AN OBJECT-BASED APPROACH FOR MAPPING QUASI-CIRCULAR VEGETATION PATCHES FROM QUICKBIRD IMAGE

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ABSTRACT: There has always existed a need in the remote sensing community for information at vegetation patch scale, but scholars have instead depended on broader scale inferences because of limitations in image spatial resolution and information extraction approach. This paper provides a preliminary assessment of an object-based approach with 0.6 m Ortho-rectification QuickBird high spatial resolution multispectral image for detecting automatically the location and areas of the quasi-circular vegetation patches as they grow upon the abandoned land and tidal flat in the Yellow River Delta (YRD), China. The quasi-circular vegetation patches detected from our methods produced a good correlation with the counts measured via comparable visual interpretation in a geographic information system with the precision rate 85.1% and F 0.802. This approach has considerable potential for the long-term monitoring of the quasi-circular vegetation patch change via high spatial resolution imagery.

1. INTRODUCTION

The quasi-circular vegetation patch encroachment upon the abandoned land and tidal flats of the Yellow River Delta (YRD), China is an ecological phenomenon which is increasing great interest from the ecological restoration and conservation perspective. The characteristically quasi-circular vegetation patches ranged in average diameter from 12-25 m are embedded in barren lands, thus forming the matrix vegetation of the quasi-circles (Liu et al., 2014). Although Liu et al. suggested that the quasi-circular vegetation patches resulted from seismic exploration of oil field (Liu et al., 2013), but to date, the formation of the quasi-circular vegetation patch remains a mystery. There is a strong need for identification and analysis of the spatial patterns of the quasi-circular vegetation patches which is important to better understand the ecological processes and succession mechanism that govern the growth and expansion of the quasi-circular vegetation patches across the YRD, thus providing help for refinements and improvements for management of wetland restoration in the YRD in the future.

Previous methods for the remote identification of location and area of the quasi-circular vegetation patches within imagery (the range of spatial resolution of imagery from 30 m Landsat to < 1 m aerial phtography) have applied visual interpretation within geographic information systems (e.g. Moll, 1994; Becker and Getzin, 2000; Ansley et al., 2001), planimetry (Frenkel and Boss, 1988), user-defined grey-scale partitioning (e.g. Game et al., 1982), two-dimensional wavelet analysis (e.g. Strand et al., 2006), per-object analysis (e.g. Smith et al., 2008), canny edge detector (e.g. Liu et al., 2011), circular Hough transform (e.g. Liu et al., 2012), mathematical morphology method (e.g. Liu et al., 2014), or absorption feature method (e.g. Liu et al., 2015). These methods can allow separate objects to be visually isolated within imagery, and generally provide information for an entire collection of objects, rather than providing information on each object separately. Although some of these methods such as two-dimensional wavelet analysis, per-object analysis and mathematical morphology method can provide information on the location and areas of each object separately, most of they are still at the experimental research stage, and couldn't come into common use for the scholars and managers.

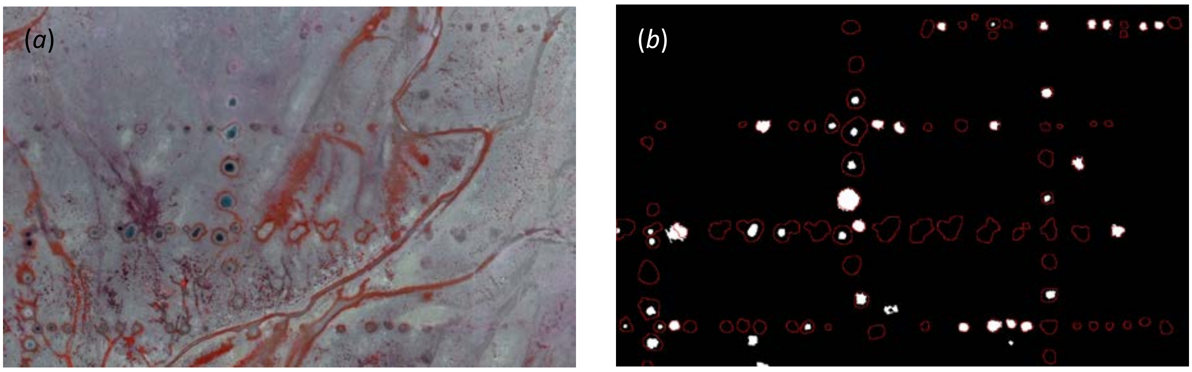
Object-oriented image analysis provides many advantages over traditional pixel-based classifications (Geneletti and Gorte 2003), and its classification procedure can account for the spatial relationship of pixels, not just the spectral values. This method is gaining increasing acceptance as it proliferates throughout the remote sensing community (Dorren et al. 2003). Recent advances in object-orientated image processing technique have demonstrated the potential to identify and assess the vegetation patches over a range of scales (Laliberte et al., 2004; Hellesen and Matikainen, 2013). Nowadays, object-oriented image analysis method has been embedded in the commonly used remote sensing software such as eCognition, ERDAS and ENVI. So it is necessary to develop the framework based on object-oriented image analysis to provide information on the location and area at vegetation patch scale which is a promising application to ecological problems.

In this preliminary study, we evaluate the potential of an object-based approach to identify and extract information on 'individual' quasi-circular vegetation patch features in the YRD from high spatial resolution QuickBird image.

2. MATERIALS AND METHODS

2.1 Study area and QuickBird imagery

This study is located in the YRD (118°7′E to 119°10′E, and 37°20′N to 38°10′N) in the Northern part of Shandong Province, China, an area characterized by the quasi-circular vegetation patches with the barren abandoned land and tidal flats. This area has a warm temperate continental monsoon climate with distinctive seasons and a rainy summer (June–August). Annual temperature averages 12.1°C. It receives an annual rainfall of 551.6 mm, against an annual evaporation of 1,962 mm. It has an aridity index of up to 3.56, belongs to arid ecosystem. The most common soil is Glyic Solonchaks with high salt content in the tidal flats. The *Suaeda salsa* and *Tamarix chinensis* and *Phragmites australis* are three main native vegetations which occur widely across the YRD. The quasi-circular vegetation patches are mainly composed of *Suaeda salsa, Tamarix chinensis, Phragmites australis*, or water and barren land at center. Since the early 1960s, petroleum exploitation has been done in the YRD. Oil wells and roads have made the considerable fragmentation of protected wetlands and damaged the vegetation communities (Bi et al., 2011). Ortho-rectification high spatial resolution (0.6 m) multispectral QuickBird image (Band1: 450-520 nm; Band2: 520-600 nm; Band3: 630-690 nm; Band4: 760-900 nm) was acquired for this area on October 3, 2011, and serves as the basis for an object-based approach. Figure 1a shows parts of the false color image RGB432 of study area for an area about 46 ha in size (Figure 1a).



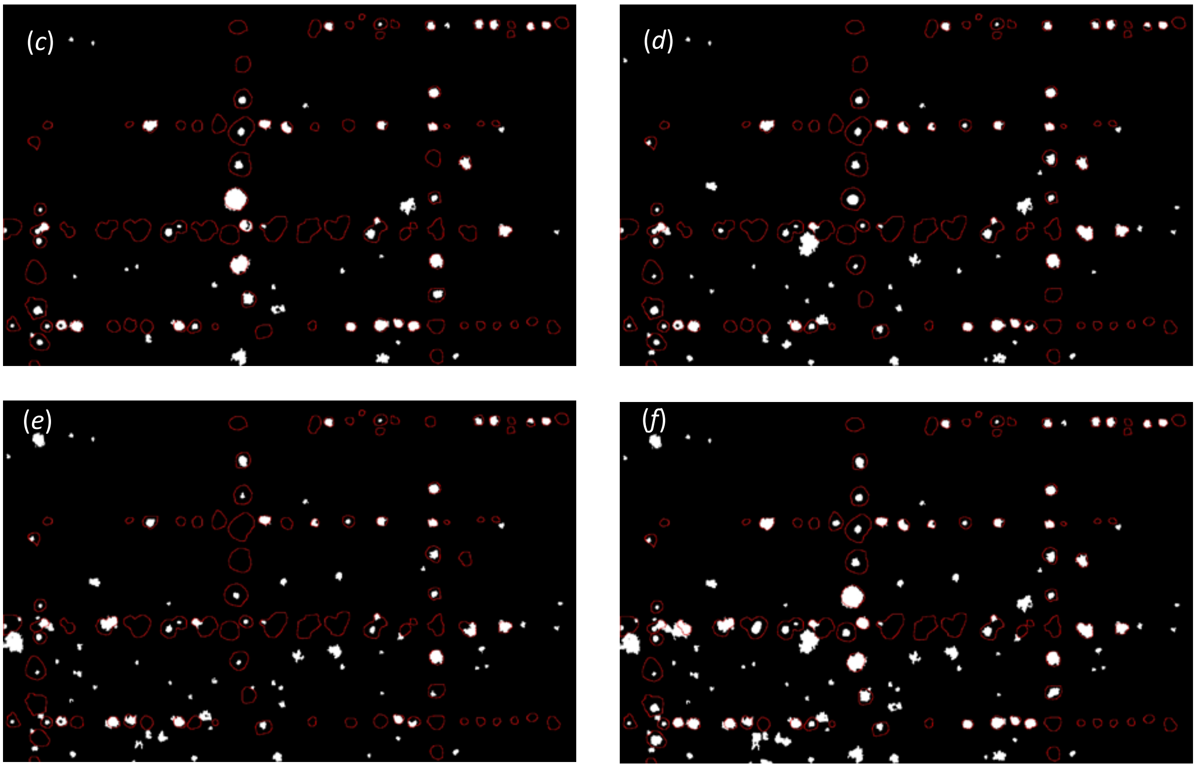


Figure 1. QuickBird image of the quasi-circular vegetation patch landscape (the area of the image is 46 ha. The black is the background, and the white are the detected quasi-circular vegetation patches, and the red polygons are the quasi-circular vegetation patches from the visual interpretation). (*a*) QuickBird false color image RGB432 (20% of the original image size). (*b*) The quasi-circular vegetation patches detected from the object-based approach (scale level 5, merge level 95). (*c*) The quasi-circular vegetation patches detected from the object-based approach (scale level 5, merge level 90). (*d*) The quasi-circular vegetation patches detected from the object-based approach (scale level 5, merge level 85). (*e*) The quasi-circular vegetation patches detected from the object-based approach (scale level 5, merge level 80). (*f*) The merged quasi-circular vegetation patches from (*a*) and (*b*) and (*c*) and (*d*).

2.2 Image analysis

For the segmentation, the Rule Based Feature Extraction image analysis embedded in software ENVI 5.1 was used. The segmentation was based on edge algorithm to distinguish the quasi-circular vegetation patches from the backgrounds because the spectral difference between most of the quasi-circular vegetation patches and the background was small, especially the quasi-circular patches with a little vegetations. The chosen settings for segmentation were based on initial testing of the different segmentation parameters and subsequent evaluation of the results in terms of what resulted in the most available objects. The scale level 5 with the different merge level 95, 90, 85 and 80 were tested. Then, classification is performed on the objects rather than single pixels using the area and roundness information. In general, the areas of the quasi-circular vegetation patches are from 50 to 1206 m^2, but for some quasi-circular vegetation patches, only the centre parts could be detected because there are the weak differences between their edges with the background. Thus, the area range from 20 to 1000 m^2 was used. Table 1 shows the classification rule parameters used in this study. After classification, post classification was used to combine classes into the quasi-circular patches and the background (Figure 1b, 1c, 1d, 1e). Finally, the classified results were merged to incorporate classes from the four classification results (Figure 1f). In this last step, a classification-based segmentation (scale level 5, merge level 20) was performed. This is an advanced segmentation based on the previous classification of the four classification results with the aim of creating a final classification (the classification rule parameters were: area range from 30 to 1000, and form factor is great than 0.4.).

The precision rate (A_d), recall rate (A_r) and F measure (F) were used to assess the accuracy of object-based classification results. These processes were described by the following equation:

$$A_d = \frac{N_c}{N_d} \times 100\% \quad (1)$$

$$A_r = \frac{N_c}{N_r} \times 100\% \quad (2)$$

$$F = \frac{2 A_r A_d}{A_r + A_d} \times 100\% \quad (3)$$

where A_d, A_r and F are the precision rate, recall rate and F measure respectively, N_c, N_r and N_d are the detected, not detected and falsely detected quasi-circular vegetation patches respectively.

Table 1 Classification parameters used for the quasi-circular vegetation patch detection

Scale level	Merge level	Area range	Roundness range
5	95	(20, 1000)	>0.6
	90		
	85		
	80		

3. RESULTS

Visual interpretation of the QuickBird image estimated 96 quasi-circular vegetation patches within the 46 ha analysis area. The minimum, maximum and mean area of the quasi-circular was about 39.2 m^2, 1113.8 m^2 and 329.4 m^2 respectively. Compared with the visual interpretation results, Figure 1 and Table 2 shows it was less successful in delineating the quasi-circular vegetation patches correctly when any one of the four merge levels was used individually. The count of the detected quasi-circular vegetation patches and F from Method 3 was the maximum of Method 1, Method 2, Method 3 and Method 4. With the merge level increasing, the count of falsely detected quasi-circular vegetation patches increased obviously, and the recall rate decreased drastically. Through merging the classification results from Method 1, Method 2, Method 3 and Method 4, the count of the detected quasi-circular vegetation patches increased, but the recall rate and F measure were not the best. The errors were from big irregular vegetation patches (such as the three big patches in the centre of the image of Figure 1a) and small patches with weak difference with the background (such as the six patches in the lower right of the image of Figure 1a). After removing these patches, the precision rate was 85.1% and F was 0.802.

Table 2 Accuracy statistics from the visual interpretation for the quasi-circular vegetation patches that were detected and not detected with the object-based image classification

	All the quasi-circular vegetation patches	Detected A_d	Not detected A_r	Falsely detected F
Method 1: Scale level 5, merge level 95	96	40 41.7%	56 95.2%	2 0.580
Method 2: Scale level 5, merge level 90		47 49.0%	49 71.2%	19 0.581

Method 3: Scale level 5, merge level 85		53 55.2%	43 61.6%	33 0.582
Method 4: Scale level 5, merge level 80		46 47.9%	50 48.4%	49 0.482
The combination classification		63 65.6%	33 52.1%	58 0.581
The final classification	74	63 85.1%	11 75.9%	20 0.802

4. DISCUSSION

The accurate detection of the quasi-circular vegetation patch location and size will enhance our understanding of the vegetation responses to environmental variability, and may shed light on relationships between landscape patterns and ecological processes. Quantifying the quasi-circular vegetation patches within an image using object-based approach depends on the spatial resolution of the image, the minimum vegetation patch size, the difference between the vegetation patch and the background, and the roundness of the quasi-circular vegetation patch. Because the quasi-circular vegetation patches in the different evolution phases have the different component fraction (vegetation, water, bare soil), and the different spectral and spatial differences from the background, segmentation based on edge detection algorithm could achieve the better segmentation results than the intensity algorithm. Limitations of this technique can be expected to identify the irregular vegetation patches and small vegetation patches, and conglutination vegetation patches may be incorrectly detected as larger vegetation patches.

5. CONCLUSION

The object-based approach is a useful tool for mapping the quasi-circular vegetation patches and quantifying the vegetation patch extensions and ecological patterns. Further research in the irregular vegetation patch and conglutination vegetation patch detection could improve the identification accuracy which yield the rapid, objective, available and important information about vegetation patch succession, biogeochemical properties, and landscape composition across large areas.

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