VEGETATION COVER CHANGE MONITORING AND ANALYZING IN HUANGHE-HUAIHE-HAIHE ZONE BASED ON MULTI-SOURCE INFORMATION FUSION

Chen Huailianga* Liu Zhongyanga Jiang Qingxiab

a Henan Institute of Meteorology, Zhengzhou, 450003; b Luohe Meteorological Bureau, Luohe, Henan, 462000

Commission VII, WG VII/5

KEY WORDS: Holdridge Unsupervised Classification; Yellow River-Huai River-Hai River Area; Multi-source Information; Changing of Vegetation Coverage

ABSTRACT:

Vegetation, as the comprehensive reflection of climate and other environmental elements, is closely related with climate changes. The article, on the basis of Holdridge life zone index method and the unsupervised classification method, the climate data, NDVI data and DEM data in 1982, 1992 and 2002 of the research area as well as the multi-source information after amalgamation, undertakes unsupervised classification and concludes the vegetation coverage changing map from 1982 to 2000 in the Yellow River-Huai River-Hai River area after post-classification processing, space analysis and data development. According to the result, the vegetation coverage changes slowly and consistently in the Yellow River-Huai River-Hai River area in the past nearly 20 years. The areas with relatively fierce changes are mainly located at the meeting part between the 1st and 2nd terrain stages, the area around the 400mm annual precipitation line, the hill area in Shandong and the lower reach area of the Huai River.

The promotion of classification accuracy has been always the focus of the research on abstracting the information on vegetation coverage types with the method of remote sensing classification. With the consistent discovery of new remote sensing data sources, the new methods on promoting the classification accuracy come one after another, among which data amalgamation is one of the best. Data amalgamation is widely applied into multi-sources image composition, automatic contact identification, target check and tracking and the smart instrument system of robots. In the field of remote sensing, data amalgamation refers to the technology which smartly compounds the mutli-sources images in the same area to produce the analysis results more diversified, accuracte and reliable than the single data source. Compared with single data source, multi-sources image amalgamation is information. analysis[1,2]The types and distribution of the vegetations on the surface of the land are decided by three factors including solar energy, precipitation and humidity[3]. Vegetation is the comprehensive reflection of climate and other environmental elements[4]. Each climate type or region has its own types of vegetations[5]. That is to say, vegetation and climate are correspondent to each other. In view of the relativity between vegetation and climate, it is possible to undertake vegetation coverage classification on the basis of the relations between comprehensive climate index and the distribution of regional natural vegetations.

The article, using the NOAA/AVHRR NDVI time sequence series of image and adopting the classification method of multi-times remote sensing in combination with accessory data {namely, the remote sensing vegetation coverage classification method with multi-sources information amalgamation including vegetation (NDVI), climate (temperature, precipitation and evapotranspiration) and terrain (DEM)}, classifies the vegetation coverage in the Yellow River-Huai River-Hai River area and analyzes the annual changing characters.

1 INTRODUCTION TO THE RESEARCH AREA AND THE SOURCE OF DATA

1.1 Introduction to the research area

The Yellow River-Huai River-Hai River Plain (110°E~123°E，32°N~42°N), located at eastern China, meets Bohai Sea and the Yellow Sea in the east, lies on the Taihang Mountain and the Tongbai Mountain in the west, and reaches the Great Wall in the north and the Huai River in the south. It covers the most territories of Beijing, Tianjin, Hebei, Shandong and Henan in the middle and lower reaches of the Yellow River, Huai River and Hai River, northern Jiangsu, northern Anhui and the Fenwei Basin on the branches on the Yellow River[7]

1.2 Source of data and its pre-processing

The data on remote sensing of the article comes from NASA GIMMS NDVI, with the space differentiating rate of 8 km×8 km and the time differentiating rate of 15d. The data has gone through air correction and maximum compound and turns to the monthly NDVI data in three years of 1982, 1992 and 2002. The national 1:250,000 DEM and the national fundamental geological data with the scale of 1:250,000, 1:1,000,000 and 1:4,000,000 all come from the State Fundamental Geological Information Center. The DEM data, through rounds of strict geometrical emendation, correction and projection processing, matches with the NDVI data reference frame. The data on vegetation types comes from the China Resources Environment Data (1:4,000,000) finished by the National Lab of the Resrouces and Environmental Information System of Geological Institute of Chinese Academy of Science on the basis of the land resources satellite. The design of code of Chinese vegetations follows the classification system of the Map of China Vegetation Classification ((1:4,000,000) [6]. During the classification and accuracy examination, the Collection of China Vegetations (1:1,000,000) [7] is also referred to. The data on annual precipitation and temperature from the 122 basic and standard meteorologic stations comes from the Meteorological Bureau of China.

2 RESEARCH METHODS

2.1 oldridge Life Zone Classification System

According to the researches in recent years, Holdridge's method has been considered to the most delicate and finest vegetation-climate classification system in the methods for the calculation of the relations between vegetation colonies and climates[8]. It is a formula expressing the nature of natural vegetations with simple climate indexes including annual average BT, annual P and annual PER[9,10]. BT refers to the average temperature helpful to the nutrition increasing of plants. It is considered to be 0-30℃. The temperature lower than 0℃ and higher than 30℃ shall be considered to be 0℃ or 30℃ during the calculation. Possible evapotranspiration is the function of temperature and PER is the ratio between PET and P[4]. Here follows the formula：

$$BT = \sum T/12 \quad (1)$$

$$PET = BT \times 58.93 \quad (2)$$

$$PER = PET / P = BT \times 58.93 / P \quad (3)$$

2.2 Classification technology processes

The research, using the data sources of mutli-sources data compound images including PE index, NOAA/AVHHR NDVI time sequence series of images and GE, adopting the geological information system software of ArcGIS and the image processing software of Erdas as the data processing stages and taking unsupervised classification as the classification method, classifies the vegetation coverages in the Yellow River-Huai River-Hai River area in 1982, 1992 and 2002 (See processing diagram 1)

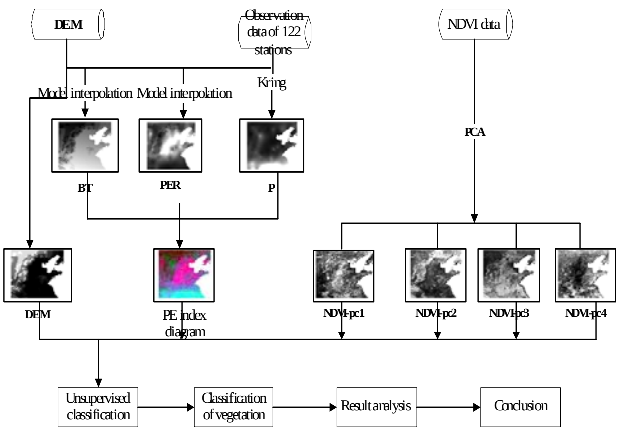

Diagram 1 Classification process of vegetation coverages in the Yellow River-Huai River-Hai River area

3 AMALGAMATION OF MUTLI-SOURCES SPACE INFORMATION

3.1 Creation of PE image of possible evapotranspiration index in the Yellow River-Huai River-Hai River area

According to formula 1, BT image of the Yellow River-Huai River-Hai River area is created and the formulas (formula 4-6) concerned with BT, Lo, La and A in 1982, 1992 and 2002 are concludd with the multi-regression method by adoptig the data from 122 stations.

$$BT=-4.604Lo-0.975La-0.037A+423.925 \quad (4)$$

$$BT=.825Lo-0.919La-0.036A+423.110 \quad (5)$$

$$BT=-4.941Lo-1.007La-0.037A+446.051 \quad (6)$$

According to formulas 4 to 6, the annual average BT of each grid point in the Yellow River-Huai River-Hai River area on the basis of DE is worked out and the BT image is also processed by regression. The annual P image in 1982, 1992 and 2002 is created by interpolating the annual precipitation of the 122 stations with the Kriging Method. According to formula 3, each grid point calculation of BT and P images is undertaken to get the PER image in 1982, 1992 and 2002.

Through amalgamating the digital images of PER, BT and P, the multi-wavebands image is created. Through the principal component analysis, the first main composition is chosen as the PE index image in the Yellow River-Huai River-Hai River area in 1982, 1992 and 2002 (see Figure 2).

3.2 Creation of NDVI and DEM images in the Yellow River-Huai River-Hai River area

Through amalgamating the NDVI data from Jan. to Dec. in 1982, 1992 and 2002, the multi-wavebands image including 12 wavebands is created. In order to get rid of the unnecessary information on the multi-waveband, the 4 former main wavebands of each year (the accumulative information of the 4 former main wavebands are 92.19%, 92.84% and 93.29%) are chosen as the lofic wavebands in the classification for the analysis on main compositions. The 4 main wavebands also go through regression processing (see Figure 3-5). The DEM image of the Yellow River-Huai River-Hai River area is created with the software of ArcGIS. After going through regression processing, the regional DEM images (see Figure 6) are created.

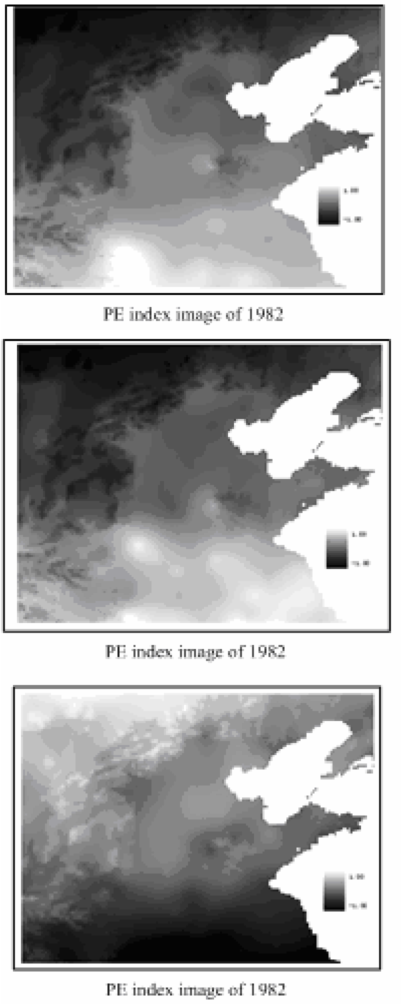

Figure 2 P E index image of 1982, 1992 and 2002

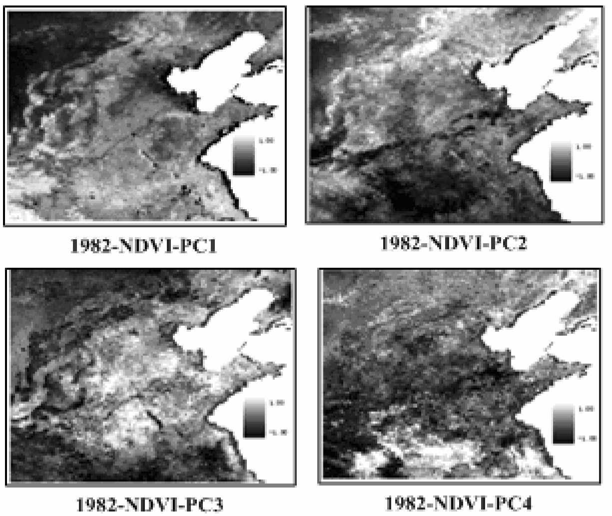

Figure 3 4 former main wavebands images of NDVI in 1982

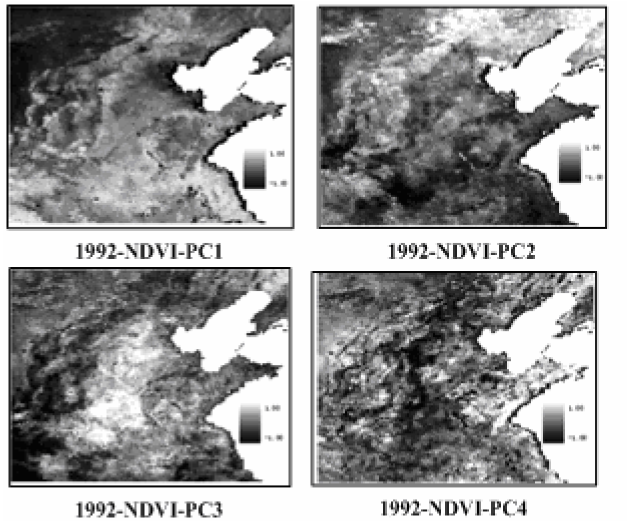

Figure 4 4 former main wavebands images of NDVI in 1992

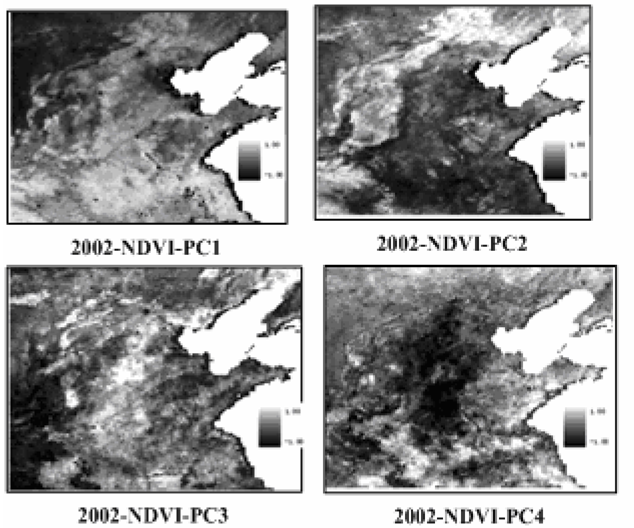

Figure 5 4 former main wavebands images of NDVI in 2002

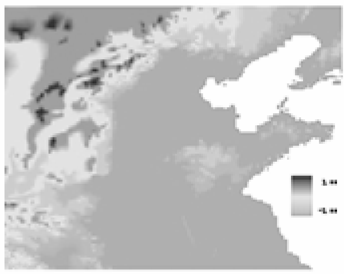

Figure 6 DEM of the Yellow River-Huai River-Hai River area after regression processing (1:250,000)3.3 Amalgamation of multi-sources images

The research, by comprehensively considering the effects of vegetation, climate and terrain on the classification of vegetation coverage and adopting the 4 former main wavebands image of NDVI, PE index image and DEM image as the basic parameters on controlling the vegetation coverage distribution pattern in the Yellow River-Huai River-Hai River area, creates the multi-sources images of 1982, 1992 and 2002 in the research area after amalgamation with the pixel position matching method with the ArcGIS software and undertakes colorful compounding at last (see Figure 7).

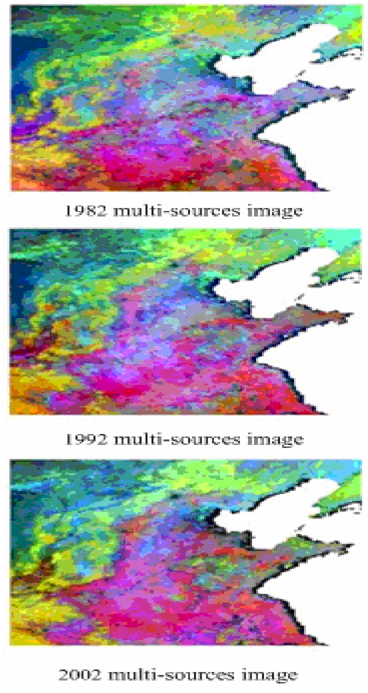

Figure 7 Colorful synthetical map after multi-sources data amalgamation in 1982 (left), 1992 (central) and 2002 (right)

4 ANALYSIS ON COMPREHENSIVE VEGETATION COVERAGE CLASSIFICATION AND ITS ACCURACY ON THE BASIS OF MULTI-SOURCES SPACE INFORMATION

4.1 Unsupervised classification

The common large-scale vegetation coverage classification methods with AVHRR NDVI image are supervised and unsupervised classifications. As for supervised classification method, it is hard to provide various transcendent distribution information as well as its probability[11], so that higher classification accuracy may be difficult to be achieved[12]. Unsupervised classification method, comparatively speaking, is simple in operation which needs no transcendent distribution information, but it is also possible to lose some detailed and important information. Therefore, it is necessary to have post-classification processing[13]. IGBP's DIScover Global Vegetation Coverage Data Sets, with the 1km AVHRR NDVI image, is the typical example of undertaking regional or global unsupervised classification[14,15].

On the basis of the recognition to the vegetation coverage types and vegetation distribution in the region and the data like Chinese vegetation maps and documents, it is confirmed that there are about 12 types of vegetation coverages. Under the assistance of the Unsupervised Classification module of ERDAS software, the types are set into 40 clusters, with the iterative times of 40 (Actual iterative times shall be 12.) and the unit length of 0.985. Through computer automatic classification, the results are relatively mixed with some mistakes. In order to reduce the negative effect on the later analysis[16], the raster classification maps shall be processed after classification, including type selection, type combination and type superposition. After transforming the raster map into vectorgraph, the subject maps (see Figure 8) are finally created through compounding the mixed parts, optimizing the details, filling hollows and compiling the natures.

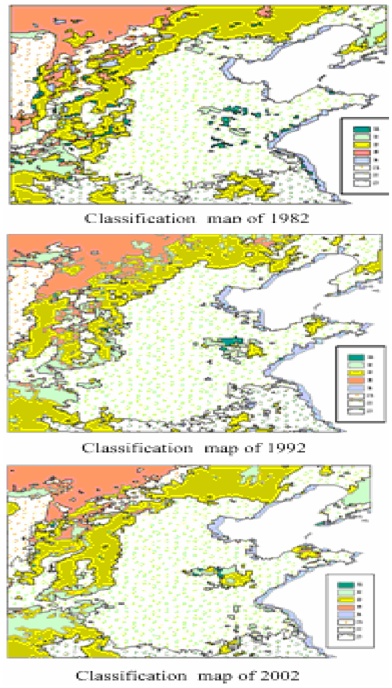

Figure 8 Special maps on vegetation coverage types in 1982, 1992 and 2002

4.2 Analysis on the accuracy of unsupervised classification

The research, using the China Vegetation Classificatin Map (1:4,000,000) [6] and the Map Collection of China Vegetations (1:1,000,000)[7] (finished in 1990-1994) as the reference of classification accuracy examination, undertakes accuracy examination of 1982 and 1992 respectively. Since there is no vegetation type examination data in the same period of 2002, the article has no accuracy examination to the classification of 2002. In addition, due to the time limitation (28-5 years) of classification targets compared with the year of 2007, the vegetation types

Type accuracy evaluation is adopted in accuracy examination on the types and locations of the remote sensing classification results. Several independent samples will be chosen randomly, the mixed matrix will be established and the drawing accuracy, users accuracy and Kappa index[17-21] will be calculated. According to the examination, the Kappa indexes in 1982 and 1992 are 0.79 and 0.78, with the general accuracy reaching 0.85 and 0.84, which are pretty accurate. It indicates that it is relatively reliable to undertake unsupervised classification for the multi-sources data after amalgamating the PE data and DEM data from meteorologic data with the 4 former main wavebands by adopting the monthly NDVI index.

5 ANALYSIS ON THE RESULT OF VEGETATION COVERAGE CHANGES

5.1 Data abstraction

In order to research on the space distribution of vegetation coverage changes in the research area, the space distribution map on the vegetation coverage types of the Yellow River-Huai

River-Hai River area from 1982 to 1992 and from 1992 to 2002 is worked out on the basis of ArcGIS9.2 (see Figure 9). Meanwhile, the transferring matrix is also calculated to reveal the changes and sources of each type of vegetation coverage[22], so that the space changes of vegetation coverage can be expressed. Please refer to the Table 1, Table 2 and Table 3.

The article, from the aspect of vegetation coverage changes, also researches on the time changing characters of the vegetation coverage in the past nearly 20 years in the research area. The dynamic degree of vegetations, which is widely applied to the measuring of the land using/coverage changing in the research area, is capable of describing the changing speed of the quantity of the vegetation in the research area[22-23]. It is active for comparing the difference of vegetation changing area and predicting the development of vegetation quantity in the future[24-27]. The dynamic degree of vegetations includes single dynamic degree and comprehensive dynamic degree[22].
The formula of single dynamic degree is：

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \qquad (7)$$

The formula of comprehensive dynamic degree is：

$$L_C = \frac{\sum_{i=1}^{n} \Delta L_{Ui-j}}{\sum_{i=1}^{n} L_{Ui}} \frac{1}{T} \times 100\% \qquad (8)$$

In formula 7, Ua and Ub refer to the quantity of a certain type in the beginning and ending of the research; T refers to the time duration of the research. In formula 8, LUi refers to the area of No. i type from the starting time of the monitoring; ⊿LUi-j refers to total area of other types transferring from the No. i type of vegetation coverage during the monitoring period; T refers to the time duration of the research.

According to the formulas on dynamic degree, the vegetation chaning situation is calculated in the research area. In case T is 10a, then the annual dynamic degree of single type of vegetation coverage as well as the annual changing rate on the research area is concluded just as what is showd in Table 1-3 to reflect the changing speed of the quantity of vegetation coverage types in the past nearly 20 years of the research area.

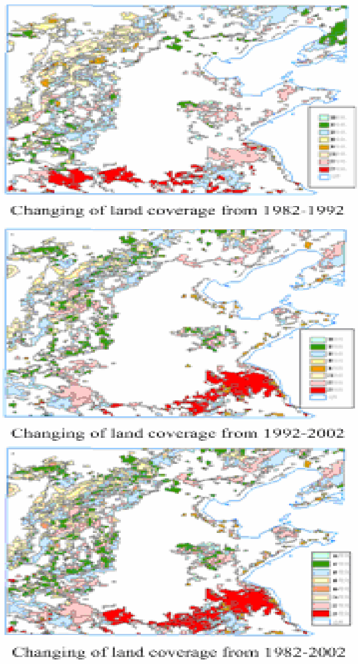

Figure 9 Space distribution of vegetation coverage changing

Year	1992									
	Type	11	12	13	15	16	21	22	23	Annual dynamic degree
	11	**7.34**	15.59	20.81	5.75	3.17	1.86	43.43	2.06	-6.43
	12	0.11	**34.10**	19.39	5.62	0.00	0.37	40.41	0.00	6.13
	13	0.35	10.35	**59.74**	6.37	0.18	1.10	17.28	4.63	-0.62
	15	0.00	14.66	8.56	**67.98**	0.00	5.87	2.93	0.00	-1.34
1982	16	0.52	0.01	14.54	1.64	**71.19**	7.27	2.88	1.95	0.79
	21	3.05	15.85	22.54	0.00	0.00	**51.70**	6.86	0.00	-3.17
	22	0.31	2.02	4.73	0.54	2.00	0.02	**86.91**	3.46	0.82
	23	0.00	0.04	12.77	0.00	1.22	0.00	23.91	**62.05**	-0.87
Whole research area										2.96
					Kappa=0.63					

Note: 11: taiga; 12: latifoliate forest; 13: shrubbery and bushes; 15: grassland and grassland with rare trees and bushes; 16: meadow and herbage meadow; 21: crops and coldness-resistant economic crops with one cultivation in one year; 22: crops with two cultivations in one year or three cultivation in two years, defoliation fruit trees and nonwood forests in warm and humid area; 23: crops with 2 cultivations in 1 year, evergreen and defoliation nonwood forest as well as fruit trees in subtropics (here referring to as the same contents).

Table 1 Table on the percentage distribution of each transferred area and the annual dynamic degree from 1982 to 1992 (％)

Years		**1992**								
	Type	11	12	13	15	16	21	22	23	Annual dynamic degree
	11	**23.98**	28.73	10.94	3.23	0.00	4.29	28.82	0.00	-3.05
	12	0.34	**34.76**	34.24	14.35	0.00	6.52	9.79	0.00	0.85
	13	0.36	9.36	**63.71**	4.38	0.00	7.82	9.40	4.97	0.67
	15	0.02	5.05	14.06	**64.39**	0.00	13.03	3.44	0.00	-1.32
1982	16	0.00	0.61	0.70	0.00	**67.14**	0.00	27.90	3.64	-2.72
	21	0.00	2.53	9.14	8.61	0.00	**69.72**	10.00	0.00	4.32
	22	0.13	4.39	8.33	0.38	0.27	0.03	**85.35**	1.12	0.11
	23	0.00	3.42	2.66	0.00	0.66	0.00	38.20	**55.05**	-2.49
Whole research area										2.85
Kappa=0.64										

Table 2 Table on the percentage distribution of each transferred area and the annual dynamic degree from 1992 to 2002 (%)

Year		**1992**								
	Type	11	12	13	15	16	21	22	23	Annual dynamic degree
	11	**0.95**	13.99	30.60	0.41	0.72	1.19	52.14	0.00	-4.22
	12	0.22	**53.05**	18.82	0.43	0.00	1.57	25.91	0.00	2.74
	13	0.28	9.06	**61.03**	5.15	0.00	6.98	14.44	3.06	-0.11
	15	0.00	7.24	11.00	**69.13**	0.00	8.23	4.40	0.00	-0.63
1982 年	16	0.63	0.79	9.90	1.72	**65.15**	12.10	8.38	1.34	-1.07
	21	0.00	6.02	17.06	9.27	0.00	**56.22**	11.44	0.00	-0.11
	22	0.32	2.82	7.50	0.35	0.77	0.02	**87.72**	0.51	0.47
	23	0.00	2.29	7.26	0.00	0.54	0.00	31.66	**58.26**	-1.57
Whole research area										1.41
Kappa=0.64										

Table 3 Table on the percentage distribution of each transferred area and the annual dynamic degree from 1982 to 2002 (%)

5.2 Analysis on the changing of vegetation coverage in the Yellow River-Huai River-Hai River area

According to the Tables from 1982 to 2002 above, the vegetation coverage types in the Yellow River-Huai River-Hai River area in the past nearly 20 years have certain changes especially in the hill area in the mountainous area of Yellow River-Huai River-Hai River area including the Taihang Mountain, Funiu Mountain, the hill area of Shandong and the lower reach of the Huai River, while the cropping area in the central area has slight changes.

1. Through overlapping analysis by every two samples of the three samples, we can conclude that the vegetation coverage distributions in 1982, 1992 and 2002 are relatively the same. The Kappa of transferred matrix is 0.63 from 1982 to 1992, 0.64 from 1992 to 2002 and 0.67 from 1982 to 2002, which are relatively on the same level. Generally speaking, the vegetation coverages maintain their consistence in the sample time without obvious changes. The vegetation type in the Yellow River-Huai River-Hai River area is changing from south to north and the vegetation with tow cultivations in one year is changing from north to south.

2. Through calculating the dynamic degree of vegetation types in the research area, we can conclude that the vegetation coverage change in the Yellow River-Huai River-Hai River area in the past nearly 20 years is relatively consistent. The annual

vegetation changing rate is 2.96％ from 1982 to 1992, 2.85％ from 1992 to 2002 and 1.41％ from 1982 to 2002. As for the types of vegetations, in the natural vegetations, taiga shares the largest changes, with the changing rate of -6.43, -3.05% and -4.22% in 1982－1992, 1992－2002 and 1982－2002; latifoliate forest shares the second largest changes, with the changing rate of 6.13％, 0.85％ and 2.74％; the changing rates of shrubbery, grassland and meadow are all decreasing slowly. In agricultural vegetations, the crops with 1 cultivation in 1 year share the largest changing rate of -3.71%, 4.32% and -0.11%; the changing rates of crops with 2 cultivations in 1 year are 0.82％, 0.11％ and 0.47％ and the the water and land crops with 2 cultivations in 1 year shares the changing rates of -0.87％, -2.49％ and -1.57％.Through space analysis, we can conclude that due to the effect of the elements like climate, the areas with relatively large vegetation changing rate are mainly located at the meeting part of the 1st and 2nd terrain stages, the region around the 400mm annual precipitation line, the hill of Shandong and the lower reach of the Huai River. The changing of vegetation types in plain crop area is relatively slower. The vegetation type with great changes is taiga in mountainous areas, with the annual changing rate of -4.22%. 52.14% of taiga is changed into the land crop vegetation (rice in part of the area) with 2 cultivations in 1 year or three cultivations in 2 years and defoliation fruit trees as well as nonwood forests in the warm-temperature area. The other vegetation with large changes is the crop with 1 cultivation in 1 year and the coldness-resistant economic crops, 17.06% of which is turned into shrubbery and bushes. The vegetations in agricultural area, due to the effect of national policies on crops and agriculture (such as the protection policy of fundamental farmlands), have slight changes.

6 CONCLUSIONS

The article, adopting the Holdridge life zone index method and the unsupervised classification method, concludes the changing characters of vegetation coverage in the Yellow River-Huai River-Hai River area through space analysis on the basis of classification of vegetation coverage in the Yellow River-Huai River-Hai River area based on multi-sources remote sensing information.

1. On the basis of the Holdridge life zone index method and the unsupervised classification method and through selecting proper parameters for vegetation classification, the classification accuracy reaches high level which also meets the reality.

2. The vegetation coverage change in the Yellow River-Huai River-Hai River area is slower and consistent. As for the types of vegetations, in the natural vegetations, taiga shares the largest changes, with the changing rate; latifoliate forest shares the second largest changes; the changing rates of shrubbery, grassland and meadow are all decreasing slowly. In agricultural vegetations, the crops with 1 cultivation in 1 year share the largest changing rate; the changing rate of crops with 2 cultivations in 1 year is the second largest followed by the the water and land crops with 2 cultivations in 1 year.

3. Due to the effect of the elements like climate, the areas with relatively large vegetation changing rate are mainly located at the meeting part of the 1st and 2nd terrain stages, the region around the 400mm annual precipitation line, the hill of Shandong and the lower reach of the Huai River. The changing of vegetation types in plain crop area is relatively slower.

REFERENCES

[1] Niejuan. The Comparison Research of Integrative Land Cover Classification in China[D].Beijing:Beijing Normal University,2003.

[2] Yu rong. China's land vegetation cover change analysis based on the time series of remote sensing data[D].Beijing：Institute of Remote Sensing Applications,2006.

[3] Chang Hsin-shih Yang Dian-an Ni Wen-ge. The potential evapotranspiration(pe) index for vegetation and vegetation-climatic classification(Ⅲ)——an introduction of main methods and pep program [J]. Acta Phytoecologica Sinica, 1993,17(2):97-109.

[4] Nijian. Indexes of Vegetation-Climate Classificateon and its Applications [J]. Chinese Journal of Ecology,1998,17(2):33-44.

[5] Chang hsin-shih. The potential evapotranspiration(pe)index for vegetation and vegetation-climatic classification(1)—an introduction of main methods and pep program [J]. Acta Phytoecologica Sinica,1989,13(1):1-9.

[6] Institute of Botany, the Chinese Academy of Sciences.1:4000000 Vegetation Atlas of Chian [M].Beijing:Sinomaps Press,1982.

[7] The Editorial Board of Vegetation Map of China,Chinaese Academy of Science.1:10000000 Vegetation Atlas of Chian [M].Beijing:Science Press,2001.

[8] Watt K. E. F.. Principles of Environmental Science [M]. McGraw Hill Book Co.,1973.

[9] Holdridge L R. Life Zone Ecology [M]. San Jose, Costa Rica: Tropical Science Center, 1967.

[10] Holdridge L R. Determination of word plant formations from simple climatic data [J]. Science, 1947, 105: 367-368.

[11] Justin D, Paola, Robert A. Schowengerdt. A detailed Comparison of Back propagation Network and Maximum—likelihood classifiers for Urban Land Use Classification [J]. IEEE. Transactions on Geoscience and remote Sensing, 1995, 33(4): 981-995.

[12] Sun danfeng,Ji changyuan,Lin pei. Landcover Classification of Remote Sensing Imagery Using Self organizing Neur al Network [J]. Journal of Remote Sensing, 1999, 3(2)：139-144.

[13] Loveland T R, Reed B C, Brown J F, et al. Development of a global land cover characteristics database and IGBP DISCover from 1 km AVHRR data [J]. International Journal of Remote Sensing: 2000, 21 (6): 1303-1330.

[14] Hansen M C, Defries R S, Townshend J R G, et al.. Global land cover classification at 1 km spatial resolution using a classification tree approach [J]. International Journal of Remote Sensing, 2000, 21(4): 1331-1364.

[15] Hansen M C, Reed B. A comparison of the IGBP DISCover and University of Maryland 1 km global land cover products [J]. International Journal of Remote Sensing, 2000, 21 (6): 1365-1373.

[16] Dang anrong,Wang xiaodong,Chen xiaofeng,et al.Erdas Images analyse [M].Beijing: Tsinghua Press,2003.

[17] Lu H H, Wang W J, Xie B G.. A Study on Landscape Changes of Eco-zone in Contiguous Area of Shanxi, Shaanxi and Inner Mongolia Using Remotely Sensed Data [J]. Research of Environmental Sciences, 2001, 14(6):50-53.

[18] Wang G X, Guo X Y, Cheng G D. Dynamic Variations of Landscape Pattern and the Landscape Eco logical Functions in the Source Area of the Yellow River [J]. Acta Ecologica Sinica, 2002, 22(10): 1587-1598.

[19] Wu B, Ci L J. Temporal and spatial patterns of landscape in the MuUs Sandland, Northern China[J]. Acta Ecologica Sinica, 2001, 21(2):191-196.

[20] Jia B Q, Ci L J, Ren Y P. The analysis on the oasis landscape dynamics[J]. Acta Ecologica Sinica, 2001, 21(11):1948-1951.

[21] Bu R C, Li X Z, Hu Y M, et al. Scaling effects on map agreement[J]. Acta Ecologica Sinica, 2004, 24(4):659-665.

[22] Wang jing. Remote monitoring of land resources and evaluation methods[M].Beijing：Science Press，2006.

[23] Zhu huiyi,Li xiubin,He shujin,et al.Spatio-temporal Change of Land Use in Bohai Rim[J].Acta Geographica Sinica,2001,56(3):253-260.

[24] Wang xiulan,Bao yuhai.Study on the methods of land use dynamic change research [J].Progress In Geography,1999,18(1):81-86.

[25] Zhu huiyi,Li xiubin,He shujin,et al. Spatio-temporal Change of Land Use in Bohai Rim[J].Acta Geographica Sinica,2001,56(3):253-260.

[26] Wang siyuan,Liu jiyuan,Zhang zengxiang,et al. Analysis on Spatial-Temporal Features of Land Use in China[J].Progress In Geography,2001,56(6):631-639.

[27] Wu Xiuqin, Cai Yunlong. Land cover changes and landscape dynamics assessment in lower reaches of TARIM river in China [J]. Chinese Geographical Science, 2003, 14(1): 28-33.