Extraction and application of Impervious Surface Area in Yellow River Delta

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Abstract—Impervious surfaces as a special factor mainly made by human not only can indicate changes of LUCC and the Urbanization, and is also a good indicator of environmental quality. In this paper, we took the TM image data of the Yellow River Delta (YRD) region especially the Dongying city in 2009 as study area, used the Normalized Mixing Spectral Analysis Model (NSMA) and aided the product of maximum likelihood classify to obtain the high accuracy map of percent impervious surface (PIS). In addition, the urban (town) were distinguished by setting appropriate threshold according to the PIS and the investigation data. The results indicated that, the combination of the NSMA and the maximum likelihood method was effective to differentiate alkaline land from build-up area; In the whole study area of YRD, the non-urban (non-town) area was an absolutely dominant type with the 92% percent area, while in the area with the PIS value of grater than 10%, the percents area of the urban (town) were 63%, specifically to the low, middle, high development levels area, each was 13%, 22%, 28% in sequence; The relationships between PIS and LST, ET revealed that the higher the PIS, the higher the LST while the lower the ET and there would be a clearly positive (negative) exponential relationships between the PIS and the LST (ET). And the study on impervious surface would be useful to further research on its sprawl and quantitative relationships between the PIS and the other land surface parameters.

Keywords-Impervious Surfaces ; Normalized Spectral Mixed Analysis Model; Maximum likelihood classify; Land surface parameters;Relationship; Yellow River Delta

I. INTRODUCTION

As the intensity of human activities, the changes of LUCC and the process of urbanization become more and more quickly and the research on LUCC and urban sprawl has been a hot spot. However, the precise definition of urban area boundary is a difficult problem for land utilization and planning departments[1-3]. Impervious surface as water cannot infiltrate easily area, mainly include sidewalks, driveways, rooftops, parking lots and so on, and it not only can indicate changes of LUCC and the urbanization but also a good indicator of environmental quality[4]. The development of remote sensing technology and the attention on the urban sprawl (impervious surface sprawl) urge many foreign experts and scholars to identify the impervious surface area as the construction area and to extract it by using remote sensing technology [4-7]. But, the mixture pixel problem in the remote sensing is a bottle-neck to precise extraction of the impervious surface. Based on this, many researchers have been adopting improved extraction methods and models to try to tackle this problem. For examples, Vegetable-Impervious-Soil (V-I-S) model were used for urban ecosystem analysis through remote sensing[8]; Constrained linear spectral mixed analysis method was used to evaluate the impervious surface area distribution of Columbian, the capital of Ohio [9]; In 2004, Wu advanced to apply Normalization Spectrum Mixed Analysis (NSMA) method, further improved the extraction precision[10]; Qian Lexiang et al., not only effectively removed the effects of the hill-shades to brightness but also improved the accuracy of the impervious surface with the NSMA model[11]. Although, the extraction accuracy of impervious surface was improved in a big degree with the NSMA model, there are still many errors, such as high albedo pervious surface areas are mistaken as impervious surface areas and the low albedo impervious surface areas are mistaken as pervious surface areas. Except that, to the Yellow River Delta (YRD), where is a strong confusion between the alkaline land and the construction area, no matter from the spectral characteristic or other features. Based on those problems, we used the NSMA and the maximum likelihood method to obtain the high accuracy map of percent impervious surface (PIS) in YRD, and distinguished the urban (town) area from non-construction area by setting appropriate threshold according to the PIS and the investigation data.

The specific study area is the core of YRD, Dongying city, which includes five administrative regions, such as Dongying, Kenli, Lijin, Gunagrao, Hekou and so on, locates the north of Shandong province and borders on the Bohai sea, and is one of the youngest region of China. Nowadays, it has been not only an important protected natural wetland but also a hotspot region both at home and abroad.

II. DATA AND METHODOLOGY

A. Data and preparation

The main data sources we used were the TM image of study area in 2009, the field investigation data in 2010 which included 730 record stations and almost covered all land-use types of the research area. In order to reduce the data distortion error and to improve image quality, TM data was processed by radiation correction, geometrical correction, as well as image enhancement. In detail, we used FLAASH module in ENVI instead of the traditional 6s model to run atmosphere calibration easily. About the investigation data, we transformed them from GPS to ArcGIS software, got the accuracy information of each

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station and route. The overlay information map of TM image and the investigation route could be seen in Fig.1.

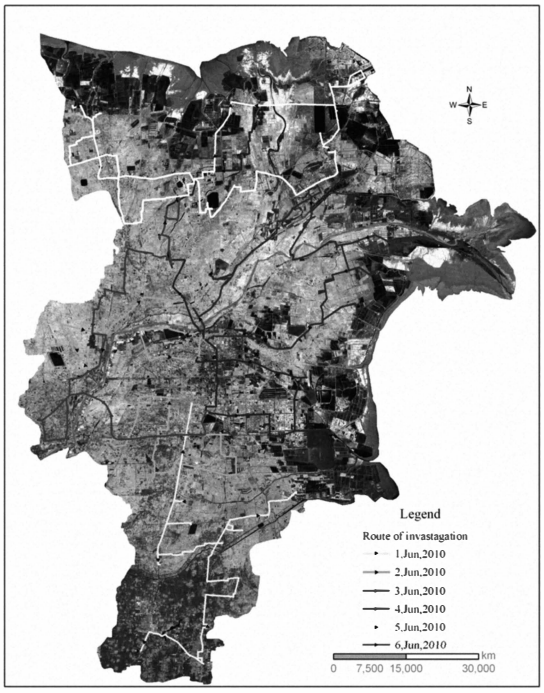

Fig.1 The overlay map of TM image and investigation route

B. Methodology

1. Normalization Spectrum Mixed Analysis (NSAM)

With a selected set of end members, SMA methods are typically utilized to calculate the fraction of each end member in a mixed pixel using an inverse least square devolution method and end member spectra [12]. One basic assumption of SMA models is that the spectrum for each pixel is a linear or nonlinear combination of end member spectra dependent on the significance of multiple scattering of light on land cover types. NSMA model is a fully constrained linear SMA method with the normalized spectra and can effectively removed the effects of the hill-shades to brightness [9]. In the study of YRD, we used the four end members (Construction, vegetation, water, soil) in the NMSA. The related equations are as follows.

$$\overline{R}_b = \sum_{i=1}^{n} \bar{f}_i \overline{R}_{ib} + e_b \qquad (1)$$

where

$$\sum_{i=1}^{n} \bar{f}_i = 1 \text{ and } \bar{f}_i \geq 0 \qquad (2)$$

where $\overline{R}_b$ is the normalized reflectance for each band b in an TM pixel; $\overline{R}_{ib}$ is the normalized reflectance of end member i in band b for that pixel; $\bar{f}_i$ is the fraction of end member i; and e_b is the residual. The fraction of each end member in a pixel can be calculated using a least squares method in which the residual e_b is minimized.

2. Maximum Likelihood classification

Maximum likelihood classification is an effective classification method. It assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless you select a probability threshold, all pixels are classified. Each pixel is assigned to the class that has the highest probability. If the highest probability is smaller than a threshold you specify, the pixel remains unclassified. The software of ENVI can complete the classification process easily [13]. In this paper, we used the Maximum likelihood classification method classify the study area into six land-use types: building, vegetation, water, alkaline land, insula in flumine nata and unused land.

C. Flow chart of data processing

With the purpose of removing the confusion of the alkaline land to construction, we adopted the maximum likelihood classification method firstly to obtain a land-use map approximately. Then, the NSMA method was used to extraction the PIS based on the excluded mask layer of alkaline land, meanwhile, the other classify results were referenced. The detailed flow chart of data processing was as follow, Fig.2.

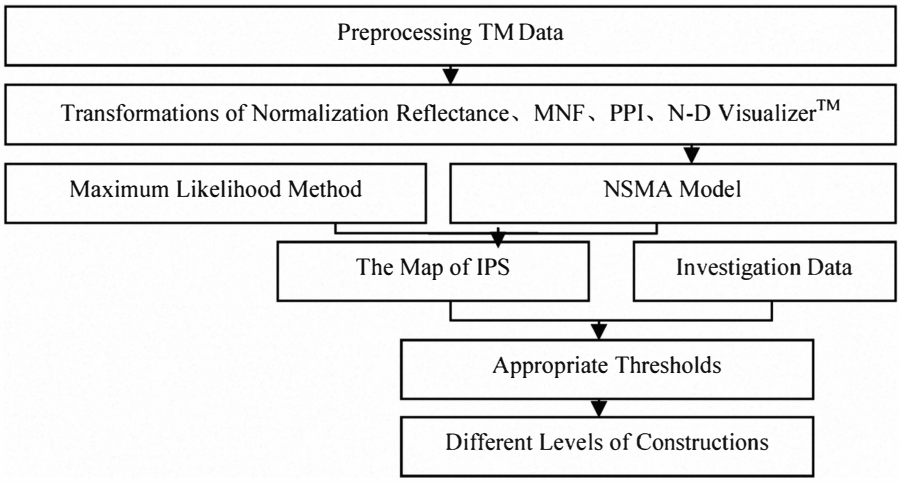

Fig.2 The flow chart of processing

III. RESULTS

A. The map of Percent Impervious Surface

The map of percent impervious surface, gotten by using of the combination method of the NSMA and the maximum likelihood classification, had been verified by the investigation data and could be seen in Fig.3. It showed a spatial distribution of the constructions in different degree with the increased of the value of PIS from 0% to 100%. Based on the Fig.3, we found that, in the center of all cities, such as Dongying, Kenli, Hekou, Lijin, Guangrao, there were high percents value, while on the edge of them, PIS took on a decreased trend; In other regions of the whole study area, main distributed the low PIS in large extent.

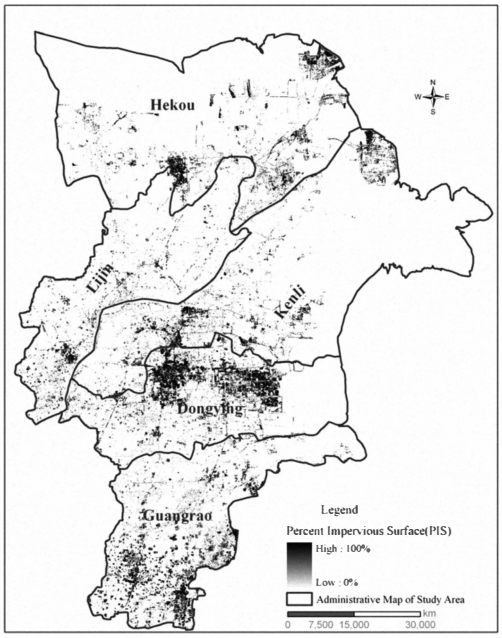

Fig.3 The map of Percent Impervious Surface

B. The distribution of different leves urban (town)

Precise definition of urban (town) boundary has always been a difficult problem for land use and planning department. With the improvement of urbanization, more and more natural surface land becomes impervious surface area. So researchers both at home and abroad to put forward the suggestion that using impervious surface area to represent urban area boundary [4-7, 14-16]. George Xian proposed to define the urban areas in Tampa Bay, Florida. And they were defined as low density, middle density and high density urban areas respectively according to the impervious surface abundance value [16]. Qian Lexiang[15], Guanzhong[17] and so on, used NSMA model to study the land surface composition and got the following conclusion: Areas whose impervious surface area abundance value in the range of 80%~100% are Central Business District (CBD)areas; value in the range of 30%~60% are residential areas, and value in the range of 0%~20% are rural areas. However, it is an important and a hard thing to definition the thresholds of different levels urban (town).

In this paper, we accorded to the impervious surface abundance map extracted from TM data and the investigation data which included 730 stations and almost covered all land-use type, and got the following concluded: In the study area of YRD, areas whose abundance value was larger than 0.5, almost included all developed urban land, such as, low density, high density, residential districts, industrial and commercial districts. Therefore, we selected 50% as the threshold. i.e., if the percent impervious surface value was greater than 0.5, the pixel was defined as urban area naturally. Otherwise, it was defined as non-urban area. Correspondingly, the degree of urban (town) development can also be defined by setting appropriate thresholds. We used 60%, 80% to quantitative the middle and high development degree of urban (town) respectively. i.e., it would be a low density, a middle density and a high density development area respectively when the PIS value was among 50% and 60%, 60% and 80%, and larger than 80%. Based on the Fig.3, the further research results indicated that, in the whole study area of YRD, the non-urban (non-town) area was an absolutely dominant type with the 92% percent area; in the area with the PIS value of grater than 10%, the percents area of the urban (town) were 63%, specifically to the low, middle, high development levels area, each was 13%, 22%, 28% in sequence.

c. The relationships

As we all known, the impervious surface not only is a good indicator of the environment quality but also is an important land surface parameter. The relationships between it and other land surface parameters, such as land surface temperature (LST), evapotranspiration (ET) are crucial. So, we selected a test area sized of 16km* 16km in Guangrao of YRD and furthered to discuss the relationships simply. The LST and ET data , could be seen in Fig.4-a, Fig.4-b, were obtained by the Mono-window Algorithm and the Surface Energy Balance Algorithm for Land (SEBAL) Model respectively based on the TM data.

Fig.4-a The map of LST

Fig.4-b The map of ET

Based on the scatter plots of relationships between PIS and LST, ET in Fig.5-a, Fig.5-b, we found that, the higher the PIS, the higher the LST while the lower the instantaneous ET; There would be a clearly positive (negative) exponential relationship between the PIS and the LST (ET); Moreover, the higher the PIS, the greater the impacts of human activities on the environment.

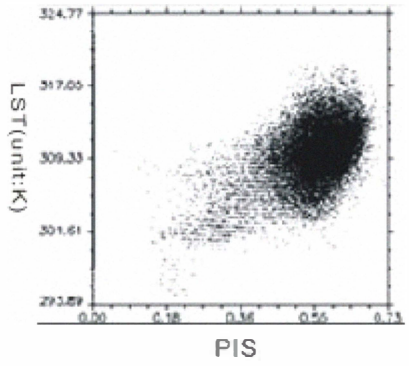

Fig.5-a The scatter plot of PIS vs. LST

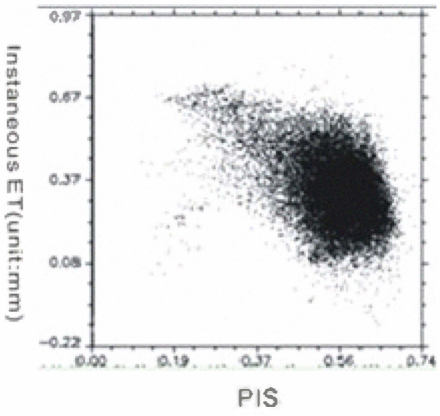

Fig.5-b The scatter plot of PIS vs. ET

IV. CONCLUSIONS

Due to importance of the impervious surfaces, in this study, we extracted the IPS and discussed relationships between it and LST, ET. The results of PIS indicated that, the combination of the NSMA and the maximum likelihood method was effective to remove the confusion of the alkaline land to build-up area, although, it is hard to distinguish them in each singular method. The classifies of low, middle and high development degree of urban (town) suggested that PIS provided a possible way to define different urban (town) development levels and indirectly showed the impact degree of human activities on the land-use. And the study on relationships between the PIS and LST, ET reminded us to research on the PIS and other land surface parameter with quantitative methods.

V. ACKNOWLEDGMENT

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