*sustainability*

MDPI

*Article*

# Evaluation of the Level of Farmland Infrastructure Based on High-Resolution Images of UAV

**Jingrui Pan, Chunyan Chang *, Zhuoran Wang, Gengxing Zhao *, Yinshuai Li, Shuwei Zhang and Yue Chen**

National Engineering Research Center for Efficient Use of Soil Fertilizer, College of Resources and Environment, Shandong Agricultural University, Tai'an 271000, China; 2021110197@sdau.edu.cn (J.P.); wangzr@sdau.edu.cn (Z.W.); 2020110360@sdau.edu.cn (Y.L.); 2020110691@sdau.edu.cn (S.Z.); 2021110191@sdau.edu.cn (Y.C.)

* Correspondence: chyan0103@sdau.edu.cn (C.C.); zhaogx@sdau.edu.cn (G.Z.)

**Abstract:** The evaluation of the level of farmland infrastructure is a necessary objective condition for the use of arable land and agricultural development. In order to investigate the evaluation index system and method of farmland infrastructure level, this article uses the Kenli District of the Yellow River Delta as the research region. In the study region, six typical observation sample areas are chosen. Each area receives high-resolution UAV photos, which are then used to extract information about the farmland infrastructure of the field. A farming infrastructure evaluation index system was built, consisting of 10 indexes for four aspects, including farmland roads, field plots, ditches, and forest belts, using the 100 m by 100 m grid method to divide the evaluation units. The comprehensive index technique was used to calculate the farmland infrastructure score of each unit and identify the degree of excellent, good, and poor farmland infrastructure. The weight of each indication was decided by the hierarchical analysis method. There were 20 excellent grades, 77 good grades, and 29 poor grades among the 126 evaluation units in the study area, with excellent and good grades accounting for 79.13% and area proportions of 14.29%, 64.84%, and 20.87%, respectively. Among the six sample areas, sample areas E and F had the highest percentages of excellent grades, sample area A had 82.62% of the good grades, and all sample areas except A and C had a percentage of poor grades that was higher than 20%. Regularity of the fields, average size of the fields, and the agricultural plot's slope are the dominant indexes of farmland infrastructure in each observation sample area, and the indexes of the ratio of the perimeter of roads to the perimeter of fields, density of ditches, and the ratio of area of agricultural forest networks to area of fields need to be optimized and improved. The spatial distribution of each grade differs significantly. The evaluation results are consistent with the real situation in the study region and have positive reference meaning for the development and management of farming infrastructure, according to the study's proposed evaluation system and methodology.

**Keywords:** UAV images; extraction of features; farmland infrastructure; evaluation system



**Citation:** Pan, J.; Chang, C.; Wang, Z.; Zhao, G.; Li, Y.; Zhang, S.; Chen, Y. Evaluation of the Level of Farmland Infrastructure Based on High-Resolution Images of UAV. *Sustainability* **2023**, *15*, 12778. https://doi.org/10.3390/su151712778

Academic Editor: Jacopo Bacenetti

Received: 15 July 2023
Revised: 18 August 2023
Accepted: 21 August 2023
Published: 23 August 2023



## 1. Introduction

The carrying capacity of resources and the environment are becoming more and more stressed due to China's population expansion. The country's easy-to-develop reserve resources of arable land have been depleted, and inefficient utilization issues like water and soil mismatch, fragmented pattern and ownership, and inadequate infrastructure have seriously hampered the sustainability of the country's current arable land production [1]. Building high-standard farmland is a key measure to improve the comprehensive grain production capacity and potential of farmland production and promote high-quality agricultural development. It has extremely important practical significance and far-reaching impact on promoting agricultural and rural modernization and accelerating the construction of an agricultural power [2]. The protection of arable land resources and a steady supply of grain depend heavily on ideal farmland infrastructure facilities, which are a crucial component of high-standard farmland building. By taking actions like organizing farmland plots, enhancing irrigation and drainage systems, and stepping up farmland protection, economic, social, and ecological benefits can be produced [3]. Therefore, for the current production and development of food, as well as the usage and protection of arable land, there is an objective need for quick access to information on farmland infrastructure and accurate assessments of the amount of farmland infrastructure.

The level of farmland infrastructure can directly affect the quality of arable land [4–8], production of grain [9–11], and productive potential of agricultural land [12–15]. Numerous Chinese academics have explored farm plots, field roads, irrigation and drainage systems, and farmland forest in order to improve the construction of farmland infrastructure. For instance, using high-quality remote sensing pictures, Ren Hongyu [16] and Liu Changjuan [17] investigated the dispersion of cropland and estimated the plant cover of cropland. Yuan Cuixia [18] discovered that the U-Net network can successfully recognize high-grade rural roads in a variety of environments after researching the techniques for farmland road recognition. Wu Fenghua [19] did a preliminary investigation of rural road networks and designed an evaluation system for road networks based on field road accessibility. Gu Zhengming [20] used remote sensing data from UAVs to investigate and monitor the use of roads and ditches in land renovation projects. In order to find the best protection mode of farmland water conservancy for the study region, Zhou Yingtang [21] built an evaluation index system for such models. Yahui Lu [22] studied the automatic recognition method of high-resolution remote sensing for the farmland forest network using a 0.5 m Geo Eye-1 satellite remote sensing image as the data source and fully using the texture and spectral information of the image. On the basis of remote sensing (RS) and geographic information system (GIS) technologies, Shi Xiaoliang [23] investigated the assessment process of the effects of agricultural protection forest on the yield of crops. It has been demonstrated that farmland shelterbelt will, to some extent, encourage a rise in maize yield, particularly in low-production locations with unfavorable environmental conditions. The measurement and evaluation techniques for the completeness of farmland infrastructure have been studied by Ouyang Jinming [24].

In the field of farmland infrastructure evaluation research, there is still a lack of targeted evaluation index system and method standards, and the systematic research on extracting farmland infrastructure information from high-resolution remote sensing images and carrying out qualitative analyses and the quantitative evaluation of farmland infrastructure is still very rare. In this study, Kenli District, which has a large difference in the level of farmland infrastructure in the Yellow River Delta, is selected as the research area. It is planned to extract information about farmland infrastructure from UAV high-resolution images and build an level evaluation index system to understand the level and distribution of farmland infrastructure in the sample area so as to explore the information extraction and level evaluation methods of farmland infrastructure and provide a scientific basis for the utilization, protection, and construction management of farmland; it also provides a reference for similar regions and countries.

## 2. Materials and Methods

### *2.1. Study Area Overview*

Kenli District is a part of Dongying City in Shandong Province. Its coordinates are 118°15′ and 119°19′ E and 37°24′ to 38°10′ N, at the mouth of the Yellow River. The terrain is low, with the entire terrain from the southwest to the northeast estuary lower. The location is in the warm temperate monsoon climate zone. The soil salinization is significant due to an overall high groundwater level along the coast, and Yellow River water and natural precipitation are the main sources of surface water. Wheat, corn, and cotton are the principal crops grown in the region's arable land, salt wasteland, and water areas. The region is a good fit for this study, since there are considerable variances in the management of the usage of arable land there and in the amount of infrastructure on farms in various cropping areas.

According to the current land use status in Kenli District, agricultural land is mainly located along the Yellow River in the northeast and in the higher terrain area in the southwest. Large portions of the eastern coastline region are covered in mudflats, mining land is concentrated in the north and central-west, sizable amounts of saline land are dispersed across the district, and an airport is located in the east. The observation sample areas' spatial distributions vary from one another. Three different types of land are present in the sample locations: irrigated land, paddy land, and dry land. The distinctions in the farms, roads, ditches, and forest networks between the areas are easily apparent. The sample areas have a range of infrastructures for farming that are well-represented (Figure 1).

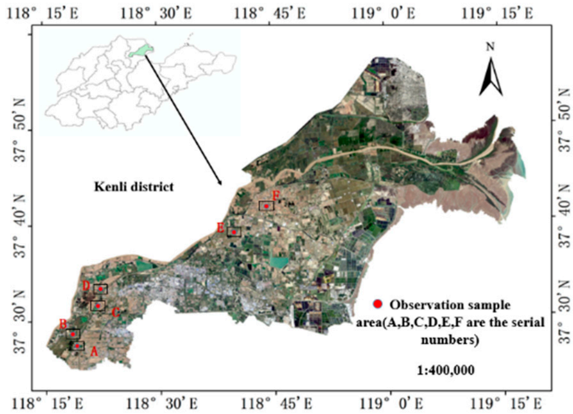



**Figure 1.** Distribution of the study region and observation sample areas (Landsat8-OLI NIR, red and green band synthetic images).

## *2.2. Data Acquisition and Preprocessing*

On 7 and 8 July 2022, data collection and UAV images were conducted. The benefits of UAV mapping include high flexibility, affordability, and speed. The Matrice600PRO hexacopter UAV with a high-precision and high-stability GPS navigation system is equipped with a Sequoia multispectral camera, which is widely used in agricultural research to collect multispectral data and fly safely and reliably, and this allows it to fully acquire and utilize the spectral information of the UAV images. Designed to adapt to all types of UAVs, the Sequoia sensor consists of a combination of five cameras, each with a different filter, containing four 12-megapixel sensors that capture multispectral farmland image data in four spectral bands: green band (wavelength of 550 nm, bandwidth of 40 nm), red band (wavelength of 660 nm, bandwidth of 40 nm), red-edge band (wavelength of 735 nm, bandwidth of 10 nm), and near-infrared band (wavelength of 790 nm, bandwidth of 40 nm). The 16-megapixel sensor may also record visible images while in flight for examination. The multispectral camera can take photos quickly and without regard to location, since it employs a daylight illuminance meter for self-calibration and a 16 Mpx RGB camera for surveying. During the flight, the camera was pointed parallel to the main flight path, with a 60% side-to-side overlap and an 80% flight heading overlap. Equal time interval photography was the method used, and each image result was geo-tagged. The drone could fly up to 120 m in the air, its altitude was set at 100 m to assure high-resolution images, the rectangular area where the flight area was determined by the closest distance to the same type of farmland infrastructure was the flight area, the flying time was 9:00–12:00, the flying altitude was 100 m, the speed was 8.7 m/s, and the ground resolution was 4.4 cm/PX. The weather was clear and windless.

As a ground marker point for the spatial correction of the UAV high-resolution photos, a TrimbleGeo7 portable differential GPS was utilized to measure the latitude and longitude coordinates of the turning points at road intersections in the region. Additionally, to increase the precision of the extraction of an image feature parameter, a tape measure was employed to gauge the real width of the road and ditch in the field.

To obtain orthographic UAV high-resolution images, the obtained image data were imported into Pix4D mapper 4.4.12 software for the stitching of multiple images, correction of radiation, and alignment of geographic coordinates. ENVI 5.3 software was used to pick the near-infrared, red, and green bands of the images for RGB false color synthesis and image cropping to produce images of each observation sample area (Figure 2).

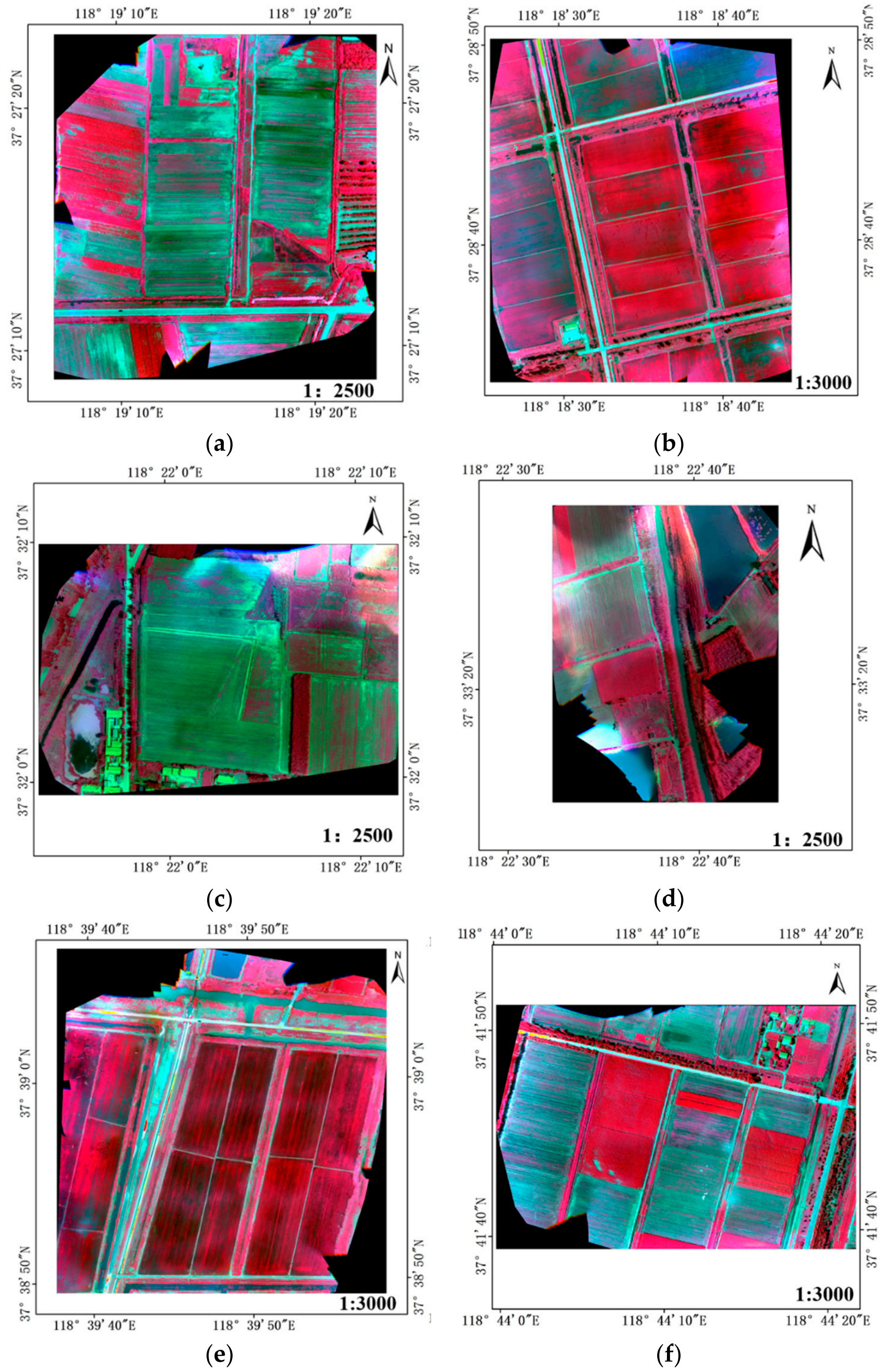



**Figure 2.** UAV false color composite images of the observation sample areas. (**a**) Observation sample area A. (**b**) Observation sample area B. (**c**) Observation sample area C. (**d**) Observation sample area D. (**e**) Observation sample area E. (**f**) Observation sample area F.

The decision to use drone mapping to acquire high-resolution images for this study was made after taking into account that drones have fewer requirements for the geographic airspace in which they fly, as well as for meteorological conditions, that the summertime weather in the study area changes quickly, that drones are known for their quick response to mapping, and that the preparation time for takeoff is only about 15 min. The usual high-resolution satellite image data gathering cycle is lengthy, and the timeliness is poor. Of course, drone remote sensing also has some shortcomings. The image obtained from the drone is time-specific, and it is not possible to carry out continuous observation for a long period of time due to the battery factor. Additionally, the drone does not have the advantage of remote sensing mapping in a large area range, and it is necessary to increase the amount of work and the capital investment if accuracy and precision are desired. Therefore, it is necessary to choose the most suitable remote sensing method according to the actual demand. Since there is no demand for data continuity in this work and the observation sample area is tiny, choosing UAV remote sensing to acquire data is the best option.

### 2.3. Research Methods

#### 2.3.1. Information Extraction from UAV Images of the Agriculture Infrastructure

In this study, eCognition software 9 is used to implement the object-oriented classification method of segmentation followed by classification, which overcomes the limitation of traditional remote sensing software to classify images based solely on spectral information and significantly increases the accuracy of the automatic identification of high spatial resolution data. Traditional classification techniques collect typical information in terms of individual pixels. This leads to a situation where the localization is overemphasized while the geometric structure of the surrounding patch as a whole is neglected. On the other hand, artificial intelligence machine learning algorithms provide the advantages of efficiency, autonomous learning, and problem solving, but no single algorithm is capable of handling every problem flawlessly. For instance, large and well-structured databases are essential for machine learning classification methods like Random Forest and Support Vector Machines. In order to find the best method, it is also necessary to repeatedly debug the algorithm's parameter optimization and variable selection. This is a labor-intensive, highly complex, and time-consuming procedure. Six small-scale UAV images were used in this investigation, but the amount of data used to build the dataset was insufficient to meet all of the desired conditions, making it challenging to build an accurate model. As a result, AI machine learning algorithms are not the best approach for classifying data. Combining the above, the object-oriented supervised classification method of eCognition software is the most appropriate classification method for classifying farmland infrastructure. This method ensures the completeness of each type of infrastructure and the high accuracy of the classification at the same time. The following is the process of categorization.

Segmentation of images. To determine the ideal segmentation scale for the picture segmentation, a bottom-up segmentation method (multiresolution segmentation) was chosen. As an illustration, consider observation sample area E. The graphic illustrates the differences in segmentation effects at various scales (Figure 3). The parameter for the scale is 500, and the differences in segmentation effects at various scales are given in the picture to verify that the segmentation object is full, coherent, and clear.

Select samples and construct feature sets. Characteristics of the categories that classify the various types of farmland infrastructures are constructed by combining the spectral features of each infrastructure, such as the mean, brightness, standard deviation, etc. The objects that correspond to each infrastructure, as determined by visual interpretation, are chosen as their classification samples, and the nearest neighbor configuration algorithm is applied to configure the nearest neighbor features.

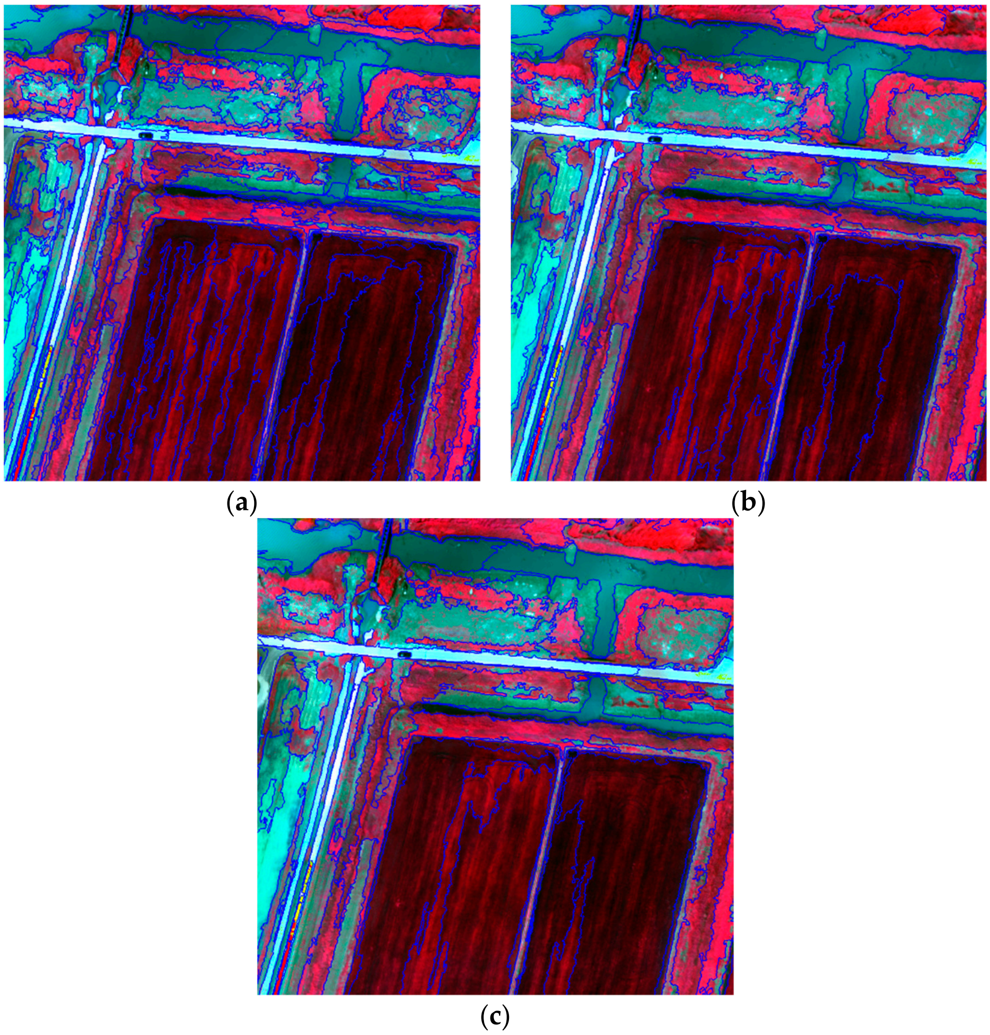


**Figure 3.** Segmentation of images under different segmentation scales. (**a**) The parameter for the scale is 300. (**b**) The parameter for the scale is 500. (**c**) The parameter for the scale is 700.

Classification of images. A sample-based supervised classification method is utilized to finish the categorization of farming infrastructure information based on the numerous classification samples that were chosen and the predefined criteria. Figure 4 displays the results of the classification.

Placing the importance of the four different forms of infrastructure and completeness first when prioritizing the extraction of agricultural fields and farm roads. Regular fields, well-constructed roadways, and trunk canals were all successfully extracted during the extraction operation. After the classification using eCognition software is finished, the extraction results need to be further corrected by visual interpretation to ensure the accuracy of the infrastructure classification results, because some of the drainage ditches, branch canals, and forest belts are interspersed with weeds. The results from the visual interpretation method were quite accurate for small sample sizes. Arcgis 10.7 software was used to calculate the area ($m^2$) and length (m) of each classified object using the Calculate Geometry function. The Field Calcultor function was then used to further calculate quantitative indexes like regularity, density, and ratios.

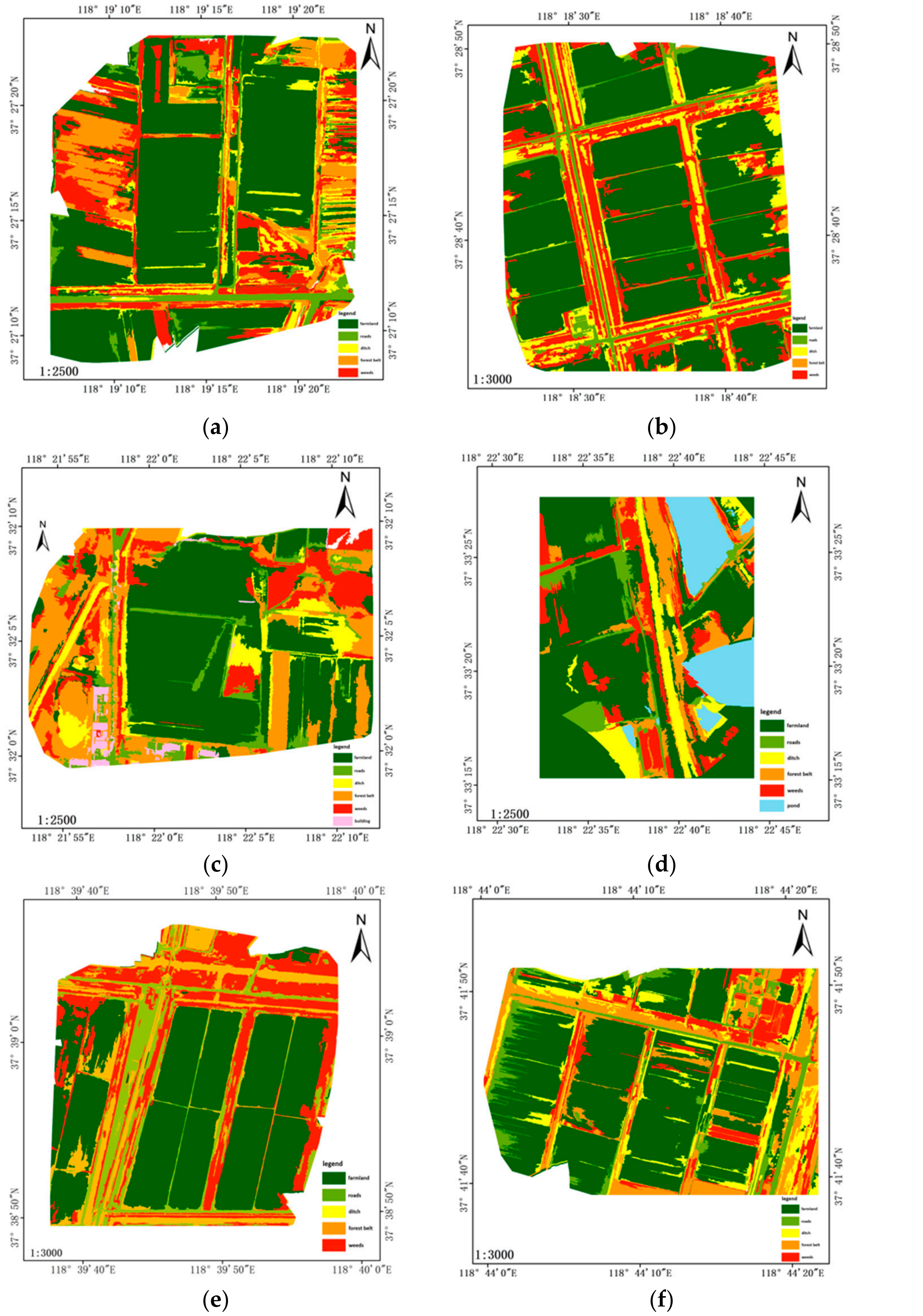



**Figure 4.** Pictures of the results of classification of the farmland infrastructure in each observation sample area. (**a**) Results of classification of sample area A. (**b**) Results of classification of sample area B. (**c**) Results of classification of sample area C. (**d**) Results of classification of sample area D. (**e**) Results of classification of sample area E. (**f**) Results of classification of sample area F.

2.3.2. Establishment of Indexes and Systems for Evaluating Farmland Infrastructure

The infrastructure for farmland is the infrastructure that supports agriculture and is a crucial component in the creation of high-quality farmland. The development of agricultural land's soil conditions, agricultural ecological environmental protection, and the construction of field roads are just a few of the numerous components of building an infrastructure for farmland [25]. This study establishes an index system for the evaluation of a multilevel farmland infrastructure with a target layer, criterion layer, and index layer in conjunction with the real situation in Kenli District. The level of farming infrastructure is the target layer. The criteria layer includes farmland fields, farmland roads, farmland ditches, and farmland forest networks. Under each criterion layer, 2–3 impact indexes are chosen in accordance with the principles of difference, feasibility, and effectiveness. The four categories of infrastructure and the significance of each indicator are defined in the following sections.

Farmland fields: farmland field is a basic agricultural unit surrounded by fixed trenches, canals, roads, and ridges at the end of the field. The regularity of fields, average size of fields, and the agricultural plot's slope are the major indexes of farmland. The following are explanations for the three indexes.

a. Regularity of fields: The regularity of fields is a statistic used to quantify the complexity of field geometry, which has an immediate impact on the condition used for the farming of agricultural machinery facilities. The more regular the field, the easier it is to operate agricultural machinery. Using machinery to farm can reduce labor costs and increase productivity. The shape index of landscape ecology, which indicates the regularity of fields, represents the level of regularity of the farmland shape. The simplest shape, measured by the shape index, is a square, which spans from 1.0 to 2.0. When the area is equal, the plot's shape becomes more complex the higher the value [26]. The calculation model of field regularity is

$$R_1 = 2\log(P/4)/\log A_1 \tag{1}$$

In Equation (1), $R_1$ represents the regularity of fields, P represents the field's perimeter (m), and $A_1$ represents the field's area ($m^2$).

b. Average size of fields: The most fundamental spatial attribute of agriculture is the average size of fields. Farmland is more conducive to farmers' farming activities and intensive production; the larger the average size of fields within a given scale, the smaller the fragmentation of farmland, and the higher the degree of concentration, which, to some extent, diminishes farming costs and boosts the agricultural efficiency of agricultural production [27].

$$Sa = S/N \tag{2}$$

In Equation (2), Sa represents the average size of fields, S represents the total area of agricultural land ($m^2$), and N represents the number of plots of agricultural land.

c. The agricultural plot's slope: The slope of a surface unit determines how steep it is, and a slope is typically defined as the slope's ratio of vertical height to horizontal distance. The values of the slope of the observed plots were estimated by utilizing the statistical tools for spatial analysis after the values of the slopes of the cloud platform for geospatial data "http://www.gscloud.cn/search (accessed on 10 August 2022)" were processed to acquire the DEM of the study region.

Farmland roads: Farmland roads are the final layer of the network of farm roads, and they are facilities for connecting fields and roadways used for production operations, such as the movement of agricultural products, farm workers, and farm machinery. The density of roads and the ratio of the perimeter of roads to the perimeter of fields are the major indexes for farmland roads. The following are explanations for the two indexes.

d. Density of roads: The distribution of farmland roads, which are further separated into field roads and production roads, is referred to as the density of roads. More roads are distributed, and agriculture movement is more convenient as the density of a population increases.

$$D_1 = L_1/S_1 \tag{3}$$

In Equation (3), $D_1$ represents the density of roads, $L_1$ represents the total length of roads in the evaluation unit (m), and $S_1$ represents the total area of fields in the evaluation unit ($m^2$).

e. The ratio of the perimeter of roads to the perimeter of fields: It is the ratio of the total length of the roads and the field's perimeter. The road that encircles the field is better when the ratio is higher, which also reflects better traffic conditions for the field.

$$P = L_1/L_2 \quad (4)$$

In Equation (4), P represents the ratio of the perimeter of roads to the perimeter of fields, $L_1$ represents the total length of road in the evaluation unit (m), and $L_2$ represents the total length of the field perimeter in the evaluation unit (m).

Farmland ditches: Farmland ditches refer to field irrigation channels, field drains, and drainage pipes, which are used to divert water to irrigate farmland or discharge rainwater and wastewater and shoulder the role of field water transport and drainage. The density of ditches and the ratio of the perimeter of ditches to the perimeter of fields are the two most important indexes of farmland ditches. The following are explanations for the two indexes.

f. Density of ditches: Describe the general distribution of ditches. The more ditches there are overall and coverage of basic distributions of irrigation and drainage is higher, the better the area's ability to irrigate and drain itself. It meets the basic water needs and drainage requirements.

$$D_2 = L_3/S_1 \quad (5)$$

In Equation (5), $D_2$ represents the density of a ditch, $L_3$ represents the total length of ditches in the evaluation unit (m), and $S_1$ represents the total area of fields in the evaluation unit ($m^2$).

g. The ratio of the perimeter of ditches to the perimeter of fields: The larger the value, the better the capacity for irrigation and drainage, the higher the efficiency of irrigation and drainage of ditches, and the fewer occurrences of missing irrigation or waterlogged fields. This index represents the area of a field irrigated per unit length of ditch.

$$R_2 = L_3/S_1 \quad (6)$$

In Equation (6), $R_2$ represents the ratio of the perimeter of ditches to the perimeter of fields, $L_3$ represents the perimeter of ditches in the evaluation unit (m), and $S_1$ represents the total area of fields in the evaluation unit ($m^2$).

Farmland forestry networks: A farmland forest network is a shelter forest in the form of a narrow forest belt and small grid, which is designed and planted with single or more than two rows of trees or shrubs according to certain spacing, width, structure and direction around the roadside, channel, ridge, and farmland. The density of agricultural networks, completeness of agricultural networks, and the ratio of the area of agricultural forest networks to the area of fields are the indexes of the farmland forest network. The following are explanations for the three indexes.

h. Density of agricultural networks: This term refers to how densely a network of forests is arranged and indicates how well or poorly farmland is protected. The protection will be diminished by a straightforward composition and sparse distribution of forest strips. The density of agricultural networks needs to meet the requirements for effective protection.

$$D_3 = L_4/S_1 \quad (7)$$

In Equation (7), $D_3$ represents the density of agricultural networks, $L_4$ represents the total length of forest networks in the evaluation unit (m), and $S_1$ represents the total area of fields in the evaluation unit ($m^2$).

i. Completeness of agricultural networks: The higher the completeness, the better the protection, as it reveals whether or not the network is absent and the extent of the degree of the protection. A comprehensive, well-maintained, and safe forest serves as a greening force, in addition to providing ecological advantages.

$$I = (B - C)/B \quad (8)$$

In Equation (8), I represents the completeness of agricultural networks, B represents the length of forest belt (m), and C represents the total length of fractured forest belts (m).

j. The ratio of the area of agricultural forest networks to the area of fields: The size of a unit area of a field protected by a unit length of a forest belt is represented by the area ratio of forest networks to fields. The bigger the ratio, the better the protection, which has a favorable impact on the ecological improvement of farmland.

$$A_2 = S_2/S_1 \tag{9}$$

In Equation (9), $A_2$ represents the ratio of area of agricultural forest networks to area of fields, $S_2$ represents the area of forest network ($m^2$), and $S_1$ represents the total area of field plots ($m^2$).

2.3.3. Division of the Evaluation Unit and Determination of Index Weights

1. Division of the evaluation unit

For the purposes of evaluating rural infrastructures, the evaluation cell is the smallest spatial unit. Superposition and grid methods are frequently used to divide evaluation cells. Here, we employ the grid approach, The principle of dividing the evaluation area into discrete grids of uniform size and shape is accomplished by creating a fishing grid using Arcgis 10.7 software [28], which is a straightforward and practical method and which covers the entire area of the observation sample.

The key to this work is figuring out the smallest grid cell that can hold data on various forms of agriculture infrastructure. According to Google Maps images, the majority of the farmland parcels in the Kenli District are between 1.5 mu and 4 mu in size, with an average plot size of roughly 2 mu. Ditches and forest belts are typically listed close to the roads, and the relative distance between roads ranges from 60 to 130 m. The optimal grid size of the cell was found to be 100 m × 100 m, with 5–7 plots in each unit, taking into account the length and width of the plots in the observation sample areas and the layout structure of farmland infrastructures. This was done because there are differences in the distribution of major farmland infrastructures in each evaluation unit.

2. Determination of index weighting coefficients

The weights of the indexes in this study were determined by combining the Analytical Hierarchy Process (AHP) with the Delphi Method. Using the 1–5 score scale method, expert scoring was used to produce the score matrix table (Table 1). The score judgment matrix was entered into SPSSAU to perform a matrix analysis and obtain the eigenvectors and weight values of each factor. The consistency test was used to check for logical errors in the judgment matrix, and a CR value of less than 0.1 meant that the consistency test was successful.

**Table 1.** Scores of 1–5 on a scale of importance.

| Scale | Statement of Importance |
|---|---|
| 1 | Indicates that two factors are of equal importance compared to each other. |
| 2 | Indicates that the former is slightly more important than the latter when comparing the two factors. |
| 3 | Indicates that the former is significantly more important than the latter when comparing the two factors. |
| 4 | Indicates that the former is more strongly important than the latter when comparing the two factors. |
| 5 | Indicates the extreme importance of the former over the latter when comparing the two factors. |
| reciprocal | If the ratio of the importance of factor i to factor j is aij, then the ratio of the importance of factor j to factor i is aji = 1/aij. |

Farmland fields: farmland roads: farmland ditches: farmland forest networks = 3.0:2.5:3.5:1.0, assigning the scores to each factor after comparing the importance of the factors participating in the evaluation, and creating a judgment matrix to complete the division of the weights of the second-level indexes according to the importance of various farmland infrastructures were the decisions made using the Delphi method. Table 2 displays the distribution of the weights and scores for each index.

**Table 2.** Determination of the weights and scores of the farmland infrastructure participation factors.

| First-Order Indexes | | | Secondary Indexes | | |
|---|---|---|---|---|---|
| Indexes | Weights | Score | Indexes | Weights | Score |
| Farmland fields | 0.30 | 30 | Regularity of fields | 0.171 | 17 |
| | | | Average size of fields | 0.086 | 9 |
| | | | The agricultural plot's slope | 0.043 | 4 |
| Farmland roads | 0.25 | 25 | Density of roads | 0.167 | 17 |
| | | | The ratio of the perimeter of roads to the perimeter of fields | 0.083 | 8 |
| Farmland ditches | 0.35 | 35 | Density of ditches | 0.228 | 23 |
| | | | The ratio of the perimeter of ditches to the perimeter of fields | 0.123 | 12 |
| Farmland forestry networks | 0.10 | 10 | Density of agricultural networks | 0.054 | 5 |
| | | | Completeness of agricultural networks | 0.029 | 3 |
| | | | The ratio of area of agricultural forest networks to area of fields | 0.016 | 2 |

### 2.3.4. Infrastructure and Grading Scales for Farmlands

1. Setting the evaluation standards

The three classification criteria listed in Table 3 were developed based on reflection after looking through the pertinent data and incorporating findings from related studies. The usage of variables with already established criteria was chosen, such as the regularity of fields and the agricultural plot's slope. However, no unique standard was found for the density, perimeter ratio, or area ratio; therefore, we used the total indicator data of the six study sample areas as the foundation, dividing it into three grades of varying degrees, each with its own quantitative standard. This was done by taking into consideration the relevance of the high and low values of each indicator of farming infrastructure. Various levels signify various levels of infrastructure support for agricultural land, as well as various functional strengths of infrastructure. Grade 1 denotes a strong service function, Grade 2 denotes an average service function, and Grade 3 denotes a weak service function, and the criteria and scores corresponding to each level are shown in Table 3 below.

**Table 3.** Standards for the quantification and classification of the indexes of farmland infrastructure.

| Indexes | First Grade | | Second Grade | | Third Grade | |
|---|---|---|---|---|---|---|
| | Criteria for Classification | Score | Criteria for Classification | Score | Criteria for Classification | Score |
| Regularity of fields | <1.3 | >12 | [1.3, 1.6] | [12, 6] | >1.6 | <6 |
| Average size of fields | >1 | >6 | [1, 0.5] | [6, 3] | <0.5 | <3 |
| The agricultural plot's slope | <2 | >3 | [2, 5] | [3, 1] | >5 | <1 |
| Density of roads | >0.7 | >12 | [0.7, 0.3] | [12, 6] | <0.3 | <6 |
| The ratio of the perimeter of roads to the perimeter of fields | >2 | >6 | [2, 1] | [6, 3] | <1 | <3 |
| Density of ditches | >0.7 | >16 | [0.7, 0.3] | [16, 8] | <0.3 | <8 |
| The ratio of the perimeter of ditches to the perimeter of fields | >0.6 | >8 | [0.6, 0.3] | [8, 4] | <0.3 | <4 |
| Density of agricultural networks | >2 | >4 | [2, 1] | [4, 2] | <1 | <2 |
| Completeness of agricultural networks | >1 | >2 | [1, 0.6] | [2, 1] | <0.6 | <1 |
| The ratio of area of agricultural forest networks to area of fields | >2 | >1.5 | [2, 1] | [1.5, 1] | <1 | <1 |

2. Calculating the score for the evaluation unit and classifying the evaluation levels

Adopt the index and procedure to determine the overall rating of each unit index. The index system calculates the index score and comprehensive score of each evaluation index in the assessment unit based on the weight and score assigned to each index [24]. The following equation is used to determine the comprehensive score:

$$E = \sum_{k=1}^{m} Ak \times \mathrm{B}ik \tag{10}$$

In Equation (10), $E$ represents the composite score of cell i, $Ak$ represents the weight of the $k$th factor, i represents the cell number, k represents factor number, m represents the number of factors, and $Bik$ represents the index score of the kth factor in the ith evaluation unit.

The weighted total score of each area is determined using the weighted scoring method, taking into account the weights assigned to each indication in the index system, the actual scores for each unit index, and the number of units in the sample area. The following is the calculating formula:

$$F = \sum P\mathrm{iWi}/\mathrm{m}(\mathrm{i} = 1, 2, 3, \ldots\ldots n) \tag{11}$$

In Equation (11), $F$ represents the weighted average score of the sample area, $P$i represents the score of the ith index, Wi represents the weight of the ith index of the table, N represents the number of evaluation indexes, and M represents the number of sample area cells.

The level of farmland infrastructure is broken down into three grades—excellent, good, and poor—according to the complete score of each unit, with excellent scoring 60–100, good scoring 30–60, and poor scoring 0–30. The definitions of the three levels are summarized below.

Excellent grade: The farmland infrastructure is very complete; the fields are flat, regular and concentrated; the roads are in good condition and easily accessible; the irrigation canals and drainage ditches are in good condition: neatly repaired, clearly visible, and free of weeds; and the forest belts are neatly arranged, with moderate density and no breaks.

Good grade: The farmland infrastructure is relatively complete; the fields are regular and slightly undulating; the roads are clear and able to meet transportation needs; the irrigation canals and drainage ditches are relatively complete, but there are weeds growing in them; and the forest belts are slightly broken, but the overall arrangement is in order.

Poor grade: The farmland infrastructure is incomplete, with roads, weeds, and wasteland in the fields, arranged in a haphazard manner; roads are visibly broken or missing, making them inconvenient for transportation; ditches are incomplete, visibly broken, or with weeds growing in them; and forest belts are arranged in an unorganized manner, missing or without forest belts.

## 3. Results

### *3.1. Quantitative Results of the Evaluation Indexes of the Farmland Infrastructure*

We completed the quantification of each observation sample area in Arcgis 10.7 using the Calculate Geometry and Field Calcultor functions in accordance with the quantification formula of 10 indexes, and we obtained the results of six observation sample areas by combining them with the grading standards of each index in Table 3. The outcomes are displayed in Figure 5, using observation sample area F as an example.

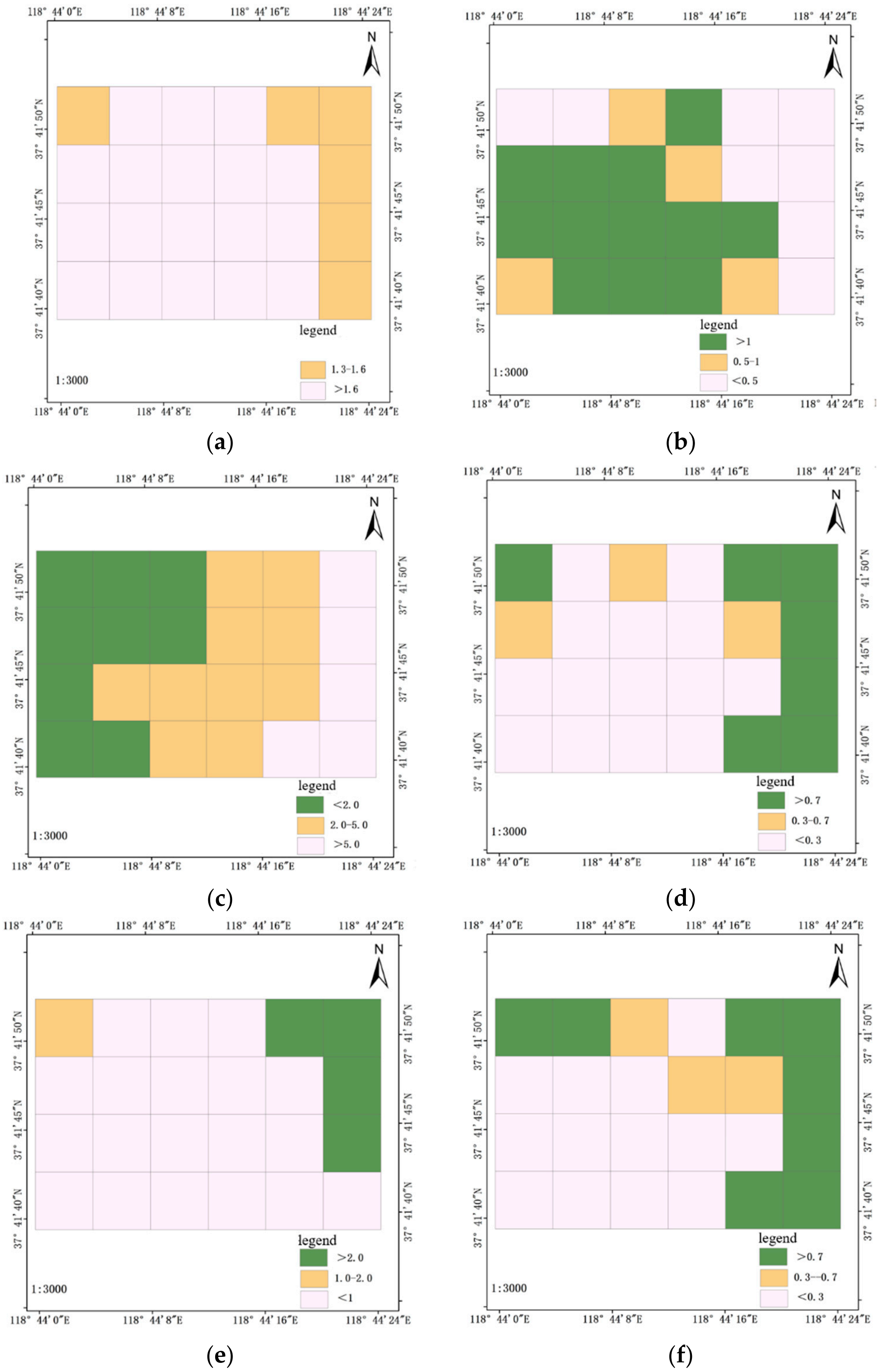



**Figure 5.** *Cont*.

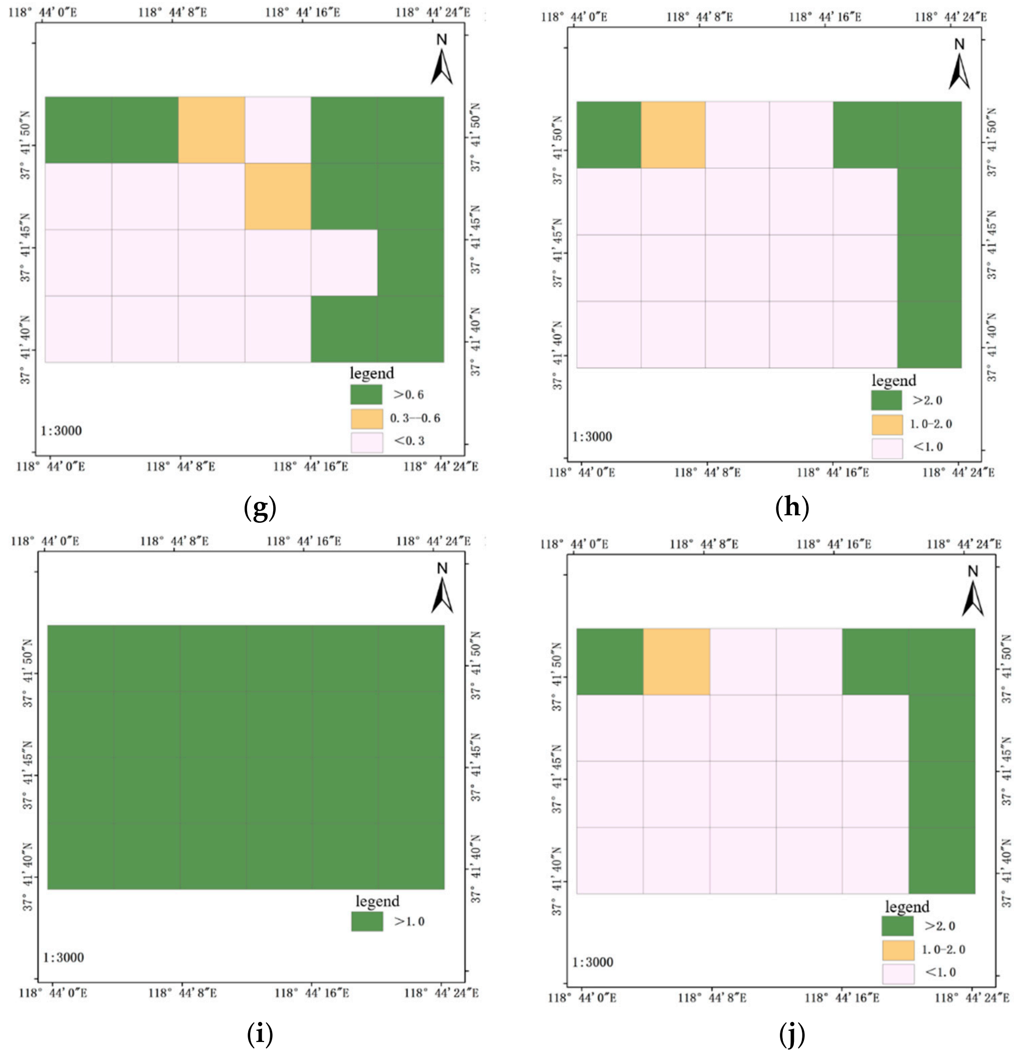



**Figure 5.** Quantitative results of the indexes of the farmland infrastructure in observation sample area F. (**a**) Quantitative results of the regularity of fields (**b**) Quantitative results of the average size of fields in observation sample area F. (**c**) Quantitative results of the agricultural plot's slope. (**d**) Quantitative results of the density of roads in observation sample area F. (**e**) Quantitative results of the ratio of the perimeter of roads. (**f**) Quantitative results of the density of ditches to the perimeter of fields in observation sample area F. (**g**) Quantitative results of the ratio of the perimeter of ditches. (**h**) Quantitative results of the density of agricultural to the perimeter of fields in observation sample F networks. (**i**) Quantitative results of the completeness. (**j**) Quantitative results of the ratio of the area of agricultural forest networks to the area of fields in observation sample area F.

### *3.2. The Overview of the Farmland Infrastructure in the Observation Sample Areas*

According to the statistical results, there are 20 evaluation units with excellent grades, 77 evaluation units with good grades, and 29 evaluation units with poor grades out of a total of 126 evaluation units in the study area. The percentage of evaluation units with both excellent and good grades is 79.13%. The good grade farmland infrastructure covered 655,893.99 square meters or 64.84% of the entire area, which was the biggest percentage. The excellent and low grades made up 14.29% and 20.87% of the total area, respectively. It suggests that the infrastructure for farming in the study area is generally good but might be improved.

Table 4 lists the weighted scores for the levels of farmland infrastructure in the six sample areas that were actually observed. Sample areas A and F have close scores, around 70, and are generally better; sample areas B and C have close scores, around 60, and are in the middle; and sample areas D and E almost have the same scores and are generally worse.

**Table 4.** Weighted scores of the level of farmland infrastructure in each observation sample area.

| Observation Sample Area | Sample Area A | Sample Area B | Sample Area C | Sample Area D | Sample Area E | Sample Area F |
|---|---|---|---|---|---|---|
| Weighted score | 70.89 | 61.20 | 60.29 | 56.46 | 56.40 | 69.68 |

### *3.3. Analysis of the Area Corresponding to the Level of Farmland Infrastructure in the Observation Sample Areas*

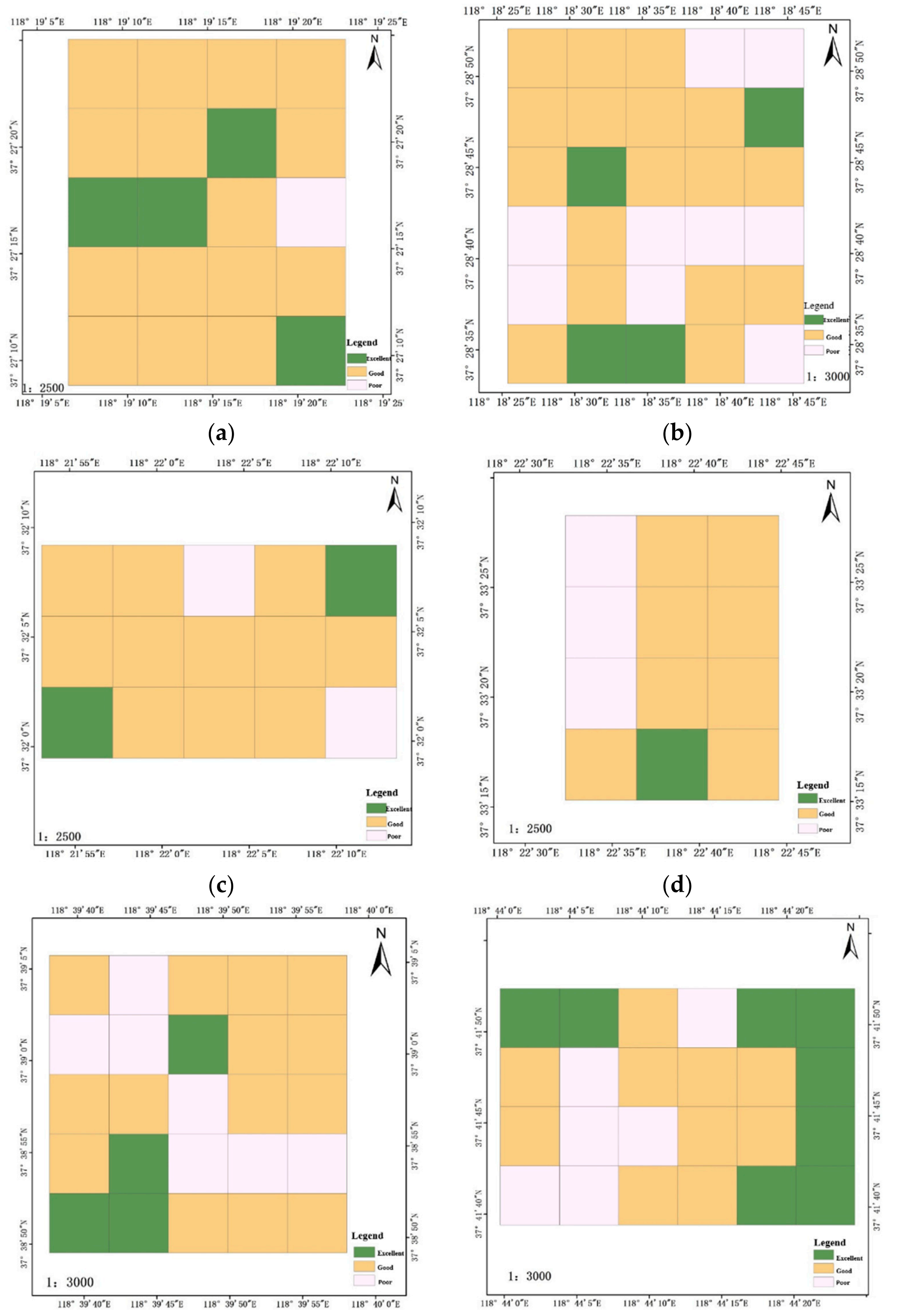
Table 5 displays the statistics for the degree of farmland infrastructure in each sample area. Of the areas with outstanding infrastructure, sample area F accounted for the highest percentage (21.76%), followed by sample area E (19.09%) and sample area D (9.04%). All sample areas had a maximum percentage of good and equal, with sample area A having the highest percentage (more than 80%) and the rest being above 50%. The percentages of sample areas A and C that received poor grades were, respectively, 6.76% and 10.84%, which were both quite low, whereas the percentages of the other sample areas were above 20%.

**Table 5.** Statistics of different levels of farmland infrastructure in each observation sample area.

| Observation Sample Area | Total Area ($m^2$) | Excellent Grade | | Good Grade | | Poor Grade | |
|---|---|---|---|---|---|---|---|
| | | Area ($m^2$) | Proportion | Area ($m^2$) | Proportion | Area ($m^2$) | Proportion |
| Sample Area A | 147,845.89 | 15,691.13 | 10.61% | 122,154.76 | 82.62% | 10,000.00 | 6.76% |
| Sample Area B | 233,723.58 | 24,352.42 | 10.42% | 145,724.48 | 62.35% | 63,646.68 | 27.23% |
| Sample Area C | 127,568.34 | 14,835.22 | 11.63% | 98,904.88 | 77.53% | 13,828.24 | 10.84% |
| Sample Area D | 110,628.15 | 10,000.00 | 9.04% | 72,523.71 | 65.56% | 28,104.44 | 25.40% |
| Sample Area E | 209,498.42 | 39,986.77 | 19.09% | 123,061.30 | 58.74% | 46,450.35 | 22.17% |
| Sample Area F | 182,304.71 | 39,671.97 | 21.76% | 93,524.86 | 51.30% | 49,107.88 | 26.94% |
| Total | 1,011,569.09 | 144,537.51 | 14.29% | 655,893.99 | 64.84% | 211,137.58 | 20.87% |

### *3.4. Spatial Distribution of the Different Levels of Farmland Infrastructure in Each Observation Sample Area*

Figure 6 shows the level distributions of farmland infrastructure in each observation sample area. It can be seen that there are four units in sample area A with an excellent grade, which are concentrated in the middle and southeast of the sample area. In sample area B, there are three excellent units distributed dispersedly, while the poor units are concentrated in the central and southern parts of the sample area. In sample area C, two excellent units are distributed in the southwest and northeast of the sample area. The total area of sample area D is relatively small; one excellent unit is located in the south of the sample area, while three poor units are concentrated in the northwest of the sample area. The excellent level of sample area E is concentrated in the southwest of the sample area, while the poor units are concentrated in the northwest and southeast of the sample area. There are many excellent and poor grade units in sample area F, which are concentrated in the east and southwest of the sample area.




(e) (f)

**Figure 6.** Distribution of farmland infrastructure at different levels in each observation sample area. (**a**) Grade distribution map of observation sample area A. (**b**) Grade distribution map of observed sample area B. (**c**) Grade distribution map of observed sample area C. (**d**) Grade distribution map of observed sample area D. (**e**) Grade distribution map of observed sample area E. (**f**) Grade distribution map of observed sample area F.

### *3.5. Index Analysis on the Level of Farmland Infrastructure*

1. Table 6 shows the scores for each assessment index. The better the index score, the less the variance of the score, and the higher the concentration of the index score, the larger the ratio of the average score to the total index score. The regularity of fields, the agricultural plot's slope, and completeness of the agricultural networks had score ratios greater than 0.5 from the study area's overall score, and the variance was under 2.5, indicating that these evaluation indexes performed well and were concentrated, making them the main indexes of the level of farmland infrastructure. The ratio of the perimeter of roads to the perimeter of fields, density of agricultural networks, and the ratio of the area of agricultural forest networks to the area of fields are all less than 0.25, with a variance of less than 10, demonstrating that three indexes have concentrated and low scores, which are the limiting indexes of the degree of farming infrastructure and require further improvement in the ensuing building of farmland infrastructure.

**Table 6.** Analysis of the scores of each evaluation index of the level of farmland infrastructure.

| Indexes | Average Score | Variance of Scores | Total Score of Indexes | Average Score/Total Index Score |
|---|---|---|---|---|
| Regularity of fields | 10.31 | 1.25 | 17 | 0.61 |
| Average size of fields | 5.18 | 10.56 | 9 | 0.58 |
| The agricultural plot's slope | 2.46 | 0.69 | 4 | 0.62 |
| Density of roads | 7.23 | 34.82 | 17 | 0.43 |
| The ratio of the perimeter of roads to the perimeter of fields | 1.83 | 6.05 | 8 | 0.23 |
| Density of ditches | 9.14 | 55.52 | 23 | 0.40 |
| The ratio of the perimeter of ditches to the perimeter of fields | 5.4 | 18.62 | 12 | 0.45 |
| Density of agricultural networks | 0.95 | 2.54 | 5 | 0.19 |
| Completeness of agricultural networks | 1.62 | 2.08 | 3 | 0.54 |
| The ratio of area of agricultural forest networks to area of fields | 0.36 | 0.37 | 2 | 0.18 |

2. According to the index scores of each observation sample area (Table 7), the ratio of the perimeter of roads to the perimeter of fields and the ratio of the area of agricultural forest networks to the area of fields in sample areas A and F ranged from 0.19 to 0.36, respectively, and both need to be further improved. Due to the absence of forest belt deployment, indexes related to the farmland forest network have a restrictive effect in sample areas B and E. In contrast, sample areas C and D have lower values for the ratio of the perimeter of roads to the perimeter of fields and density of ditches indexes, ranging from 0.19 to 0.32, which are indexes that need to be improved for future construction. The regularity of fields, average size of fields, and the agricultural plot's slope were the dominating indexes in each of the six sample regions, with ratios around 0.6; in the sample areas with deployment of the forest belt, it was clear that indications of the completeness of agricultural networks played a dominant role.

**Table 7.** The proportion of each sample area's overall scores to the average scores of the indexes used to evaluate farmland infrastructure.

| Indexes | Sample Area A | Sample Area B | Sample Area C | Sample Area D | Sample Area E | Sample Area F |
|---|---|---|---|---|---|---|
| Regularity of fields | 0.57 | 0.61 | 0.62 | 0.62 | 0.60 | 0.62 |
| Average size of fields | 0.54 | 0.59 | 0.52 | 0.62 | 0.61 | 0.56 |
| The agricultural plot's slope | 0.69 | 0.60 | 0.55 | 0.67 | 0.61 | 0.60 |
| Density of roads | 0.48 | 0.34 | 0.42 | 0.37 | 0.53 | 0.42 |
| The ratio of the perimeter of roads to the perimeter of fields | 0.19 | 0.15 | 0.25 | 0.19 | 0.34 | 0.25 |
| Density of ditches | 0.50 | 0.40 | 0.32 | 0.28 | 0.33 | 0.46 |
| The ratio of the perimeter of ditches to the perimeter of fields | 0.42 | 0.48 | 0.42 | 0.41 | 0.46 | 0.46 |
| Density of agricultural networks | 0.31 | 0.00 | 0.38 | 0.24 | 0.00 | 0.34 |
| Completeness of agricultural networks | 0.89 | 0.00 | 0.87 | 0.86 | 0.00 | 0.97 |
| The ratio of area of agricultural forest networks to area of fields | 0.23 | 0.00 | 0.42 | 0.23 | 0.00 | 0.36 |

## 4. Discussion

1. As can be seen from the evaluation's findings, the area with the highest percentage of good grades is 64.84%, followed by areas with the lowest percentages of excellent grades (only 14.29%) and poor grades (20.87%), indicating that the sample area's infrastructure level is generally good but needs to be strengthened and improved. According to the scores of the evaluation indexes, the regularity of fields and the agricultural plot's slope, two indications with high and concentrated scores that are prominent indexes (sample areas A and F are the most significant), show that the general level of farmland fields is high. The overall state of farmland roads and the farmland forest network is poor, and the three limiting indexes—the ratio of the perimeter of roads to the perimeter of fields, the density of agricultural networks, and the ratio of area of agricultural forest networks to the area of fields—have low scores and are limiting indexes (sample areas B and E are the most significant). Consideration should be given to adapting to local conditions, formulating scientific and reasonable construction contents for roads and forest belts, attenuating or removing limiting factors, and raising the level of farmland infrastructure in order to improve the construction of farmland infrastructure in the future.
2. In contrast to the findings of previous studies [24,29], this paper uses UAV remote sensing images as the data source, obtains the data directly by using eCognition software and Arcgis 10.7 software to complete the extraction and computation, and further constructs the index system, which is an effort to integrate UAV remote sensing with farmland infrastructure assessments. This method is distinct from gathering data through field research or compiling visual text material. UAV remote sensing can not only significantly reduce time and financial outlays but also guarantee the accuracy of the data. This research falls under the category of remote sensing technology applied research.
3. There are certain shortcomings in this study. The fact that farmland infrastructure has strong geographic complexity and dynamics, and the evaluation indexes, weights of the indexes, and methods of classifying the grades applied to farmlands of different geomorphological types, different crops, different climates, and different land types are different, which are not discussed in detail in this paper, as well as the evaluation index system of the study, all serve to limit its usefulness. It requires additional in-depth study. Additionally, the information collected from UAV images has its own

limitations, and the quantification of specific indicators requires a better theoretical foundation (such as perimeter ratios and area ratios), which will need to be improved in the future.

4. At present, the research on farmland infrastructure evaluations is not systematic and precise and lacks application and practice. In the future, if the farmland infrastructure evaluation system is to be applied to a large range of areas for practical application while improving the evaluation system continuously, it is necessary to use multi-scale remote sensing methods to achieve large-scale remote sensing inversion of the farmland infrastructure level, which can provide a simple, practical, and efficient means for the utilization and management of farmland infrastructure in a larger area.

## 5. Conclusions

In this study, a complete evaluation index system and index model were established, and the farmland infrastructure information was collected by UAV high-resolution imaging. The current situation of the farmland infrastructure of six sample areas was quantitatively tested and evaluated. The primary conclusions reached were as follows:

1. By selecting the best segmentation scale for use with UAV high-resolution remote sensing images, we were able to extract useful classification features. We then used the sample-based supervised classification method to extract each farmland infrastructure's information, ensuring classification accuracy and demonstrating the value of the object-oriented classification method.
2. By screening the first-level evaluation indexes for four aspects—farmland field, road, ditch, and forest belt—a system of evaluation indexes, which consists of 10 evaluation indexes, was created. Each index was quantitatively characterized, providing a scientific basis for the assessment of the level of farmland infrastructure.
3. The best cell for the evaluation of the level of farmland infrastructure in the study area was a 100 m by 100 m grid, the weight of each evaluation index was decided by the Analytical Hierarchy Process (AHP), the indexes were graded, and the comprehensive score of each evaluation cell was calculated by the index summation method. The level of farmland infrastructure was then divided into three grades of excellent, good, and poor, realizing the quantitative evaluation of the level.
4. There were 20 excellent grades, 77 good grades, and 29 poor grades among the 126 evaluation units in the study areas. Excellent and good grades accounted for 79.13% of the total. The proportions of the areas were 14.29%, 64.84%, and 20.87%, respectively. Among the six sample areas, sample areas E and F had the highest percentages of excellent grades, sample area A had the highest percentage of good grades, and all sample areas except A and C had a percentage of poor grades above 20%. The spatial distribution of each grade varied significantly; the indexes of farmland infrastructure in each sample area were excellent in terms of the regularity of fields, average size of fields, and the agricultural plot's slope, as well as the indexes of the ratio of the perimeter of roads to the perimeter of fields and the density of agricultural networks. The proportion of good grades in sample area A was 82.62%, and the proportion of poor grades in all sample areas except sample areas A and C was more than 20%.

This study built an evaluation index system and methodological standards for the level of farmland infrastructure based on high-resolution UAV images, providing a scientific basis for the quantitative evaluation, scientific utilization, and construction management of the level of farmland infrastructure.

**Author Contributions:** Conceptualization, software, methodology, and writing—review and editing, J.P.; methodology, resource, formal analysis, and writer—review and editing, C.C.; validation, data curation, investigation, and writer—review and editing, Z.W.; conceptualization, funding acquisition, supervision, and writing—review and editing, G.Z.; data curation, writing—original draft preparation, and software, Y.L.; visualization and formal analysis, S.Z.; and software and data curation, Y.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study was funded by the National Natural Science Foundation of China (41877003), the Major Scientific and Technological Innovation Project in Shandong Province (2019JZZY010724), and the Supplementary Fund for the "Double First-Class" Award in Shandong Province (SYL2017XTTD02).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available upon request from the corresponding author.

**Acknowledgments:** The authors sincerely thank the anonymous reviewers for their valuable comments and suggestions to improve the quality of this paper.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Liang, X.; Jin, X.; Han, B. Evolution of the national cultivated land strategic reserve system under the background of storing grain in the land. *J. Resour. Sci.* **2022**, *44*, 181–196. [CrossRef]
2. Building High-Standard Farmland and Consolidating the Foundation of Food Security—The relevant person in charge of the Farmland Construction Management Department of the Ministry of Agriculture and Rural Affairs answers the journalists' questions on the construction of High-standard farmland. *J. Agric. Compr. Dev. China* **2023**, *238*, 4–7.
3. Lu, J.; Zhang, Z.; Feng, Q. The construction of high-standard farmland promotes the grain industry and the development of rural economy. *J. Henan Nongye* **2021**, *586*, 6–7.
4. Yang, F.R. Land consolidation and agricultural development in the Netherlands. *J. China Land* **2017**, *376*, 43–44.
5. Zhang, T.; Li, Z.; Fei, K.; Zhan, X.; Gao, L.; Zhang, M.; Ma, Y. Effects of high-standard farmland construction on farmland quality and contribution of irrigation and drainage index. *J. Agric. Resour. Environ.* **2022**, *39*, 978–989.
6. Chen, Y.; Chen, Z.; Jiang, Y. Effects of Agricultural Science and Technology Progress and Land Improvement on Cultivated Land Quality in China. *J. Issues Agric. Econ.* **2021**, *42*, 132–144.
7. Li, R.; Du, C. Evaluation of the influence of high standard farmland renovation on cultivated land quality based on AHP fuzzy comprehensive evaluation method. *J. Jilin Water Resour.* **2021**, *8*, 49–54.
8. Kuang, L.; Ye, Y.; Zhao, X. Evaluation on influence of land consolidation project on cultivated land quality based on agricultural land classification correction method. *J. Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 198–205.
9. Zhu, J.; Zang, X.; Li, T. China's Food Security Risks and Prevention Strategy under the New Development Pattern. *J. Chin. Rural. Econ.* **2021**, *9*, 2–21.
10. Jiang, L.; Liu, Y. Study on grain production capacity and the influencing factors of production potential in Democratic People's Republic of Korea. *J. World Reg. Stud.* **2023**, *32*, 67–78.
11. Yao, C.; Xiao, Y.; Yang, Y. Analysis of the influence of agricultural labor transfer and agricultural mechanization on grain production in China. *J. Res. Agric. Mod.* **2022**, *43*, 306–317.
12. Sun, H.; He, C.; Yang, Y. An Integrated Assessment Model of Primary Farmland Identification Based on Suitability and Potential Productivity: A Case Study of Beijing-Tianjin-Tangshan Area. *J. China Land Se* **2011**, *25*, 72–76+97.
13. Hu, X.; Dai, M. Effects of High-standard Farmland Construction Policieson Food Production. *J. South China Agric. Univ. Soc. Sci. Ed.* **2022**, *21*, 71–85.
14. Luan, J.; Han, Y. Effects of Farmland Irrigation Infrastructures on the Improvement of TFP. *J. South China Agric. Univ. Soc. Sci. Ed.* **2020**, *19*, 84–93.
15. Qian, F.; Zhang, L.; Bian, Z.; Niu, P.; Jia, L.; Wang, Q. Research on the evaluation of cultivated land quality and site conditions in the construction of Well-Facilitated basic farmland. *Soil Bull.* **2015**, *46*, 1049–1055.
16. Ren, H.; Zhao, Y.; Li, X. Cultivatedland fragmentation in mountainous areas based on different resolution images and its scale effects. *J. Geogr. Res.* **2020**, *39*, 1283–1294.
17. Liu, C.; Yang, M.; Zhang, X. Study on the feasibility of using high resolution remote sensing image to calculate the coefficient of cultivated land. *J. Land Resour. Her.* **2007**, *5*, 48–50.
18. Yuan, C.; Zhao, C.; Ren, Y.; Liu, Y.; Li, S.; Li, S.; Yao, L. Recognition Method of High-Standard Farmland Road Based on U-Net. *Trans. Chin. Soc. Agric. Mach.* **2023**, *54*, 163–169.
19. Wu, F.; Chen, G.; Yang, J. Country Road Designing Based on Graphics Accessibility in the Land Development and Consolidation. *J. Geospat. Inf.* **2010**, *8*, 19–21.

20. Gu, Z.; Jin, X.; Yang, X. Monitoring Roads and canals utilization condition for land consolidation project based on UAV remote sensing image. *J. Trans. Chin. Soc. Agric. Eng.* **2018**, *34*, 85–93.
21. Zhou, Y.; Jia, F. Applicability Evaluation of The Farmland Water Conservancy Management Mode Based on Comprehensive Integrated Weighting Method. *J. Water Sav. Irrig.* **2018**, *8*, 71–74.
22. Lv, Y.; Zhang, C.; Yun, W. Automatic Recognition of Farmland Shelterbelts in High Spatial Resolution Remote Sensing Data. *J. Trans. Chin. Soc. Agric. Mach.* **2018**, *49*, 157–163.
23. Shi, X.; Li, Y.; Deng, R. Evaluation method for effect of farmland shelterbelts on crop yield based on RS and GIS. *J. Trans. Chin. Soc. Agric. Eng.* **2016**, *32*, 175–181.
24. Ouyang, J. Study on Measurement and Evaluation Method of Farmland Infrastructure Completeness. Master's Thesis, China University of Geosciences, Beijing, China, 2020.
25. Yang, X. Reflections on strengthening the construction and management of rural water conservancy infrastructure. *South. J.* **2005**, 47–48+12.
26. Zhang, Z.; Chen, B.; Guo, S. Index system for evaluating arable land consolidation potential. *J. China Land Sci.* **2004**, *05*, 37–43.
27. Wen, G.; Yang, G.; Wang, W. Evaluation of cultivated land fragment ation degree based on farmers' perspective: A case of Jiangxia District, Xian'an District, and Tongshan County in Hubei Province. *J. Progress in Geography.* **2016**, *35*, 1129–1143.
28. Jiao, L.; Xiao, F.; Xu, G. Spatial-temporal response of green land fragmentation patterns tourban expansion in Wuhan metropolitan area. *J. Resour. Sci.* **2015**, *37*, 1650–1660.
29. Liu, X.; Wang, S.; Wang, Y.; Kang, S.; Hao, X.; Li, F. Comprehensive evaluation of farmland infrastructure in the arid area of north-west China. *J. Irrig. Drain.* **2014**, *63*, 561–572. [CrossRef]