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Evaluation of Mechanized Upgrading of Farmland in Mountainous Areas Based on High Resolution Remote Sensing Image

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Abstract:

It is an important means to make up for the short board of Agricultural Mechanization in Hilly and mountainous areas to carry out the transformation of farmland suitable for mechanization and expand the application space of large and medium-sized agricultural machinery. At present, the research on cultivated land consolidation mainly focuses on the construction evaluation and post construction evaluation of high standard farmland remediation projects, and there is a lack of literature on the evaluation of cultivated land suitable for mechanization. This paper proposes a comprehensive evaluation method of cultivated land mechanization in the target area by using high-resolution image and high precision DEM data, based on ArcGIS sampling calculation of four index values, such as the rectangular degree, area, length width ratio, height difference, combined with the agricultural machinery structure of the area. Based on the sampling measurement of 10 villages in five agricultural areas of Nanjing, the overall rectangular degree of Nanjing is about 0.59, 84.23% of the plots are less than 0.75; the average plot area is about 0.32 ha, 87.5% of the land area is larger than 667 m2; the overall aspect ratio of the plot is about 1.67, The results showed that 81.15% of the cultivated land had a length width ratio of less than 2:1, and 95.6% of the plots had a length width ratio of less than 3:1; the average height difference of the plots was about 0.35 m, and the compliance rate of the mechanization degree of the height difference was 100%.The focus of arable land reconstruction should be on small plots to be larger, the plot shape should be rectangular and striped, and the plot length to width ratio should be no less than 3:1.

Keywords*: Arable land, Agricultural mechanization, Remote sensing, Boolean assignment, Upgrading of cultivated land.*

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I. INTRODUCTION

Agricultural mechanization and machinery equipment is an essential basis for transforming the agricultural development mode and improving agricultural productivity and an important support for implementing the rural revitalization strategy. There will be no agricultural and rural modernization without agricultural mechanization [1]. Since the *Law of the People's Republic of China on Promotion of Agricultural Mechanization* was promulgated and implemented in 2004, China's agricultural mechanization has made great progress. The comprehensive mechanization rate of cultivation, seeding and harvesting of major crops increased from 34% in 2004 to 70% in 2019, playing a significant role in promoting agricultural cost reduction and efficiency enhancement [2]. However, the problem of regional imbalance in agricultural mechanization is still prominent. Hilly and mountainous areas are the main weaknesses in the development of agricultural mechanization. To accelerate the transformation and upgrading of agricultural mechanization and equipment industry, the state has proposed to focus on supporting the hilly and mountainous areas to carry out "mechanized upgrading" transformation of farmland, expand the application space of large and medium-sized agricultural machinery, and accelerate the pace to make up for the weak basic conditions of agricultural mechanization in hilly and mountainous areas [1]. Agricultural authorities in hilly and mountainous provinces such as Chongqing, Hunan, and Shaanxi have made some explorations in the mechanized upgrading of farmland and constructed a number of model projects. However, the project management is still relatively rough, and all funds are invested based on the same subsidy criteria province-wide. For example, Chongqing grants unified subsidies based on the criteria of RMB 22,500/ha to entities undertaking the construction, resulting in a huge gap of funding in some regions with relatively poor condition sand a decline in the transformation standards. It is necessary to scientifically investigate the operation conditions of cultivated land in mechanized upgrading, assess the level of cultivated land suitable for mechanization in different regions, and accurately allocate cultivated land mechanized upgrading transformation projects based on the assessment results.

Currently, academic research on the evaluation of cultivated land transformation mainly focuses on the construction of well-facilitated farmland, including pre-construction assessment and post-construction evaluation. In the pre-construction assessment of well-facilitated farmland, the development parameters of farmland remediation target areas are mainly collected from land use structure [3], spatial pattern of farmland [4], productivity remediation, soil environmental quality, demographic and social factors,[5] topographic conditions [6], etc. Comprehensive analysis of the construction conditions of well-facilitated farmland [7-8], quantity measurement of new cultivated land[9-12], quality remediation of cultivated land[13-14], remediation of food production capacity [15-16] and other cultivated land remediation potential, and comprehensive evaluation of the remediation difficulty in the target area [17] can provide a decision-making basis for the site selection [18] and priority arrangement[19] of cultivated land remediation projects. In the post-construction evaluation of well-facilitated farmland, more attention is paid to the ecological and environmental effects of farmland re-

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mediation, including changes in soil physicochemical properties, soil nutrients, farmland ecosystems, etc. Some scholars believe that land remediation can lead to significant changes in soil properties [20-21], especially exacerbating the problem of regional imbalance in soil physicochemical properties of farmland, which, however, will gradually become less significant over time [22]. Farmland remediation will increase the heterogeneity of soil nutrients [23] and cause different degrees of spatial variability in soil pH, salinity, nitrogen, phosphorus and potassium [24], which can destroy the originally stable ecosystem of farmland [25].However, the level of farmland facilities after cultivated land remediation will be significantly improved, including water conservancy facilities, ecological protection conditions, tractor roads, and other infrastructure [26].No literature that systematically evaluates the level of farmland suitable for mechanization has been found. The literature on evaluating the level of farmland facilities also focuses on water conservancy facilities, and those related to farmland suitable for mechanization only involve the accessibility of tractor roads, with no elaboration on the operations of plots suitable for mechanization. The transformation pilot for mechanized upgrading farmland has been carried out in some hilly and mountainous areas. However, the lack of relevant evaluation methods and standards is not conducive to promoting and applying the results of the pilot projects.

Therefore, this paper is intended to select the evaluation indexes of plot suitable for mechanization from five dimensions closely related to agricultural machinery operations(such as plot shape, area, length-width ratio, height difference, and road accessibility) and use the high-resolution remote sensing images and high-precision DEM data of the sample area to map the plot boundary of the smallest unit in the sample area based on Arc GIS and calculate the values of evaluation indexes related to cultivated land. Cultivated land suitable for mechanization in the sample area was comprehensively evaluated based on the Boolean assignment method and the cask principle [27] to develop strategies for optimal allocation of agricultural machinery and mechanized upgrading of cultivated land.

II. OVERVIEW OF STUDY AREA

Located along the lower reaches of the Yangtze River, Nanjing is adjacent to the Jianghuai Plain in the north and the Yangtze River Delta in the east. Nanjing has a land area of 658,231.3 ha, with 438,039.0 ha of farmland, accounting for 66.5% of the land area. Among them, thereare245,593.1 ha of cultivated land, 940,404.1 ha of garden land, 73,927.9 ha of forest land, and 109,063.1 ha of other farmland, accounting for 37.31%, 1.43%, 11.23%, and 16.57% of the land area, respectively. The basic farmland is mainly distributed in five districts (Luhe, Jiangning, Lishui, Gaochun, and Pukou), totaling 220,389.9hm2, accounting for 96.92% of the total basic farmland area in the city. Among them, Luhe and Jiangning Districts have the largest distribution proportion of basic farmland (62,499.9ha and 55,163.3ha), accounting for 27.49% and 24.46% of the total basic farmland area in the city, respectively; the rest is scattered in the downtown areas of the six districts. The topographic features in Nanjing are as follows: 1) mainly down land. The down land

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area accounts for 53% of the land area in Nanjing. The terrain is less than 60 m above sea level, with a relative height of 10–30 m and a ground slope of 5°–10°. Despite the minor slope undulation and low elevation of down land, the operation efficiency of agricultural machinery is significantly affected by the slope undulation and road leveling condition.2) discrete distribution of hilly land. The area of hills accounts for 39% of the land area; hills and down land are scattered in various municipal districts of Nanjing.

III. DATA SOURCES AND EVALUATION METHODS

3.1 Data Sources and Processing Methods

The research data in this paper were mainly derived from 0.3 m aerial photography data (scale 1:500) covering the whole area of Nanjing in 2018, and high-precision DEM data (sampling spacing 2.5 m) generated from LIDAR airborne LiDAR data. The data processing software was ArcGIS 10.2, and the software running computer was configured with Core i7 CPU and 8G RAM. Two natural villages were randomly selected from each of the five agriculture-related districts (Luhe, Pukou, Jiangning, Gaochun, and Lishui) in Nanjing, totaling 10 sampled villages. The specific distribution of sampled villages and the overall situation of cultivated land in the sampled villages is shown in Table I. The spatial graphs of the closed boundaries of plots and other topographic elements of the sampled villages were plot separately using ArcGIS spatial work platform and analysis tools through spatial reading, overlay, analysis, and other technical means. The relevant attributes were filled in, and the area of each plotted parcel was given in the vector attribute table. The minimum enclosing rectangle (MER) of each plot was calculated by tools and means for calculating the area, length, width and other related spatial attributes; the DEM data of the corresponding area were overlaid; the average elevation of each plot was obtained by technical means such as correction and leveling.

Table I. Overall situation of cultivated land in sampled villages

Sampling number	Village	Latitude and longitude	average altitude(m)	Number of plots	Average area （hm^2）
P1	Jiangjiadun	31°19′46″N,118°57′52″E	5.85	75	0.98
P2	Youzha	31°21′48″N,118°59′22″E	9.59	100	0.87
P3	Nanshi	31°27′58″N,119°01′46″E	9.40	100	0.19
P4	Shuijing	31°31′36″N,119°01′35″E	14.35	95	0.09
P5	Dongbei	31°51′45″N,118°52′32″E	6.05	93	0.35
P6	Nanyao	31°49′20″N,118°53′43″E	5.45	97	0.14
P7	Huangdun	32°10′20″N,118°34′01″E	5.60	108	0.32
P8	Zhangdun	32°10′09″N,118°35′45″E	5.00	97	0.26
P9	Xiaogang	32°24′41″N,118°45′59″E	26.35	150	0.15
P10	Xiwangying	32°27′42″N,118°42′28″E	14.80	125	0.13

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3.2. Evaluation Indexes

In October 2019, the Ministry of Agriculture and Rural Affairs (MARA) released the *Work Guidelines on Mechanized Upgrading of Farmland in Hilly and Mountainous Areas*, which put forward the criteria for mechanized upgrading transformation of cultivated land plots and tractor roads in hilly and mountainous areas as follows.1) Plot shape: rectangular in principle; 2) Plot size: short side length 5m or more, length-width ratio 3–5:1, area 1 mu or more.3) Maximum height of excavation and filling: ≤2m. 4) 100% direct access to the production road of the plot after remediation. In view of this, the following evaluation indexes are proposed for mechanized upgrading of cultivated land in Nanjing.

1) Plot area index (*AI*). In recent years, China's agricultural machinery is developing towards large and medium sizes with larger working width. In plots with excessively small areas, the turning flexibility of agricultural machinery will be affected, and the efficiency advantages of large and medium-sized machinery cannot be fully exerted[28]. The larger the plot area, the higher the working efficiency of agricultural machinery. Hence, the measured value of plot area A was used in this paper to characterize the degree of plot area suitable for mechanization. According to the requirements of *Work Guidelines on Mechanized Upgrading of Farmland in Hilly and Mountainous Areas*, the area of cultivated land should be larger than 0.07 ha. The number of sampled plots with an area >667 m^2 was 910, accounting for 87.5% of the total number of sampled plots. The *Work Guidelines* promulgated by the MARA are more oriented to regions with poorer topographic conditions such as southwest hilly and mountainous areas. As Nanjing has a relatively higher proportion of plains in its topography, the plot area limit in Nanjing should be larger. The working width (3m) of the combine harvester model with the highest inventory in Nanjing was taken as the benchmark. The optimized tillage parameter could meet the 5 round-trip harvesting strips of the harvester with unrestricted turning performance. Based on the maximum recommended by the *Work Guidelines*, the plot area parameters in Nanjing were determined: 30m on the short side and 150m on the long side, with an area of 0.45 ha. The plot AI can be calculated according to Eq. (1).

$$\begin{cases} A \geq 0.45, \ AI = 1 \\ A < 0.45, AI = 0 \end{cases} \tag{1}$$

2) Plot shape index (SI). When the harvester travels in a straight line, the control is simple, the operation efficiency is high [29], and its motion trajectory and cutting width constitute a rectangle. Hence, where the plot shape is closer to a rectangle, the agricultural machinery has a higher working efficiency. In this paper, the degree of plot shape[30] suitable for mechanization is characterized by the rectangular degree(R),which is expressed as the ratio of the plot area (A) to the area of its MER(AMER), as shown in Eq. (2).

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$$R = \frac{A}{A_{\mathrm{MER}}} \tag{2}$$

Where R denotes the rectangular degree of the plot shape; A denotes the actual area of the plot (m^2); AMER denotes the area of its MER(m^2). The value range of rectangular degree is 0<R≤1, and R=1 when the plot shape is rectangular; the more irregular the plot shape, the smaller the R. The rectangular degree of cultivated land should be as close to 1 as possible. However, due to the high difficulty of transforming part of the terrain into rectangular plots, Cong (2017) conducted a sampling survey of farmland in Jiangsu area and found that the rectangular degree of Jiangsu plots should be no less than 0.75 [31]. The plot SI can be calculated according to Eq. (3).

$$\begin{cases} R \geq 0.75,\ SI = 1 \\ R < 0.75, SI = 0 \end{cases} \tag{3}$$

3) Plot length-width ratio index (LWI). The width of cultivated land shall be no less than the working width of agricultural machinery for it to work in the field. The turns of agricultural machinery are positively correlated with the width of cultivated land. Since no effective operation is performed during the turning, the operation efficiency of agricultural machinery is mainly lost in the turning stage[32-33]. In plots with greater length-width ratios, the time of turning accounts for a less proportion in the total working time, and the operating efficiency loss of agricultural machinery is less. Due to the complex shape of cultivated land, it can be more difficult to obtain the length and width of some plots. For the purpose of facilitating the measurement, the length-width ratio (LW) of plot MER was used to characterize the degree of plot length-width ratio suitable for mechanization in this paper. The *Work Guidelines* stipulates that the plot length-width ratio should be no less than 3:1. The plot LWI can be calculated according to Eq. (4).

$$\begin{cases} LW \geq 3:1, LWI = 1 \\ LW < 3:1, LWI = 0 \end{cases} \tag{4}$$

4) Plot elevation difference index (HI). Uneven terrain is a typical feature of hilly and mountainous areas. For paddy fields in such terrain conditions, various plots are distributed at different altitudes. There is a height difference between adjacent plots, which can affect the transfer efficiency of agricultural machinery in the field and even poses a threat to the life and property safety of individual entrepreneurs owning agricultural machine. Hence, the average plot elevation difference (h) is used in this paper to characterize the plot elevation difference, as shown in Eq. (5).

$$h_i = \frac{al_{i\max} - al_{i\min}}{m_i} \tag{5}$$

Where h_i denotes the average elevation difference of plots in the i-th sampling area (m); $al_{i\max}$ de-

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notes the maximum elevation of plots in the i-th sampling area (m); $al_{i\min}$ denotes the minimum elevation of plots in the i-th sampling area (m); m_i denotes the number of interval plots between the maximum and minimum elevation plots in the i-th sampling area. Chen (2012) believed that all models of crawler combine harvesters could complete field transfer smoothly under the condition that the field elevation difference was less than 0.5 m [34]. Hence, the plot HI can be calculated according to Eq. (6).

$$\begin{cases} h_i \leq 0.5, HI = 1 \\ h_i > 0.5, HI = 0 \end{cases} \tag{6}$$

3.3. Boolean Assignment Comprehensive Evaluation System

With the plot as the basic evaluation unit, four indexes selected above (plot shape, area, length-width ratio, and elevation difference) were sorted one by one and assigned to each evaluation index of the plot from left to right in 4-digit codes, where each digit represented the value of the corresponding evaluation index[27]. Comprehensive dimensional evaluation was conducted based on the cask principle. When and only when all four coding digits of the evaluated plots are 1, the target plots met the mechanization requirements; otherwise, the evaluated plots had deficiencies in one or more aspects such as area and shape and could not meet the mechanization requirements completely. On this basis, a coding value system was established to analyze the cultivated land suitable for mechanization from multiple dimensions (see Table II).

TABLE II. Coding values and meanings of comprehensive evaluation indexes of cultivated land suitable for mechanization

Number of code digits	Corresponding index	Coding value	
		0	1
1	Plot area (*AI*)	Small plot area	Large plot area
2	Plot shape (*SI*)	Small rectangular degree	Large rectangular degree
3	Plot length-width ratio (*LWI*)	Small length-width ratio	Large length-width ratio
4	Plot elevation difference (*HI*)	Small elevation difference	Large elevation difference

IV. EVALUATION RESULTS OF CULTIVATED LAND SUITABLE FOR MECHANIZATION

4.1. Overall Distribution of Sampled Cultivated Land Data

The image data of sampled villages were loaded into ArcGIS, and a certain number of plot boundaries were mapped for each village in a row. The plot elevations were identified by ArcGIS, and the cultivated

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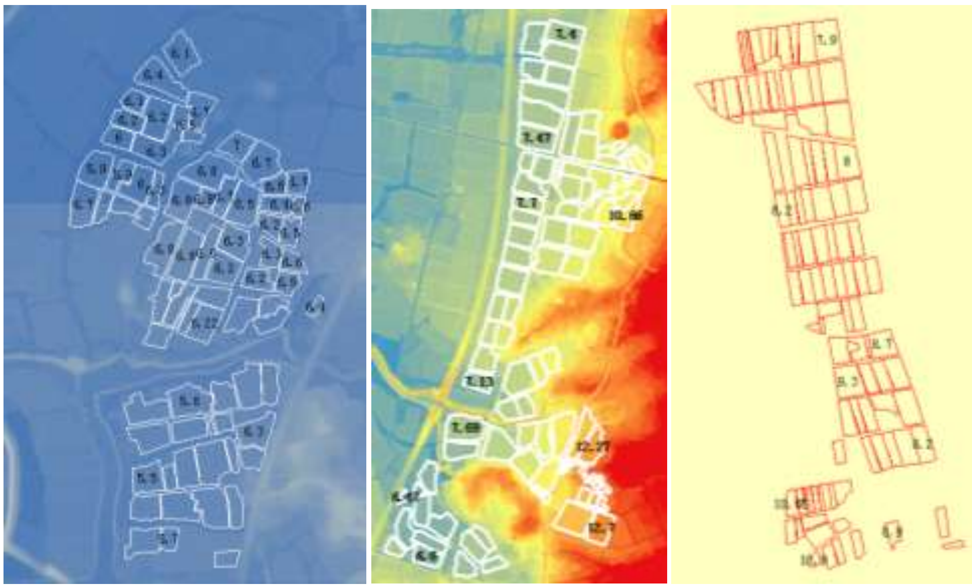
land area was calculated, as shown in Fig. 1.



a. p1 *b. p2* *c. p3*

Fig 1: Plot distribution in some sampled villages

Fig. 1 shows the plot distribution p1, p2 and p3 in sampled villages, where a single closed graphical unit is a plot and the data marked in the plot indicate its elevation. The pattern of base color change in figure is that the higher the elevation, the darker the color of the area.

TABLE III. Rectangularity of plots in sampling village

Sampling number	Area/hm^2	Rectangular degree	Length-width	Elevation difference
P1	0.98	0.61	1.38:1	0.46
P2	0.87	0.59	1.37:1	0.62
P3	0.19	0.60	2.18:1	0.19
P4	0.09	0.57	1.54:1	0.69
P5	0.35	0.54	1.80:1	0.10
P6	0.14	0.54	2.29:1	0.05
P7	0.32	0.37	1.26:1	0.06
P8	0.26	0.39	1.63:1	0.04
P9	0.15	0.68	1.55:1	0.82
P10	0.13	0.77	1.70:1	0.47
Total	0.32	0.59	1.67:1	0.35

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Table III indicates the farmland in the sampled villages fails to meet the mechanization standards in plot area, shape and length-width ratio in general; the elevation difference meets the mechanization requirements.

4.2. Evaluation Results of Cultivated Land Suitable for Mechanization

The evaluation value for each plot in the sampled villages was calculated based on the Boolean assignment comprehensive evaluation method. The details are shown in Table IV.

TABLE IV. Evaluation results of farmland in the sampled villages suitable for mechanization

Sampling site number	Coding value											
	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1100	1101
P1	0	8	0	0	0	0	0	0	0	61	0	6
P2	28	0	1	0	1	0	0	0	65	0	5	0
P3	0	82	0	10	0	4	0	1	0	0	0	3
P4	82	0	3	0	9	0	0	0	1	0	0	0
P5	68	0	5	0	0	0	0	0	20	0	0	0
P6	0	66	0	7	0	12	0	10	0	0	0	2
P7	0	104	0	0	0	0	0	0	0	4	0	0
P8	0	96	0	0	0	0	0	0	0	1	0	0
P9	110	0	1	0	36	0	3	0	0	0	0	0
P10	0	53	0	0	0	67	0	5	0	0	0	0
Total	288	409	10	17	46	83	3	16	86	66	5	11

In terms of plot area, 168 out of 1,040 plots have an area of no less than 0.45 hm2, accounting for 16.15% of total plots; mainly distributed in Jiangjiadun and Youzha Villages near Maoshan Mountain in the south, and a small number in Dongbei Village in the central area. In terms of plot shape, 148 plots have a rectangular degree of no less than 0.75, accounting for 14.23% of total plots; mainly distributed in Xiaogang and Xiwangying Villages of Luhe District. In terms of plot length-width ratio, 46 plots have a length-width ratio of no less than 3:1, accounting for 4.42% of total plots; mainly distributed in Nanyao Village of Jiangning District. In terms of plot elevation difference, 602 plots have an elevation difference of less than 0.5m, accounting for 57.88% of total plots.

In terms of comprehensive evaluation, 0 out of 1,040 plots are completely “suitable for mechanization” (code 1111); 288plots are completely not suitable for mechanization(code 0000), accounting for 27.69% of total plots; 551 plots are 25%suitable for mechanization (code 0001/0100/1000), accounting for 52.98% of total plots; 174 plots are 50% suitable for mechanization (code 0011/0101/0110/1001/1100), accounting for 16.73% of total plots; 27 plots are 75% suitable for mechanization (code 0111/1101), accounting for 2.60% of total plots.

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V. TRANSFORMATION STRATEGY FOR MECHANIZED UPGRADING OF CULTIVATED LAND

5.1. Technical Standards for Transformation

1) The sampling survey indicated that the overall rectangular degree of plots in Nanjing was about 0.59. According to the requirements of the Work Guidelines on Mechanized Upgrading of Farmland in Hilly and Mountainous Areas, the rectangular degree of cultivated land should be as close to 1 as possible. However, due to the difficulty of transforming part of the terrain into rectangular plots, the rectangular degree of plots in Jiangsu should be no less than 0.75 as appropriate[31]. Among the sampled plots in this paper, 876 plots had a rectangular degree of less than 0.75, accounting for 84.23% of total sampled plots. Hence, it could be determined that the compliance of cultivated land suitable for mechanization in Nanjing was only 15.77%, and 84.23% of the plots still required rectangular transformation; that is, the area to be transformed was about 206,863 ha.In the process of transformation, the rectangular principle should be followed if possible. The plot shape should be first designed as rectangular. Where there was special terrain that could not be transformed into rectangular shape, sharp curves and corners unfavorable to mechanization should be minimized.

2) The average plot area in Nanjing is about 0.32 ha. According to the requirements of the Work Guidelines on Mechanized Upgrading of Farmland in Hilly and Mountainous Areas, the area of cultivated land should be larger than 0.07 ha. The number of sampled plots with an area >667 m2 was 910, accounting for 87.5% of the total number of sampled plots. The Work Guidelines promulgated by the MARA are more oriented to regions with poorer topographic conditions such as southwest hilly and mountainous areas. As Nanjing has a relatively higher proportion of plains in its topography, the plot area limit in Nanjing should be larger. Based on the maximum recommended by the Work Guidelines, the plot area parameters in Nanjing were determined: 30m on the short side and 150m on the long side, with an area of 0.45 ha. The working width (3.95 m) of the combine harvester model with the highest inventory in Nanjing was taken as the benchmark. The optimized tillage parameter could meet the 5 round-trip harvesting strips of the harvester with unrestricted turning performance.

3) The overall length-width ratio of plots in Nanjing is about 1.67, with 81.15% of the plots having an length-width ratio of less than 2:1. According to the recommended length-width ratio of no less than 3:1 in the Work Guidelines on Mechanized Upgrading of Farmland in Hilly and Mountainous Areas, only 46 plots in the samples met the standard, with a compliance rate of 4.4%; 95.6% of the plots still need to be lengthened and transformed so that their length-width ratio can beno less than 3:1, thereby reducing the number of turns during the operation of agricultural machinery and improving the working efficiency.

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4) The overall average height difference of plots in Nanjing is about 0.35 m, which can meet the requirements of the Work Guidelines that the height of excavation and filling should be no greater than 2 m. As the height difference of tractor roads with direct access to cultivated land or fields is less than 0.5 m [34], it can be considered that the plot height difference in Nanjing is basically suitable for mechanization, and the transfer of agricultural machinery between fields is not affected. However, to improve the transfer efficiency of agricultural machinery, the direct accessibility of field roads should be increased, and gentle slopes should be set at the junction of roads and fields to avoid irrigation ditches from cutting off their connection.

5.2. Work Mechanism for Transformation

1) Government-led enhancement of the top-level design. The mechanized upgrading of farmland should be taken as a core element to accelerate the transformation of agricultural development and promote the upgrading of the agricultural equipment industry. Through strengthening organizational leadership, increasing financial input, coordinating the allocation of authority, financial rights and other initiatives, the mechanized upgrading of cultivated land should be implemented thoroughly. Through planning at a high starting point and clarifying objectives, tasks and construction priorities, the mechanized upgrading should be organically combined with well-facilitated farmland construction and modern agricultural parks for synchronous promotion and implementation. Through high-standard design and scientific determination of transformation content and standards, it should be ensured that farmland can be transformed into plots accessible by ditches and connected to roads, to meet the working conditions of medium and large agricultural machinery. High-quality construction should be conducted; responsibility and supervision systems should be established to ensure the progress and quality of the project.

2) Reasonable allocation of authority and financial rights for mechanized upgrading of cultivated land and orderly promotion of remediation work. Mechanized upgrading of cultivated land is a basic, comprehensive, and systematic sustainable development project of agriculture and rural areas, which requires overall planning and orderly promotion. It is necessary to allocate the authority and financial rights of cultivated land at all government levels between departments and complete the standard formulation, project review and supervision, financial support, overall planning for mechanized upgrading of cultivated land, work objectives and phased tasks, and specific implementation at counties/villages. The mechanism should be innovated to implement government-guided, owner-led, award-supplemented, built first and then subsidized model; based on the principle of "award and subsidy lump sum, self-financing for difference, competition in declaration, whoever uses shall be responsible for construction", encourage and support for major grain growers, family farms, cooperatives, leading enterprises, etc. as the main entities of project implementation. It is necessary to build mechanized upgrading transformation demonstration areas based on well-facilitated farmland construction projects in accordance with the technical specifications for mecha-

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nized transformation; cover and drive the construction of well-facilitated farmland in the direction more conducive to mechanized operations, development of modern agriculture, and ecological environment protection.

3) Integration of resources, increasing the financial investment in mechanized upgrading transformation projects. Mechanized upgrading transformation of cultivated land should be conducted based on the construction of well-facilitated farmland to improve the transformation standard of cultivated land, integrate multiple resources, and enhance support. The mechanized upgrading transformation should be combined with agricultural subsidies and continuous promotion of the construction of well-facilitated farmland. Without reducing the total financial support for agriculture, the subsidies should be adjusted to support the mechanized upgrading transformation of cultivated land. The integration of well-facilitated farmland construction with other project funds should be encouraged at the local level for the transformation of cultivated land and comprehensive agricultural development. The role of various new business entities should be fully exerted, and the involvement of social organizations and local talents should be encouraged. Through enhancing publicity, guiding social capital to participate in the transformation of farmland, supporting the cooperation of government and enterprises in the implementation of farmland construction projects, concerted efforts should be made to facilitate the mechanized upgrading of farmland in depth.

VI. CONCLUSIONS

1) In this paper, a comprehensive evaluation index system of cultivated land suitability for mechanization was proposed based on Boolean assignment method using high-resolution images and high-density DEM data through ArcGIS sampling calculation of four index values (rectangular degree, area, length-width ratio, and height difference of plots) to evaluate the cultivated land suitable for mechanization in the target area comprehensively.

2) The sampling calculation of 10 villages in 5 agriculture-related districts in Nanjing indicated that0 plot is completely "suitable for mechanization"; 27.69% of total plots are completely not suitable for mechanization; 52.98% of total plots are 25% suitable for mechanization; 16.73% of total plots are 50%suitable for mechanization; 2.60% of total plots are 75%suitable for mechanization.

3) The transformation of cultivated land in the hilly areas of Nanjing should focus on merging small plots into large ones, with rectangular and strip field shapes and a plot length-width ratio of no less than 3:1. The earthwork volume of excavation and earth filling is generally small, mainly about the re-delimitation of plot boundaries, which inevitably involves changes and adjustments of farmers' contracted land scope. Hence, it is necessary to re-coordinate the distribution of farmers' contracted land ownership properly. Merging small, cultivated land into large one will reduce the number of ridges and in-

crease new cultivated land resources in the project area.

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