological restoration and continue to implement forest conservation, returning land for farming to forestry and other measures.

Key words Ecological benefits, Evaluation, Green equivalent, Ecological migration zone, Yanchi County

1 Introduction

Yanchi County in Ningxia Hui Autonomous Region is a typical ecologically fragile zone in China. Since Yanchi County implemented ecological migration project and ecological restoration measures in 2002, the land use/cover in migration zone has been significantly changed, and the ecological environment has also been greatly improved. The ecological recovery process of ecological migration zone and benefit evaluation after migration directly affect the sustainability of the project implementation, and have significance to the efficient follow-up implementation of the project. The evaluation methods for regional ecological benefits at home and abroad include evaluation model based on green equivalent, evaluation method based on ecological footprint, and method based on factor analysis. Ma Liya *et al*. use the ecological footprint method to evaluate the ecological security in Yanchi County over nearly a decade[1]. Yang Xianming *et al*. evaluate the benefits of ecological migration in Ningxia based on factors from ecological, economic and social aspects[2]. Zhong Xiaojuan *et al*. make complete exposition on the evaluation index system and methods for the ecological benefits of returning land for farming to forestry[3]. Liu Junli *et al*. use factor analysis to study the ecological benefits of returning land for farming to forestry and grassland in the sandy areas of Ejin Horo Banner in Inner Mongolia[4]. However, there is no uniform recognized evaluation index system for regional ecological benefits. This paper selects four typical ecological migration zones in Yanchi County and uses high-resolution satellite remote sensing image and UAV aerial images as data sources for the dynamic monitoring and analysis of land use in the ecological migration zone. By establishing the ecological benefit evaluation model based on ecological green equivalent, this paper studies the ecological benefits of ecological migration zone from the perspective of ecological restoration, in order to provide guidance for the evaluation of ecological migration project.

2 Overview of the study area

Yanchi County is a county under the administration of Wuzhong city in Ningxia Hui Autonomous Region of the People's Republic of China. Covering a total area of 6748.86 square kilometers, it has a population of about 150000 people. The northern part of Yanchi County is adjacent to the Mu Us Desert, deeply influenced by sandstorms; its southeast borders the Loess Plateau. The transitional geographical environment results in the diversity and vulnerability of natural resources in Yanchi County[5]. It features a typical temperate continental monsoon climate, with perennial drought, frequent wind and sand and scarce water. The average annual precipitation is 250-350mm, and the annual average temperature is 8.31 ℃. The vegetation is low and sparse and mostly herb. The sierozem is the main soil type, followed by black loam soil, aeolian sandy soil, yellow soil, and a small amount of saline soil and Albic soil[6-7]. In this study, we select four typical ecological migration zones in Yanchi County as the study areas, involving two administrative villages and four natural villages.

Received: March 15, 2015   Accepted: May 13, 2015
Supported by National Natural Science Foundation of China (41161081).
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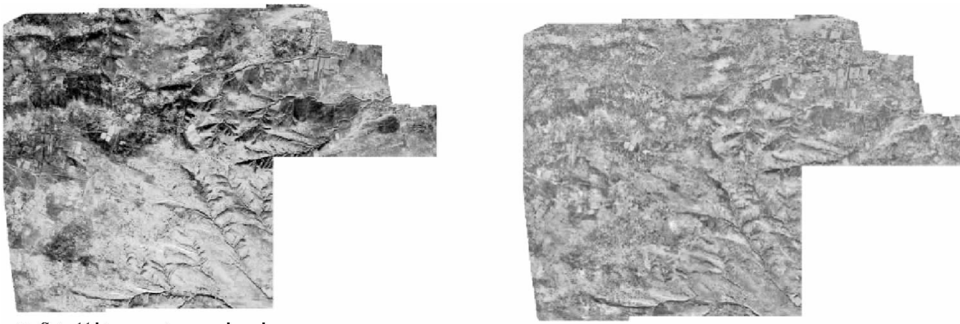
3 Data sources and research methods

3.1 Data sources

3.1.1 Satellite remote sensing image. SPOT5 satellite image has higher resolution than other satellite images such as Landsat TM\ETM and MODIS, and it is widely used in the study requiring high precision. This paper selects the SPOT5 satellite remote sensing image on September 12, 2008 in the study area, with spatial resolution of 2.5m, as shown in Fig. 1(a).

3.1.2 UAV aerophotographic image. The aerophotographic image scope covers four migrant villages such as Maiduoshan and Guanjitai in Huamachi Town of Yanchi County. The recording time is October 9, 2013; the relative flying height is 700 m; the frame size range is 1054 × 698 m; the image overlapping degree is 525 × 140 m; it carries Canon EOS 5D mark II with lens focus of 24 mm, to get UAV aerial photos. After the end of the aerial photography, the flight quality inspection software is used to check the quality of aerial photography, in line with CH/Z 3005 – 2010 *Low – altitude Digital Aerial Photography Norms*[8]. DPGrid is used to process the photos to obtain the orthophotos of the study area, with resolution of 0.2m, as shown in Fig. 1(b). UAV aerophotographic image is characterized by high precision and rich information.



(a) Satellite remote sensing image on September 12, 2008

(b) UAV aerophotographic image on October 9, 2013

Fig. 1 Comparison of satellite remote sensing image and UAV aerophotographic image

3.1.3 The land use data and other data. Land use thematic maps and other relevant information; meteorological data, statistical yearbooks, *etc*.

3.2 Technology roadmap After collecting the relevant data, we use UAV aerophotographic image in 2013 and SPOT satellite remote sensing image in 2008 as the data source. Under the geographic information system platform ArcGIS, we obtain the land use data in the study area by vector quantization, spatial overlaying and statistical analysis, and use the ecological green equivalent evaluation model to evaluate the ecological benefits in the ecological migration zone.

Table 1 Reclassification of land based on ecological green equivalent

The concept of ecological green equivalent	Land type	Merged land type
The land with green equivalent	Agricultural land	Ordinary dry land and paddy field
Garden plot	Garden plot	–
Woodland	Natural forest land, plantation land	–
	Natural grassland	Wild grassland
	Artificial grassland	Artificial pasture
	Other agricultural land	Arable land and other agricultural land in agricultural land
	Some unused land	Sparse vegetation land in unused land
The land implicitly containing green equivalent	Water body	Reed land/ponds, water surface for aquaculture, and reservoirs
The land with no green equivalent	Construction land	Land for residential, industrial and mining use, transportation land
	Unused land	Sandy land, saline land

3.3 Research methods

3.3.1 Ecological green equivalent. Ecological green equivalent is developed based on measuring the ecological compensation ability. Ecological compensation is made by natural ecosystems for ecological damage due to social and economic activity[9–10]. Forest, as the backbone of the Earth's terrestrial ecosystems, has multiple functions such as water conservation, soil and water conservation, climate improvement, atmospheric adjustment, air cleaning and biodiversity conservation[11]. The "green equivalent" means that equal amount of photosynthesis, and suitable layout, are ensured to compensate for the regional ecological functions played by certain amount of forest vegetation[12]. According to the principles of ecological green equivalent, traditional land use types can be divided into three categories as follows: (i) The land with green equivalent, including farmland, garden plot, woodland, grassland and some unused land, with the functioning mechanism of its ecosystem services similar to that of forest, which can be quantified; (ii) The land implicitly containing green equivalent, mainly referring to waters, including reed land, mudflat, ponds, water surface for aquaculture and reservoirs, with some ecological functions such as climate regulation and air cleaning (only to be research qualitatively, difficult to quantify); (iii) The land with no green equivalent, including land for residential, industrial and mining use, transportation land, water conservancy facility land and some unused land, with zero green equivalent.

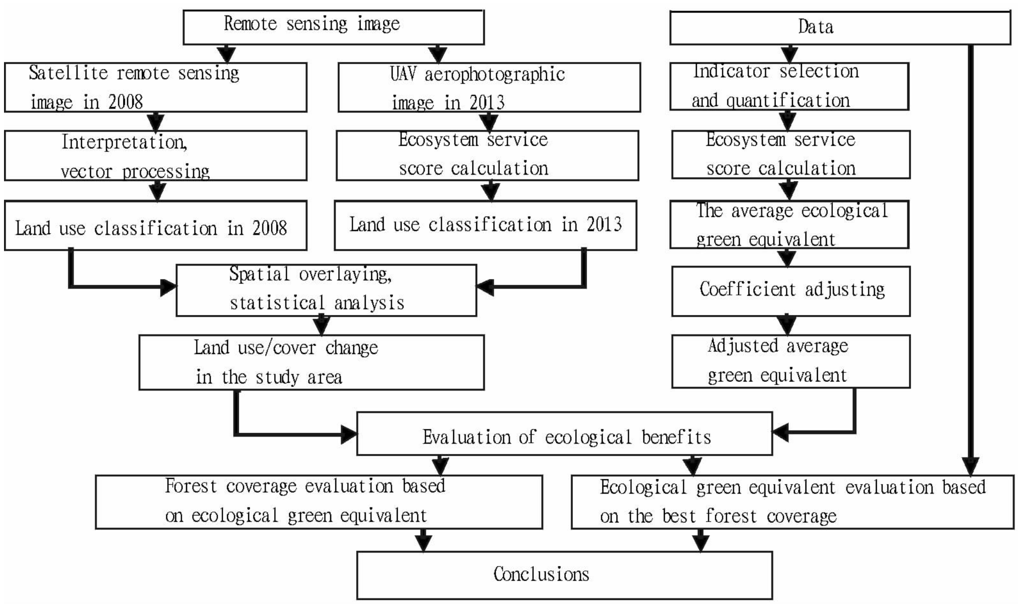


Fig. 2 Technology roadmap for evaluating the ecological benefits of migration zone

3.3.2 Indicator selection and the quantification score. According to the actual conditions of the study area, combined with fieldwork, we list 13 ecological functions from atmosphere, water, soil, natural disasters and biology, and use the rating score of Japanese experts by survey[13] to give scores to different functions, as shown in Table 2.

Table 2 The evaluation scores of various environmental functions of ecosystem

Function		Natural forest land	Plantation land	Natural grassland	Artificial grassland	Ordinary dry land	Garden plot
Atmosphere	Atmospheric composition improvement 1	9.45	9.08	6.95	7.40	6.50	6.10
	Atmospheric composition improvement 2	10.00	9.75	5.13	5.48	5.10	7.10
	Atmospheric cleansing 1	9.13	8.55	5.33	5.33	5.80	6.38
	Atmospheric cleansing 2	8.90	9.63	5.23	5.33	5.80	6.48
	Alleviation of climate change	9.45	9.28	5.23	4.90	5.40	6.26
Water	Water conservation	9.80	9.48	6.85	6.20	5.30	4.80
	Water purification	9.45	8.65	8.15	6.43	6.70	5.83
	Preventing sand and soil collapse	9.58	8.95	7.73	7.18	5.40	5.63
Soil	Preventing surface erosion	9.78	8.85	8.38	7.73	5.30	7.15
	Preventing ground subsidence	5.83	7.70	6.78	6.20	5.25	6.78
	Pollutant removal	8.40	8.13	7.28	7.40	8.10	6.20
Space	Preventing the occurrence of disasters	9.73	8.75	7.50	7.60	7.30	7.88
	Maintaining the landscape	9.12	8.45	9.45	7.93	7.00	7.65
Organism	Biodiversity conservation	9.80	7.83	6.63	5.10	4.60	4.90
	Preventing harmful animals and plants	6.95	5.65	5.63	6.18	6.00	5.73

Note: Evaluation significance (10 maximum; 7.5 large; 5 small); atmospheric composition improvement 1 (absorption of CO_2); atmospheric composition improvement 2 (producing O_2); atmospheric cleansing 1 (dust absorption); atmospheric cleansing 2 (toxic gas absorption).

3.3.3 Calculation of ecological service value and average ecological green equivalent of various ecosystems. We use the following formula to calculate the ecosystem service value of each type of vegetation:

$$P = \sum_{i=1}^{13} F_i$$

where P is total score of ecosystem services; F is the indicator value; i is the number of indicators in the indicator system.

The ecological service value is as follows: woodland (132.05); natural grassland (102.25); artificial grassland (96.39); ordinary dry land (89.55); garden plot (94.87). Thus, compared with the ecological service value of natural forest land, it is defined as follows:

$$X_i = F_i / F_{forest}$$

where X_i is the ecological green equivalent of surface green cover ecosystem i; F_i is the total ecological service value of surface green cover ecosystem i; F_{forest} is the total ecological service value of forest land ecosystem.

The green equivalent of ecosystems is as follows: woodland

(1.00); natural grassland (0.77); artificial grassland (0.73); ordinary dry land (0.68); garden plot (0.72). Taking into account different crop growth period and cropping system in different regions, according to the findings of Liu Yanfang[14], the green equivalent of each ecosystem calculated above needs to be multiplied by a growth period factor relative to year-round full planting, as shown in Table 3. The study area, located in the Northwest inland, has a desert oasis agricultural ecosystem, with one crop per year, and the growth period factor relative to year-round full planting is 0.46. Thus, the adjusted annual average green equivalent of various ecosystems is as follows: woodland (1.00); natural grassland (0.36); artificial grassland (0.34); ordinary dry land (0.31); garden plot (0.33).

Table 3 The growth period factor relative to year-round full planting

Type	Northeast and Northwest temperate regions	North warm temperate regions	Southwest and Southeast tropical regions		Subtropical regions
			Three crops two years	Two crops a year	
Cropping system	One crop a year	Two crops a year	Three crops two years	Two crops a year	Three crops a year
The growth period factor relative to year-round full planting	0.46	0.67	0.50	0.67	0.83

4 Evaluation of ecological benefits in the ecological migration zone

4.1 Current land use in the study area In accordance with *National Land Classification*, using ArcGIS, we divide the ecological migration zone into four parts based on the UAV aerophotographic image in 2013 and satellite remote sensing image in 2008. We extract the spatial range of four migration zones and perform the vector quantization on land use, as shown in Fig. 3. According to the land use classification based on green equivalent, the area of each land use type re-classified is calculated, as shown in Table 4. Based on the above data, there were great changes in the area of various land use types in the study area over the five years. There were the greatest changes in the area of plantation land and ordinary dry land. The cumulative area of plantation in four zones increased from 134.90 ha in 2008 to 236.85 ha in 2013, while the cumulative area of ordinary dry land decreased from 158.24 ha in 2008 to 53.27 ha in 2013. The ecological migration project was at the peak in 2008, so there was a dramatic increase in the area of natural grassland and natural forest land. Zhaojiliang and Majiliang are located in hilly and gully regions, and in recent years, the ecological construction is being carried out in Yanchi County. The natural grassland on both sides of gully was converted to plantation land, the area of artificial grassland decreased and the area of plantation land increased.

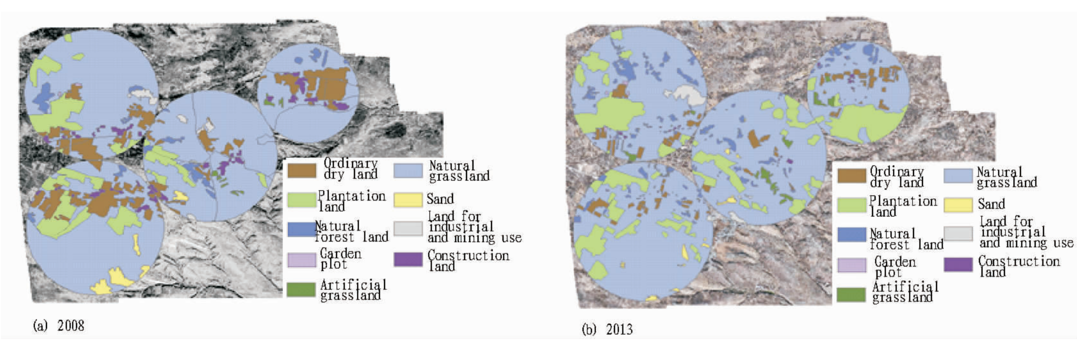


Fig.3 Land use classification vector map

Table 4 Changes in various land use types in 2008 and 2013

Different ranges	Time	Area of various land types//ha								The total area ha
		Natural forest land	Plantation land	Natural grassland	Artificial pasture	Ordinary dry land	Garden plot	Construction land	Unused land	
Maiduoshan	2008	11.26	53.43	273.70	0.00	40.33	0.63	12.28	0.00	391.63
	2013	22.89	67.42	268.32	2.13	15.38	1.66	13.83	0.00	391.63
Guanjitai	2008	3.72	59.62	271.16	0.00	56.83	0.00	8.67	17.56	417.56
	2013	8.51	63.25	326.11	0.00	13.37	0.00	1.60	4.72	417.56
Zhaojiliang	2008	6.81	21.85	325.57	2.68	19.23	0.00	16.14	4.80	397.08
	2013	10.63	49.93	314.69	7.91	7.48	0.00	3.77	2.67	397.08
Majiliang	2008	4.94	0.00	167.79	2.25	41.85	0.00	10.63	0.00	227.46
	2013	8.84	56.25	139.76	3.84	17.04	0.00	1.73	0.00	227.46

4.2 Evaluation of ecological benefits based on ecological green equivalent under the best forest coverage standards Assuming the total regional area is S_{total}, the best regional forest coverage is R, the regional woodland area in accordance with the requirements of the best forest coverage is S_{forest}, the actual regional woodland area is S_{actual}, the area of land type i is S_i, the green equivalent is g_i($i = 1, 2, 3 \ldots$), then:

(i) Determining the best regional forest coverage rate. Here based on the research methods of Zhang Jian *et al.* [15-18], according to the regional precipitation, forest soil saturation, and forest soil saturated water storage capacity, we calculate R as the reference standard for regional ecological assessment. The formula is as follows:

$$R = (P \times S_i)/(W \times S_{total}) \times 100\%$$

where P is the maximum precipitation within one year (t/ha); $S_i = S_{total}$ − (area of transportation land, industrial and mining land, paddy field and waters) (ha); W is the saturated water storage capacity per unit area of forest soil (t/ha).

(ii) Calculating the forest area under the requirements of the optimal forest coverage rate R, with the corresponding green equivalent of 1. It is calculated as follows:

$$S_{forest} = S_{total} \times R$$

(iii) Calculating the regional actual ecological green equivalent of woodland X_{forest}. It is calculated as follows:

$$X_{forest} = S_{actual}/S_{forest}$$

(iv) Calculating the total regional ecological green equivalent X_{total}. It is calculated as follows:

$$X_{total} = X_{forest} + \Sigma S_i \times g_i / S_{forest} \times 100\%$$

According to the data provided by departments of agriculture, meteorology and forestry in Yanchi County, the daily maximum precipitation within a year is 778 t/ha, and the saturated water storage capacity per unit area of forest soil is 855.42 t/ha. According to the above calculation method for ecological green equivalent, combined with land use data in 2008 and 2013, we calculate the best forest coverage rate and ecological green equivalent in the study in 2008 and 2013, as shown in Table 5.

From Fig. 4, it can be found that: (i) The ecological green equivalent of woodland and natural grassland make great contribution to regional ecological green equivalent, woodland is mainly natural forest land and plantation land after returning land from farming to forestry, and natural grassland is mainly wild grassland; (ii) The ecological green equivalent in 2008 and 2013 was less than 1 in the study area, indicating that the regional ecological environment is fragile, and there is a need to continue to implement some measures such as returning land from farming to forestry; (iii) From 2008 to 2013, the ecological green equivalent in the study area was increased, and the ecological environment of the study area was improved; (iv) The green equivalent value of natural grassland in Maiduoshan and Guanjitai shows an increasing trend, in line with the actual situation of forest conservation and natural grassland protection in these regions; the green equivalent value of natural grassland in Zhaojiliang and Majiliang shows a decreasing trend, in line with the actual situation of location in hilly areas and the implementation of afforestation measures; (v) The ecological green equivalent value in Guanjitai shows the slightest increasing trend, mainly due to the flat terrain and slight change in the proportion of natural grassland in 5 years.

Table 5 The ecological green equivalent in 2008 and 2013

Different ranges	Time	Best coverage R//%	Best forest area S_{forest}/ha	Ecological green equivalent					
				X_{forest}	$X_{natural\ grassland}$	$X_{artificial\ grassland}$	$X_{ordinary\ dry\ land}$	$X_{garden\ plot}$	X_{total}
Maiduoshan	2008	0.881	345.017	0.187	0.286	0.000	0.036	0.001	0.510
	2013	0.877	343.607	0.263	0.289	0.002	0.014	0.002	0.570
Guanjitai	2008	0.852	355.913	0.178	0.274	0.000	0.049	0.000	0.502
	2013	0.896	374.021	0.192	0.312	0.000	0.011	0.000	0.515
Zhaojiliang	2008	0.862	342.097	0.084	0.343	0.003	0.017	0.000	0.446
	2013	0.895	355.285	0.170	0.319	0.008	0.007	0.000	0.503
Majiliang	2008	0.867	197.206	0.025	0.306	0.004	0.066	0.000	0.401
	2013	0.903	205.300	0.317	0.245	0.006	0.026	0.000	0.594

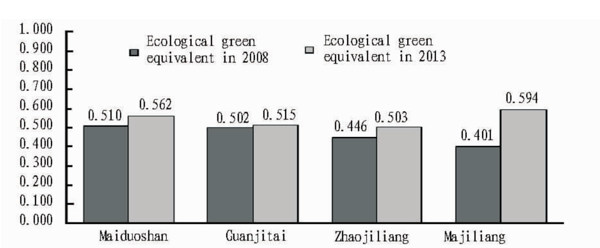


Fig. 4 Comparison of ecological green equivalent in ecological migration zone

4.3 Evaluation of ecological benefits of forest coverage rate based on ecological green equivalent Forest coverage rate can reflect the soil erosion, environmental quality and per capita green space to a certain extent. Here we refer to the formula of Liu Fangyan *et al* [14] for forest coverage rate based on ecological green equivalent:

Forest coverage rate based on ecological green equivalent = Regional woodland area + Woodland area converted from the area of other land with green equivalent/ Total regional land area (Table 6).

The results show that in 2008, the forest coverage rate based on ecological green equivalent in Maiduoshan, Guanjitai, Zhaojiliang and Majiliang was 44.92%, 42.77%, 38.47% and 34.77%, respectively, an increase of 4.34%, 3.34%, 6.58% and 18.86%, respectively, compared to 2013. The increase in the actual forest coverage rate indicates that the ecosystem conditions in the study area are gradually improved (Table 7). According to the average forest coverage rate of not less than 20 % established by the United Nations as the lowest limit of forest ecology[14] and the forest coverage rate of not less than 15% established by the State Environmental Protection Administration for the plain areas, based on Table 6, 7, the actual forest coverage rate in Maiduoshan, Guanjitai, Zhaojiliang and Majiliang was significantly lower than the lowest limit of forest ecology at 20% in 2008; the forest coverage rate in Maiduoshan and Guanjitai floated around 15% established by the State Environmental Protection Administration; the forest coverage rate in Zhaojiliang and Majiliang was significantly lower than the 15% target. It suggests that after the projects of ecological migration and returning land from farming to forestry were fully implemented in the study area from 2002 to 2008, the ecological environment was improved. As shown in Fig. 5, the forest coverage rate based on ecological green equivalent was increased from 44.92%, 42.77%, 38.47% and 34.77% in 2008 to 49.27%, 46.11%, 45.04% and 53.63% in 2013, respectively, indicating that the ecological environment was gradually improved and ecological benefits were gradually increased. As can be seen from Fig. 5 the actual forest coverage rate in the study areas is far below the current best forest coverage rate, and the proportion of forest coverage rate based on ecological green equivalent in the study areas to the best forest coverage rate is 56.18%, 51.46%, 50.32% and 59.39%, respectively, indicating that the ecological environment of the study area needs to be further improved and the migration zone can adjust land use structure and continue to implement the afforestation and other measures to strengthen ecosystem stability and increase the ecological benefits in the ecological migration zone.

Table 6 The converted green equivalent value and forest coverage rate based on ecological green equivalent in the ecological migration zone Unit: ha

Different ranges	Time	Land types	Types			Total	Forest coverage rate based on ecological green equivalent
			Area	Green equivalent	Converted area		
Maiduoshan	2008	Woodland	64.690	1.00	64.690	175.932	44.92%
		Natural grassland	273.700	0.36	98.532		
		Artificial grassland	0.000	0.34	0.000		
		Ordinary dry land	40.330	0.31	12.502		
		Garden plot	0.630	0.33	0.208		
	2013	Woodland	90.310	1.00	90.310	192.945	49.27%
		Natural grassland	268.320	0.36	96.595		
		Artificial grassland	2.130	0.34	0.724		
		Ordinary dry land	15.380	0.31	4.768		
		Garden plot	1.660	0.33	0.548		
Guanjitai	2008	Woodland	63.340	1.00	63.340	178.575	42.77%
		Natural grassland	271.160	0.36	97.618		
		Artificial grassland	0.000	0.34	0.000		
		Ordinary dry land	56.830	0.31	17.617		
		Garden plot	0.000	0.33	0.000		
	2013	Woodland	71.760	1.00	71.760	192.538	46.11%
		Natural grassland	323.980	0.36	116.633		
		Artificial grassland	0.000	0.34	0.000		
		Ordinary dry land	13.370	0.31	4.145		
		Garden plot	0.000	0.33	0.000		
Zhaojiliang	2008	Woodland	28.660	1.00	28.660	152.738	38.47%
		Natural grassland	325.570	0.36	117.205		
		Artificial grassland	2.680	0.34	0.911		
		Ordinary dry land	19.230	0.31	5.961		
		Garden plot	0.000	0.33	0.000		
	2013	Woodland	60.560	1.00	60.560	178.857	45.04%
		Natural grassland	314.690	0.36	113.288		
		Artificial grassland	7.910	0.34	2.689		
		Ordinary dry land	7.480	0.31	2.319		
		Garden plot	0.000	0.33	0.000		
Majiliang	2008	Woodland	4.940	1.00	4.940	79.083	34.77%
		Natural grassland	167.790	0.36	60.404		
		Artificial grassland	2.250	0.34	0.765		
		Ordinary dry land	41.850	0.31	12.974		
		Garden plot	0.000	0.33	0.000		
	2013	Woodland	65.090	1.00	65.090	121.992	53.63%
		Natural grassland	139.760	0.36	50.314		
		Artificial grassland	3.840	0.34	1.306		
		Ordinary dry land	17.040	0.31	5.282		
		Garden plot	0.000	0.33	0.000		

Table 7 The forest cover ratio in different study areas

Study areas	Time	Forest coverage rate		
		Actual forest coverage rate	Forest coverage rate based on ecological green equivalent	The best forest coverage rate
Maiduoshan	2008	16.52%	44.92%	–
	2013	23.06%	49.27%	87.70%
Guanjitai	2008	15.17%	42.77%	–
	2013	17.19%	46.11%	89.60%
Zhaojiliang	2008	7.22%	38.47%	–
	2013	15.25%	45.04%	89.50%
Majiliang	2008	2.17%	34.77%	–
	2013	28.62%	53.63%	90.30%

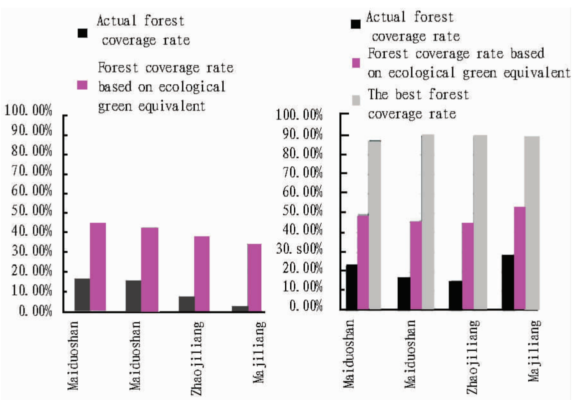


Fig. 5 The forest coverage rate in different study areas

5 Conclusions

(i) This paper explores the application of high-resolution image combined with the evaluation model of ecological green equivalent to evaluate the ecological benefits of the ecological migration zone in Yanchi County, and analyzes the status and trends of ecological benefits, which is of positive significance to the protection and improvement of the regional land ecological environment. The result shows that the from 2008 to 2013, the eco-environmental quality of the study areas was gradually improved, but the ecological green equivalent value was less than 1, the ecological environment of the migration zone was still relatively fragile, and the regional land use planning needs further adjustment. The result is in line with the restoration status of the ecological migration zone in Yanchi County and policy implementation results of ecological civilization county construction. (ii) UAV aerial photography system has a strong advantage in the small-scale operation due to its fast, high-precision image acquisition features. The UAV aerophotographic image in 2013 selected in this study has high resolution and the attribute extraction accuracy of various ground objects. Using remote sensing and geographic information system technology, we perform the dynamic monitoring and analysis on two-phase images of the study area in space and time, and the data accuracy is reliable. In the future survey, with the improvement of UAV aerial photography and reduction of relevant operation costs, the scope of survey can be further expanded. (iii) The study fully exploits the ecological service functions of all kinds of ecological land, and uses the ecological green equivalent to conduct quantitative research on the ecological restoration in Ningxia's ecological migration zone. It breaks through the limitations of traditional research based on extensive statistics, and improves the scientificity and operability of ecological evaluation, in order to provide a reference for the evaluation of restoration and benefits of related ecosystems.

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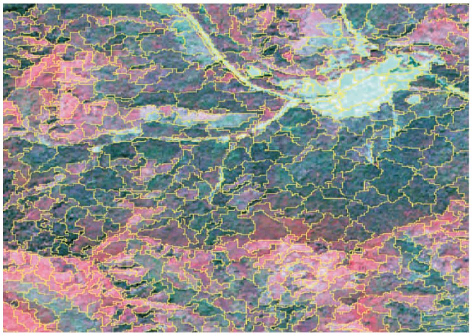

Fig. 3 Segmentation result

Having found that conifer and broad-leaved trees obviously different in reflecting near-infrared band, we separate them mostly under this condition. Comparing the sample data, pine and spruce have the detailed difference; we add the panchromic band information to separate these two kinds. As for oak and birch, we use the standard deviation of near-infrared band to identify them because they're so similar in spectral reflectance, so we have to find some texture difference as additional information in this process. The whole process is expressed Fig. 2 and segmentation result showed in Fig. 3. We can get the classification result showed in Fig. 4. We can see clearly in the image that non-forest area could be clearly seen in the red color though there are some shadow areas were wrong classified. The dominant tree species were extracted. And we can see most area covers the pine and this was the same with the truth. And there were still some broad-leaved tree species could not be identified.

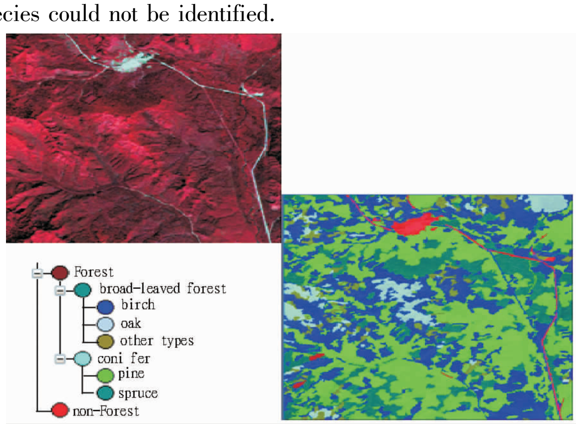

Fig. 4 Original image and classification result

In this paper, we evaluated the classification result by confusion matrix showed in Table 1. We got a high accuracy in classifying conifer forest while the oak and the birch were not that easily separated. Basically, we extracted the dominant tree species who occupied at least 65% space of sample area.

Table 1 Confusion matrix of result

overall accuracy = 0.87

Kappa coefficient = 0.83

Classes	Spruce	Pine	Birch	Oak	Total
Spruce	90	0	0	0	90
Pine	0	100	0	0	100
Birch	0	0	70	40	110
Oak	0	0	10	10	110
Total	90	100	80	50	

3 Conclusions

We can classify most of the dominant tree species in the study area. Derived from the true sample, we can conclude that due to the differences of the spectral and texture information between each kind, we can separate conifer forest and broad leaved forest, spruce and conifer , and even oak and birch. We can identify the tree category if it takes 70% space of a sample area. Choosing some object as validations, we can get all the accuracy assessment indexes clearly in the confusion matrix. The overall accuracy is about 87% and the kappa coefficient is 0.837. It reflects a high accuracy in this classification and it shows the potential to identify more detailed tree species using object-based analysis. Conclusion and Future Work: From an object we can not only get the spectral information but also texture that will help a lot in the classification. It provides us so many characteristics to express each class and make it easy to find some effective clues to extract what we need. However, our study also has some problems. (i) We can only identify the dominant tree species which occupied 65% of whole area. As to a more complicated situation, we still cannot solve. (ii) The accuracy assessment process is not that rigorous because we only have the point samples, for a further study we should use polygon samples. (iii) These thresholds used in the experiment were settled based on the data we use, as for other situations, they may not fit. (iv) We have not made any quantitative assessment of the segmentation result. Next, we can try to find a good way to assess it.

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