Effects of spatial grain size on different types of cultivated land landscape pattern in fragmented agricultural landscapes based on GF-2 imagery

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Abstract. The landscape pattern of the cultivated land determines the type, number, distribution and the allocation of cultivated land resource, which could provide theoretical basis for ecological security research, provide reference for policy formulation. The high resolution satellite image provides macroscopic, real-time, fine and dynamic data source for the study of cultivated land landscape pattern. The study of spatial grain effects on the different types of cultivated land is an important part of the study of landscape pattern, and also provides a basis for the selection of suitable spatial resolution of remote sensing image. In this study, a concentrated area of cultivated land in the suburban area of Nanjing City in Jiangsu Province was taken as the study area. Based on the analysis of China high spatial resolution GF-2 image, different types of cultivated land in the study area were extracted, including rice, soybean, vegetables, fallow land and greenhouse cultivation. On this basis, a series of landscape pattern indices were used to analyse the effects of spatial grain size on different types of cultivated land landscape pattern characteristics. The Percentage of landscape index (PLAND) of five types of cultivated land in the study area remained stable with the increase of grain size and the Area weighted mean patch fractal index (FRAC_AM) of the five types of cultivated land landscape in the study area changed slightly especially the rice landscape. The Mean patch area (AREA_MN) and Mean nearest neighbour index (ENN_MN) increased in varying degrees with the increase of grain size, while Edge density (ED), Area weighted mean contiguity (CONTIG_AM) and Patch cohesion index (COHESION) decreased in varying degrees with the increase of grain size. Among the five types of cultivated land landscape, the ED and COHESION of soybean and fallow land decreased more obviously with the increase of grain size, and the AREA_MN and ENN_MN of rice landscape increased most obviously with the increase of grain size.

1. Introduction
The cultivated land was affected by natural and human activities which has remarkable landscape characteristics. The landscape pattern of the cultivated land determines the type, number, distribution and the allocation of cultivated land resource, which could provide theoretical basis for ecological security research, provide reference for optimal arrangement of the regional resources, and provide
important data for the policy formulation of national food security and sustainable development of social economy. Remote sensing technology has the characteristics of multi-temporal, large scale and high efficiency of data acquisition which could provide macroscopic, real-time and dynamic data for the landscape pattern research of cultivated land and greatly promoted the quantitative method development of landscape pattern research [1, 2].

The patterns observed in ecological data may be influenced by spatial scale [3] and different landscape has different response to spatial scale changes [4]. The spatial scale of ecological data encompasses both grain and extent and grain refers to the resolution of the data [3]. Study of effects of grain scale on landscape pattern using remote sensing images had been carried out by many researchers [5-7]. It is difficult to reveal the spatial heterogeneity of different types of cultivated land landscape, if considering the cultivated land as a whole. However, there is still a lack of research on the effects of spatial grain size of different types of cultivated land landscape pattern.

In southern Jiangsu Province, the planting structure of cultivated land is various and the scale of cultivated land field is small. The agricultural landscape in southern Jiangsu Province is fragmented. It is difficult to extract accurate cultivated land landscape information by using medium resolution remote sensing image in southern Jiangsu Province. The GF-2 satellite, known as a member of firstly developed satellites of Chinses important project for high-resolution earth observation system, was launched on August 19, 2016, which carried one panchromatic and one multispectral camera. The spatial resolution of multispectral band is 4 m and the spatial resolution of panchromatic band is 1 m. The swath width of GF-2 is 45 km and the revisit period is 5 d combined with two cameras. The GF-2 could provide reliable data for the study of effects of grain size on cultivated land landscape pattern.

The purpose of this study was to observe the effects of grain size on different types cultivated land landscape data to identity some characteristics in fragmented agricultural landscapes. In this study, a concentrated area of cultivated land in the suburban area of Nanjing City in Jiangsu Province was taken as the study area, and the high spatial resolution GF-2 imagery was taken as the remote sensing data source. Based on the analysis of GF-2 image, the different types of cultivated land in the study area were extracted. On this basis, a series of landscape pattern indices were used to analyze the effects of spatial grain size on different types of cultivated land landscape pattern characteristics of the study area.

2. Study area and data resources

2.1. Study area

The study area is located in Jiangning District of Nanjing, the capital of Jiangsu Province, China (Figure 1). East to the study area is Jurong County of Zhenjiang, the south is adjoined by Lishui County of Nanjing, the northwest is bounded by the main urban area of Nanjing. Jiangning District is located in the lower reaches of the Yangtze River South Bank, southwest Jiangsu Province, which geographical extent ranges from 31’37” N to 32°07’ N in latitude and from 118˚28’ E to 119˚06’E. The Jiangning District belongs to the Northern subtropical monsoon climate zone with an average annual temperature of 16.8℃ and the average annual precipitation is 1, 807.7mm, which is suitable for planting rice, wheat, cotton, oil crops and vegetables. The suitable natural environment, superior agricultural machinery and water conservancy environment have created good conditions for agricultural production in this area.
2.2. Data source and processing
The basic data involved in this paper mainly include the GF-2 image and the field interpretation, validation and ground control points.

GF-2 PSM level 1A data collected at April 30, 2018 for this study was preprocessed before classification, which including orthographic correction, geometric registration, image fusion and subset cutting. Firstly, the image is orthographic corrected by RPC file supported by the satellite. Moreover, the image was geometric corrected using ground control points and achieved accuracy within 0.5 pixels. The panchromatic and multispectral data were fused to obtain the multispectral data of 1m resolution and the image of study area was extracted.

Interpretation, validation and ground control points were measured from September 1 to 10, 2018 by using global positioning system, during which time there has been little change in the land cover condition in the study area.

3. Method

3.1. Cultivated land classification
According to the China National Standards of Current Land Use Classification (GB/T 21010—2017), and the actual local situation of the study area, six landscape types were identified and used in this study, which including rice, soybean, vegetables, fallow land, greenhouse cultivation and other land. The first five of them belong to the type of cultivated land, and the sixth category includes forest land, garden plots, water area and construction land.

The extraction of different types of cultivated land and other land landscape was based on eCognition software, using object-based classification method to carry out landscape classification combined with the post classification manual rectification. The map of classification results in the study area was shown in Figure 2.
3.2. Selection of grain size

Effects of spatial grain size on the cultivated land landscape pattern were analyzed by degrading spatial resolution [8]. The result of cultivated land classification was resampled to a series of grain sizes from the original $1 \times 1m$ to $5 \times 5m$, $10 \times 10m$, $15 \times 15m$, $20 \times 20$m, $30 \times 30m$, $50 \times 50$m and $100 \times 100m$ by using ARCGIS software.

3.3. Selection of landscape indices

Landscape pattern can be reflected by a series of landscape indices related to area, edge, shape and distribution [9-11]. In this study, cultivated land landscape pattern was quantified by a series of landscape indices using FRAGSTATS software. The indices which could reflect the composition and spatial distribution of landscape components were selected to analyze the effects on grain size (1, 5, 10, 15, 20, 30, 50 and 100m) on landscape pattern, including three categories (as shown in Table 1).

The landscape classification results were transformed into grid data, and then the selected indices were calculated utilizing landscape pattern analysis software FRAGSTATS software.

| No. | Symbol | Name                              |
|-----|--------|-----------------------------------|
| Area and Edge indices                                      |
| 1   | PLAND  | Percentage of landscape           |
| 2   | ED     | Edge density                      |
| 3   | AREA_MN| Mean patch area                   |
| Shape indices                                             |
| 4   | FRAC_AM| Area weighted mean patch fractal  |
| 5   | CONTIG_AM| Area weighted mean contiguity     |
| Aggregation indices                                       |
| 6   | ENN_MN | Mean nearest neighbour            |
| 7   | COHESION| Patch cohesion                    |
4. Result

4.1. Analysis of grain size on Area and Edge indices at the class level
The PLAND of all kinds of cultivated land landscape types in the study area remained stable with the increase of grain size, which showed that there was no obvious response of grain size on the PLAND.

![Figure 3](image)

**Figure 3.** Response of PLAND for grain size changing

With the increase of grain size, the ED of five types of cultivated land landscape showed a decreasing tendency. In the range of 1 to 10 m, the decreasing rate of the ED of the five types of cultivated land was within 10%. With the increase of grain size, the decline of ED of all kinds of cultivated land landscape increased gradually, and the decline gap between different cultivated land landscape increased. At the grain size of 30m, the ED of the five types of cultivated land decreasing rate was more than 25%, of which the decreasing rate of soybean landscape was 38.26%. At the grain size of 50m, the decreasing rate of ED of soybean landscape was 52.22%. At the grain size of 100m, the decreasing rate of ED of soybean landscape was 87.70%.

![Figure 4](image)

**Figure 4.** Response of ED for grain size changing
With the increase of grain size, the AREA_MN of the five types of cultivated land landscape showed an increasing tendency. The variation range of AREA_MN of rice landscape was the most prominent. When the grain size increased from 1m to 5m, the change rate of rice landscape was 0.32, and when the grain size changed to 15m, the change rate was 0.62, and then increased gradually. When the grain size was 100m, the AREA_MN of rice landscape reached 8.67 times as much as that of 1m. In the range of 0~15 m, the maximum decrease rate of AREA_MN of soybean landscape was 11.73%, and that of fallow land was 7.02%. The AREA_MN of soybean and fallow land reached the minimum when the grain size was 10 m. In the range of 20~100m, the AREA_MN of soybean and fallow land increased with the increase of grain size, and the increasing rate enhanced gradually with the increase of grain size. When the grain size was 100 m, the AREA_MN of soybean was 9.38 times of that of 1m grain size.

![Graph](image)

**Figure 5.** Response of AREA_MN for grain size changing

4.2. Analysis of grain size on Shape indices at the class level
The FRAC_AM of the five types of cultivated land landscape in the study area changed slightly with the increase of grain size, and the absolute value of the change rate was less than 0.11. With the increase of grain size, the FRAC_AM of the other four types of cultivated land landscape except rice showed a decreasing tendency. The FRAC_AM of rice landscape increased first and then decreased in the process of increasing grain size, and then tended to stable.
At the grain size of 1 m, the CONTIG_AM of the five types of cultivated land landscape in the study area approximated to 1 (maximum). With the increase of grain size, the CONTIG_AM of the five types of cultivated land landscape showed a downward trend in varying degrees. The CONTIG_AM of soybean and fallow land landscape decreased greatly with the increase of grain size. When the grain size increased from 1m to 5m, the CONTIG_AM of soybean and fallow land decreased by 21.52% and 15.00% separately. When the grain size was 100m, the CONTIG_AM of soybean and fallow land decreased from 0.95 to 0, and that of fallow land decreased from 0.96 to 0. The decrease rate of CONTIG_AM of rice landscape was the lowest, with the maximal decrease rate of 12.37% in the range of 1~15 m, and the decrease rate of other cultivated land landscape was less than 11% in the range of 1~5 m grain size.

4.3. Analysis of grain size on Aggregation indices at the class level
With the increase of grain size, the ENN_MN of five types of cultivated land landscape in the study area showed an upward trend in different degrees. The ENN_MN of rice landscape increased the most,
followed by vegetables and greenhouse cultivation. When the grain size increased from 1m to 5m, the ENN_MN of rice landscape increased by 66.45%, the ENN_MN of vegetables landscape increased by 43.98%, and that of greenhouse cultivation was 32.23%. When the grain size reached 100m, the ENN_MN of rice was 18.42 times of that of 1m. In the range of 1~10 m, the ENN_MN of soybean and fallow land landscape increased by less than 10% especially in soybean, which maximum increase rate was 2.50%.

Figure 8. Response of ENN_MN for grain size changing

With the increase of grain size, the COHESION of five types of cultivated land landscape showed a downward trend in different degrees. The decrease rate of rice landscape was the lowest, with a decrease rate of less than 10% in the range of 1~100 m, followed by vegetables and greenhouse cultivation landscape, with a decrease of less than 15% in the range of 1~20 m, and the decrease of soybean and fallow land was larger, with a decrease rate of more than 15% in the range of 1~10 m.

Figure 9. Response of COHESION for grain size changing
5. Conclusion

In this study, high spatial resolution remote sensing data and landscape indices analysis methods were used to investigate the effect of spatial grain size on the landscape pattern of the five types of cultivated land in the suburban area of Nanjing City in Jiangsu Province.

The PLAND of five types of cultivated land in the study area remained stable with the increase of grain size, which showed that there was no obvious response of grain size on the PLAND. The FRAC_AM of the five types of cultivated land landscape in the study area changed slightly with the increase of grain size, and the absolute value of the change rate was less than 0.11 in the range of 1~100m grain size. The shape of cultivated land landscape in the study area was close to the regular rectangle, especially the rice landscape. The AREA_MN and ENN_MN increased in varying degrees with the increase of grain size, while ED, CONTIG_AM and COHESION decreased in varying degrees with the increase of grain size.

Within the range of 1~10 m, the decrease range of ED of the five types of cultivated land had little difference, and the decrease rate was less than 10%. With the further increase of grain size, the decrease trend of soybean and fallow land was more obvious. The AREA_MN of rice landscape increased most obviously with the increase of grain size, and the overall trend of AREA_MN of other cultivated land landscape with the increase of grain size was the same as that of rice, and the change rate was lower than that of rice.

At the grain size of 1 m, the CONTIG_AM of the five types of cultivated land landscape in the study area approximated to 1 (maximum). The decrease rate of rice landscape was the lowest, and the highest decrease rate was 12.37% in the range of 1~15m grain size, while the decrease rate of soybean dropped fastest, the decrease rate of soybean was 21.52% when the grain size increased from 1m to 5m, and then increased rapidly to 100%.

The ENN_MN of rice landscape increased the most with the increase of grain size, followed by the vegetables and fallow land. When the grain size of these three types of cultivated land increased from 1m to 5m, the ENN_MN increased by more than 30%. In the range of 1~10 m, the landscape of soybean and fallow land increased by less than 10%. The COHESION of rice landscape decreased the lowest with the increase of grain size, and the decrease rate was less than 10% in the range of 1~100m, followed by vegetable and greenhouse landscape, soybean and leisure land.

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