Study on Cultivated Land Concentrated Areas Delineation Based on GIS and Mathematical Morphology: A Case of Miyun County and Pinggu District in Beijing

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Abstract. The basic farmland within the protection areas was required to be of high-quality and connective in the general plans for land use. A new method was developed to delineate the boundaries of high-quality, concentrated and connective cultivated land. Based on mathematical morphology principles and GIS methods, the high quality of cultivated land blocks could be identified through dilation and erosion operations according to this rule that which inside distance was less than threshold d_1 and the number of blocks was larger than 3. This method was validated with the farmland classification data of Miyun County and Pinggu District in Beijing City, and 91% of high-quality, concentrated and the connective cultivated land could be identified by this method, so it would provide the reference method for delineating the basic farmland areas scientifically and reasonably in the general plans for land use.

Keywords: mathematical morphology; concentrated and connective; GIS; cultivated land

1 Introduction

Cultivated land resources were scarce and it was a basic state policy that everyone should cherish and utilize rationally every inch of the farmland in China [1]. Basic farmland protection system was set up and basic farmland regions were delineated to execute strict protection rules [2]. Basic farmland was the arable land which was of high-quality, good land geographic conditions, complete water conservancy facilities, concentrated and connective etc [3]. A lot of researches had been done on how to delimit basic farmland, and much emphasis had been put on the principles of quality, the distance from the farmland to the settlement. However, the distribution and concentration of the farmlands were usually ignored in these principles. These principles made the cultivated land blocks scattered, and it was difficult to realize scale management of agriculture and furthermore, it resulted in that a large number of

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scattered basic farmland had been transferred. Basic farmland protection areas planning introduced the principle of " high-quality and concentrated ", and it would focus on protecting the blocks of high-quality and concentration, reducing flow, realizing the scale of agriculture as well as controlling the non-point pollution. As a result, the concentrated and connective concept in the space planning of basic farmland was helpful to realize the management of "high-quality, concentration and connective ".

At present, the researches about connectivity at home and abroad mostly focused on Landscape ecology and ecological protection and other fields, and rarely on cultivated land protection [4]. In recent years, more and more researches were concerned about connectivity in China, such as: Yun Wenju, Zhou Shangyi[5] proposed the methods for measuring space connectivity by calculating the link index of blocks with grids; Duan Gang[6] raised a method based on the buffer analysis of vector; Guo Zihan[7] determined whether the cultivated land was connected by setting up distance threshold for the grid length. These methods were helpful to select the cultivated land areas which were of high-quality, concentrated and connective. However, too long calculating time and the distance threshold which was difficult to ascertain had a significant impact on delimiting concentrated areas in the study area. As a new subject of image processing and analysis, the principal theory and methods of Mathematical Morphology had been successful applied in the fields such as the biomedical, remote telemetry, highway and transportation, mechanical engineering and weather etc. For example, Li Deren [8] analyzed Chinese characters of scanned binary images; Feng Qingzhi [9] used these theories and methods in image enhancement and detection for license plates and complicated fingerprints; Wu Dan [10] had studied application status in GIS and recognition and the position of image mark; Zhang Qingnian [11] proposed the method of identification and generalization of clusters by mathematical morphology and proved to be quite effective.

Considering that the cultivated land concentrated area could be regarded as area clusters, this research referenced Zhang Qingnian's methods on identifying area clusters. Firstly, the basic operations of mathematical morphology were introduced. Secondly, the identifying methods were probed to delineate concentrated area of cultivated land based on mathematical morphology. Thirdly, take the farmland classification data of Miyun County and Pinggu District in Beijing City for example, this method's feasibility was verified and it would provide the reference method for delineating basic farmland protection areas scientifically and reasonably in the general plans for land use.

2 Theory and methodology

2.1 Basic operations of mathematical morphology

The areal geographical phenomenon of discontinuous distribution was suitable to be expressed by raster[11]. Mathematical morphology could analyze the structure of data and extract features through transforming the raster data structure [12]. Grid-based areal features were expressed in polygon, called blocks. The kind of map data was easily processed using the mathematical morphological methods.

Mathematical morphology was a nonlinear image processing and analysis theory, which discarded the traditional view of value modeling and analysis. It described and analyzed the image from the perspective of set operations, focusing on the geometric structure of image, in order to extract the targets' size, shape, connectivity, convexity, smooth , directional characteristics and so on[11]. In some sense, mathematical morphology opened the new theory and the new method of image processing, analysis and identification. The operations allowed for efficient handling of grid data in morphological transform and pattern recognition, as well as other types of data.

Basic operations of mathematical morphology included dilation erosion and opening, closing, thinning, thickening, top-hat transform and low-hat transform derived from dilation and erosion. Among them, dilation and erosion were the most basic operators of mathematical morphology. Because the other operators could be derived by dilation and erosion, this paper just introduced the two operators.

X was input image, B was structural element,

(1) **dilation**： $X \oplus B = \{x+b : x \in X, b \in B\} = \bigcup_{b \in B} X[b]$

Geometrically, dilation was the union of all calculation results with input image X translation of b.

(2) **erosion**： $X \Theta B = \{x : x + b \in X, b \in B\} = \bigcap_{b \in B} X[b]$

Geometrically, erosion was the union of all calculation results that input image X was translated –b, also was composed of all points within input image X after structural element B was translated x.

Operation results of dilation and erosion were shown in fig.1 below.

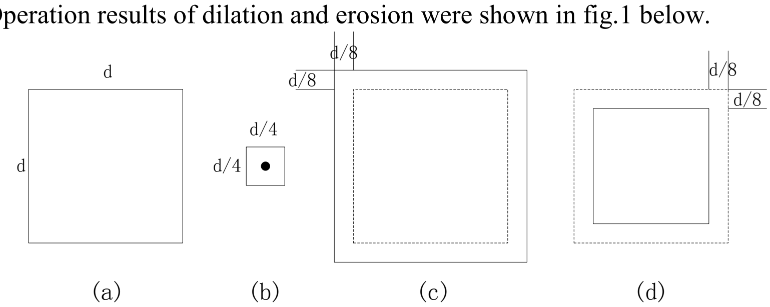


Fig.1 dilation and erosion

(a) Input Image X (b) Structural element B (c) dilation, X ⊕ B (d) erosion, X Θ B

2.2 Identifying cultivated land concentrated areas by mathematical morphology

"Connectivity" is an indicator which showed the spatial distance and distribution of cultivated land blocks with the same property. When the distances among cultivated land blocks were smaller than the threshold value, they could be considered to be connective[5]. "Clusters" was a group of features whose distances were less than the threshold value L, and the clusters were usually defined by human eyes. In this paper, a new method of identifying cultivated land block clusters, based on mathematical morphology, was developed to identify and delineate connective cultivated land regions.

Cultivated land clusters were identified based on two criterion, (1) the distances among features inside clusters; (2) the ratio between distances inside and outside cluster. Cultivated land blocks were considered as connective when their maximum distance d1 inside clusters was less than the distances mean value d2 outside clusters, while the block number of cluster was not less than 3.

Four steps were included to implement this method, as were shown as follows:

(1) Determinating the distance threshold d1 of concentrated areas. Firstly, cultivated land blocks were selected randomly as a cluster in the image. Secondly, the distances from each block to other blocks inside clusters were calculated. Thirdly, the maximum distance value was considered as the threshold of concentrated areas. The implement methods were as: There were n blocks Pk(k∈(1,n)) in the image X, the formula was needed to be looped until . B was the structural element with radius of 1, w was the number of loops, dk was the minimum distance between the block Pk and the others(k∈(1,n)) which equaled with w, the maximum of dk was considered as the threshold of concentrated areas d1. Image GH was assigned by X.

(2) Identifying the blocks aggregation which internal distance was less than threshold d1 and the number of blocks was not less than 3. Firstly, Image PR was dilated by structural element Br with radius of d1/2, and the arithmetic expression was . Image PR was composed of blocks Ck (whose number was h)(k∈(1,h)). Secondly, the aggregation inside Ck could be got through (k∈(1,h)). The number of blocks n inside was counted, and judged whether n was less than 3 or not. If n<3, the blocks were considered scattered and they would be deleted from GH, then they could be expressed as . Otherwise, the blocks were considered as connective, and the aggregation was initialized.

(3) Judging whether the blocks aggregation met with the criteria d1/d2≤1/2. The formula was needed to iterate by structural element B with radius of 1 until it met with this criteria . The variables were as follows: w was the iteration number, d2 was the minimum distance between the initialized aggregation and the other surrounding blocks, which was equal to w. If d1/d2≤1/2, PCk was seen as clusters.

(4) Identifying the aggregation for which inside distance was smaller than before by reducing d1 in the rest of the blocks. The identified clusters were deleted from image GH and it could be expressed by the formula GH=GH-PC, after uniting with all recognized clusters through (k∈(1,w)).

If , d1 was assigned with the value of d1-d*2% . Go back to Step 2 when d1≥ Ds*St/Ss to identify the clusters with smaller inside distance in the rest of the aggregation until all clusters inside image X were iterated through. Among them, Ds was the minimum distance discriminated by human's eyes in the target image. Ss and St were the scale denominators of the original image and the target image, respectively.

The operation flow to identify the cultivated land concentrated areas was shown in Fig.2 below.

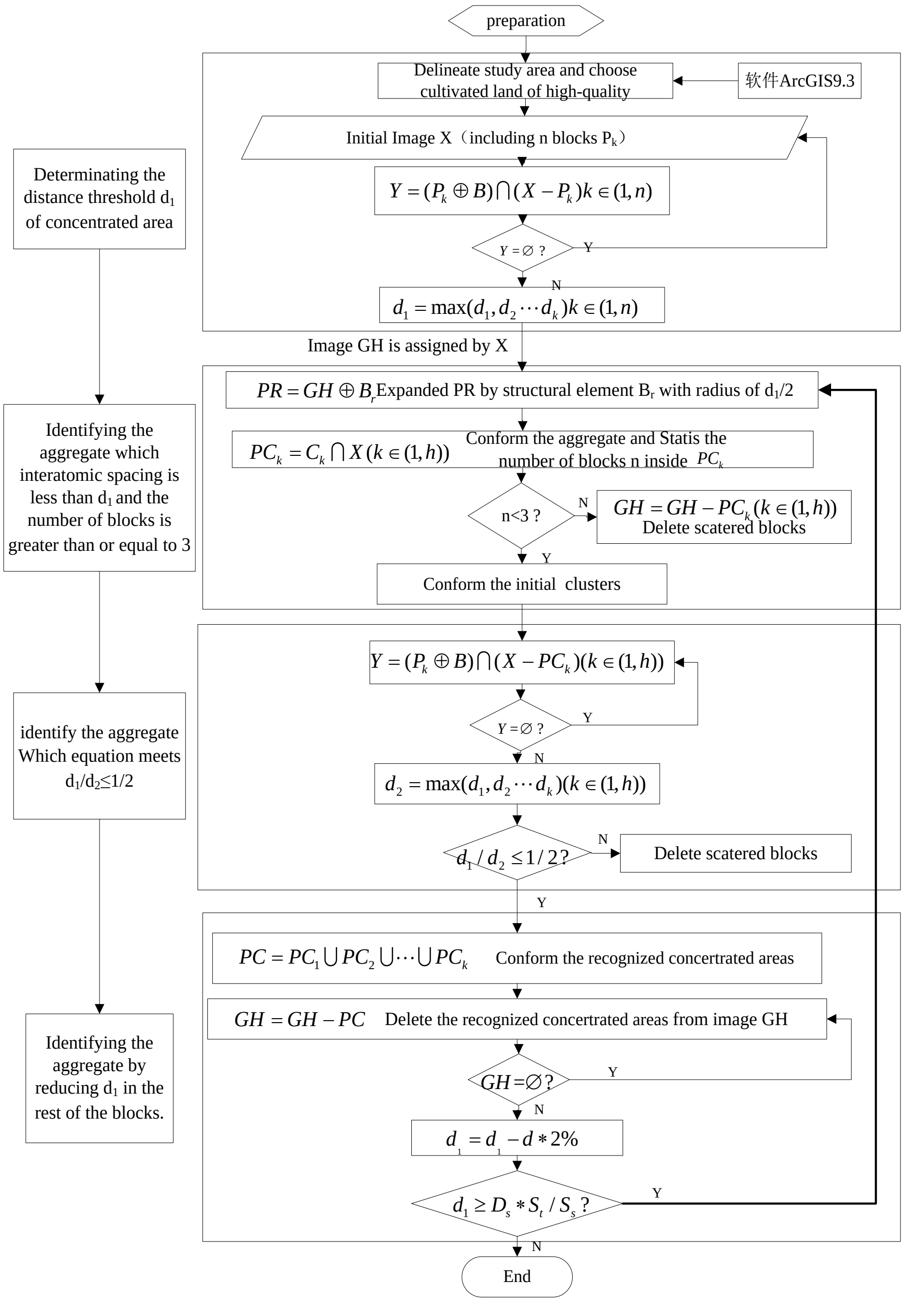


Fig.2 operation flow to identify the cultivated land concentrated areas

3 Application and demonstration

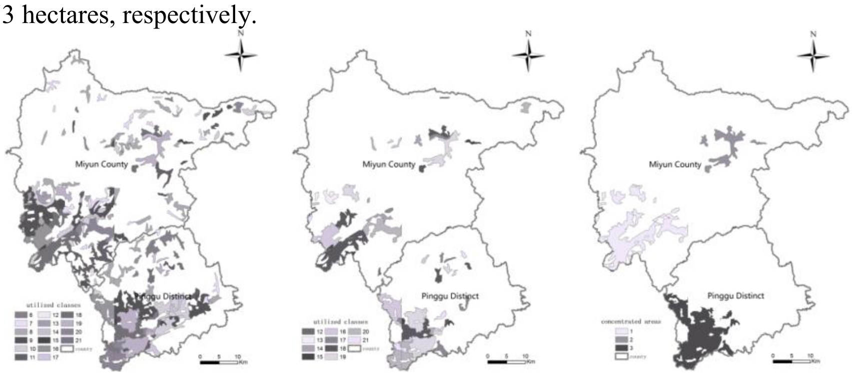
The method based on dilation and erosion operators of mathematical morphology, was applied and validated by identifying the concentrated areas of cultivated land in Miyun County and Pinggu District with the help of the Classification of Agricultural Land Map.

Classification of Agricultural Land Map in was Miyun County and Pinggu District in Beijing City was shown in Fig.3 (a) and its coordinate projecting system was Beijing 54. The agricultural land classes were determined by the project team according to the technical line of "Regulation for Classification of Agricultural Land" [15]. The regulation was the result of comprehensive evaluation in accordance with local natural factors including climate, soil, topographty as well as the utilization level and so on. The utilized agriculture land was ranged from 6 to 21grades and total area was 52548 hectares. According to the standard of protecting basic farmland, it was defined that the farmland above 11 grades was the high-quality cultivated land (In fact, the high-quality grade could be defined by local land administration departments). The high –quality agriculture land was ranged from 12 to 21 grades and total area was 42799 hectares, accounting for 81.45% of the total utilized agriculture land area.

The steps to delineate the concentrated area of high-quality cultivated land were described as follows.

Step 1: The farmland blocks above 11 grades (high quality) were extracted based on their property value, and they were shown in Fig.3 (b).

Step 2: Identifying the concentrated areas of cultivated land based on mathematical morphology. After rasterizing the resulting image in step 1, the operation flow in Fig.2 were to run to identify the cultivated land concentrated areas. Finally, 3 concentrated areas were identified, and they were expressed by different colors in Fig.3 (c). The 3 concentrated areas were 13647 hectares, 4008 hectares, 14953 hectares, respectively.



(a) (b) (c)

Fig.3 Delineate concentrated areas of high-quality cultivated land
(a)the map of utilized classes ,(b)the map of high-quality,(c) the map of concentrated areas of high-quality cultivated land

The result showed that the delineated concentrated areas of high-quality cultivated land was 32608 hectares which was accounting for 91% of the total high-quality cultivated farm land area (35862 hectares) in Miyun County and Pinggu

District in Beijing City. It showed that this method was feasible and precise result was attained. Therefore, it was helpful for delineating basic farmland protection areas.

4 Conclusion and Discussion

Protecting basic farmland was an elementary state policy in china. A new method was developed in this research to delineate the connective concentrated basic farmland based on mathematical morphology principles and GIS technology. Furthermore, this method was validated with the farmland classification data of Miyun County and Pinggu District in Beijing City and 91% of the connective and concentrated farmland could be identified by this method. The achievements of this research were as follows: (1) the method was able to locate the position of the connective cultivated land and it could be identified satisfactorily with great computational efficiency and high computational accuracy; (2) delineating concentrated and connective cultivated land was helpful to consolidate basic farmland as well as to control basic farmland transformation. Therefore, it was of significant meaning to protect and supervise basic farmland.

At present, there had been few studies on the connectivity of cultivated land, and the attempt was made based on mathematical morphology in this paper, it showed that the method was effective to delineate connective and concentrated cultivated land. However, further efforts should be made on these aspects: (1) the maximum threshold value of cultivated land block area should be defined, for the reason that when the area of cultivated land were large enough to management connectively, it was not meaningful to delineate any more;(2) the number of the scattered cultivated land should be further considered according to different situations. In this paper, the blocks number was set 3, when the scattered cultivated land were less than 3, they were not taken into the concentrated and connective the aggregates. When the area of cultivated land blocks was large, the error would be amplified, so improvement should be made for this method in the further researches latterly.

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