

# Analysis of cultivated land consolidation potential in China

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**Abstract:** Land consolidation plays an important role in increasing cultivated land. Therefore, the paper proposed a method to measure the cultivated land consolidation potential in China. Meanwhile, based on survey data of land use changed in 2008, the farmland classification data and background information of typical project of cultivated land consolidation, the potentials of the cultivated land consolidation were evaluated qualitatively and quantitatively at the county scale. The results proved the considerable and concentrated potential capacities in China. The counties with high quantitative potential mainly distributed in Heilongjiang and Jilin in northeast China, Henan, Anhui and Hubei in the east, Sichuan, Guizhou and Yunnan in the southwest, Xinjiang in the northwest; Those with high qualitative potential were in Heilongjiang in the northeast, Xinjiang, Inner Mongolia and Ningxia in the northwest, Shandong and Anhui in the east, Hubei and Hunan in central China, Guizhou, Sichuan and Yunnan in the southwest. The study can facilitate recognition about distribution of the potentiality and designation of the key regions of cultivated land consolidation in China, and can provide data reference for planning national comprehensive land management.

**Key words:** land use, consolidation, measurements, potential, evaluation, China

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## 0 Introduction

Cultivated land is an essential component of land resources and their sustainable use is the key for regional sustainable development<sup>[1-2]</sup>. Land consolidation and land development was initiated in China in the 1990s and developed rapidly since then. It helps to assure the food security and maintain dynamic balance of the total amount of cultivated land<sup>[3-4]</sup>. The evaluation on cultivated land consolidation potential paves the way for planning land development and consolidation, and it plays an important role in setting up the objective and principle of cultivated land consolidation, and also in guiding the choice of the target areas and the consolidation practices. In accordance with the definition in the *National Plan for Land Development and Consolidation 2001-2010* issued by the Administration of National Territory and Resources, the agricultural land consolidation means the increment of the effective area of the cultivated land, improvement of the land quality and ecological conditions, and reduction of the production risks through technical and administrative measures, so as to

transfer the extensive, low-efficiency cultivation to an intensive, efficient one. Cultivated land consolidation is especially crucial in the agricultural land consolidation. And their potential mainly lies in the expansion of the areas, improvement in land quality and ecological conditions. In China, the goal of land consolidating has gradually changed from purely quantitative growth to the pursuit higher quality and better environmental factors<sup>[5-8]</sup>. The potential evaluation can help to master the local land use, design the layout and set the objectives in cultivated land consolidation. At present, there is a variety of methods for potential evaluation<sup>[9-15]</sup>, among which there is noticeable difference according to varied scales. Compared with that for the regional scale, the approaches for national scale have a more macro base<sup>[16-20]</sup>. Yet past researches have not paid enough attention to them, especially at the county level. Given that the existing data sources such as the classification of agricultural land in China can sufficiently support the evaluation of cultivated land consolidation potential, this research tries to find out the method to evaluate the potential of national cultivated land consolidation under the new situation at county scale, in order to specify the quantitative and qualitative potentials as well as their distribution, and guide the designation of key areas in consolidation and comprehensive use of cultivated land resources in China.

## 1 Connotation of cultivated land consolidation

The connotation of cultivated land consolidation

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concerns several aspects, such as the environment, economy and social activities. It is highly related to the geological, topographical and hydrological facts, the development and productivity of land development and productivity, and the socio-economic conditions.

In China's new phase of development, the potentials in consolidating cultivated land may involve:

### 1.1 Potential of newly added cultivated land

Adding new cultivated land is the important content in future land consolidation. In other words, it refers to the increase in the effective area of cultivated land after the consolidation. The increased area mainly comes from: 1) comprehensive rearrangement of roads and canals, 2) land leveling, integrating small patches of cultivated land and reducing the field ridges, and 3) land use adjustment.

### 1.2 Potential of higher quality in cultivated land

In addition to the increment of the effective area, through cultivated land consolidation, the land quality can be improved. The land quality is pertaining to the stable factors such as soil, topography, climate and geographic position, and meanwhile affected by the changing factors such as fertilization, irrigation and management. The land quality and productivity determine the grain production, which in turn serves as their indicator in practice.

### 1.3 Potential of better ecological conditions

The cultivated land consolidation can enlarge the area, increase the production and promote the productivity through improving the productive conditions. In the meantime, it needs to be combined with risk management to reduce or even avoid the soil contamination and improve the ecological conditions, so as to add environmental value and mitigate the production risks.

## 2 Evaluation steps of cultivated land potential in China

Considering the difficulty in measuring the third potential mentioned above, the present evaluations of land consolidation always focus on the quantitative and qualitative potentials, so does this research. The steps of the evaluation herein are as follows:

### 2.1 Data and relevant information collection

The data and information mainly include the area of cultivated land at the county level in China (the survey data of land use change in 2008), the farmland classification data at the county level and the information about the typical projects of cultivated land consolidation in different regions in the past three years.

### 2.2 Indicator system for evaluation establishment

The results of the evaluation on potentials of the cultivated land consolidation are supposed to be represented by the indicators, among which the newly added cultivated land indicates the quantitative potential, and the increase of productive capacity proves the qualitative potential.

### 2.3 Evaluation unit determination

The evaluation units directly affect the accuracy of evaluation. Theoretically, to ensure the precise evaluation,

the units should feature similar resource endowment, land use structure and pattern, and socio-economic development. Meanwhile, the availability of data needs to be considered. This research adopts the county as the basic evaluating unit. Based on the county-level results, the potential of cultivated land consolidation are measured at the provincial, national land use regions and national as well.

### 2.4 Scale of land consolidation estimation

This research tends to evaluate the future theoretical potential of cultivated land consolidation. It identifies the area of the cultivated land that need be consolidated according to the survey data of land use and its changes as well as the latest statistics of land resources. To be specific, the consolidation area covers the overall cultivated land in 2008 survey for the land use changes in the target administrative units.

### 2.5 Key coefficient specification

There are two key coefficients in the potential evaluation of cultivated land consolidation:

1) The coefficient of newly added cultivated land area, which is identified for each region through the analysis of the statistic data in accordance with the rate of newly added cultivated land in typical consolidating projects.

2) The coefficient of qualitative improvement, which is identified by the uplifts of cultivated land classes in different regions.

The key coefficients should be specified to the different regions, which have to be divided beforehand in consideration of the farmland classification, standard cultivating patterns, and types of land development and consolidation. The divided regions should have similar land use, and geologic and topographic conditions. The national classification of farmland qualities is available now in China after the farmland classification. In the classifying process, the factor index areas had been established. This research borrows the third-level factor index areas as the regions to specify the key coefficients. In general, thanks to the uniform land use and terrain, the same coefficients can be applied within one index area.

The research analyzed the data of the typical project areas in previous years and found that the indicator of newly added cultivated land varied noticeably in different periods. The earlier consolidation projects were usually measured together with land development or reclamation, and thus resulted in higher rate of newly added cultivated land, sometimes over 20%. Gradually, this rate dropped to around 5%. In the national statistic yearbooks from 2001 to 2008, it can also be found that the rate kept decreasing. Because of the socio-economic development, the background has changed for cultivated land consolidation in China. In current land consolidation, the quantitative potential, i.e. increase of areas, is shrinking. And the focus has been shifted to improving land quality. Therefore, this research, to accommodate this change, adopts the average coefficient 3% for the newly added cultivated land in China. Moreover, in accordance with their data of consolidation projects, the target regions are

assigned with the individual coefficients ranging from 0 to 5% about the newly added cultivated land.

**2.6 Potential measurement in cultivated land consolidation**

**2.6.1 Quantitative potential**

In line with the regional division, this research calculates the coefficients of newly added cultivated land in the typical project areas of land consolidation within each region to obtain the general coefficient in that region, which is considered to be the coefficient for the counties within that region. According to the coefficient and the consolidating scale in each county, the quantitative potential can finally be indentified for cultivated land consolidation. The formula is as follows

$$Q_i = A_i \cdot R_i \tag{1}$$

Where  $Q$  is the quantitative potential of cultivated land consolidation in County  $i$  ( $\text{hm}^2$ );  $A$  means the consolidating scale in that county  $i$  ( $\text{hm}^2$ ); and  $R$  refers to the area coefficient of newly added cultivated land in the region to which county  $i$  belongs.

**2.6.2 Qualitative potential**

This research computes the qualitative potential of cultivated land consolidation in terms of the *goal grade method*.

The data of qualitative potential consist of two parts, namely the increased productivity from the original cultivated land and that from the newly added ones. This research presumes that the quality of the original cultivated land will be improved in all counties through land consolidation. And a county's average utilization grade of

cultivated land can reach the highest in the third-level factor index area to which the county belongs. Thus a county's qualitative potential of the original cultivated land partly means the gap between that highest utilization grade and the average utilization grade of the county before the consolidation. The other part comes from the newly added cultivated land which can presumably reach the average utilization grade in the county. As a result, the total qualitative potential is the combination of these two parts of productivity. The formula is as follows

$$W = A \cdot T \times 100 + Q_i \cdot K \tag{2}$$

Where  $W$  refers to the qualitative potential in cultivated land consolidation in county  $i$  ( $\text{kg}$ );  $A$  means the consolidated areas ( $\text{hm}^2$ );  $T$  is the difference between the highest land use level in the third-level factor index area and the average land use level of a county within that area; 100 is the standard unit production of a land use level ( $\text{kg}/\text{hm}^2$ );  $Q$  indicates the newly added area of cultivated land ( $\text{hm}^2$ );  $K$  is the standard unit production of the average land use level in the county ( $\text{kg}/\text{hm}^2$ ).

**3 Results and analysis**

The quantitative and qualitative potentials are evaluated in China's cultivated land consolidation in accordance with Formula 1 and 2. The results are illustrated in Fig. 1. On the basis of county-level potential analyses, the general quantitative and qualitative potentials are identified for the cities, the provinces, the nine major national land use regions and China as a whole.

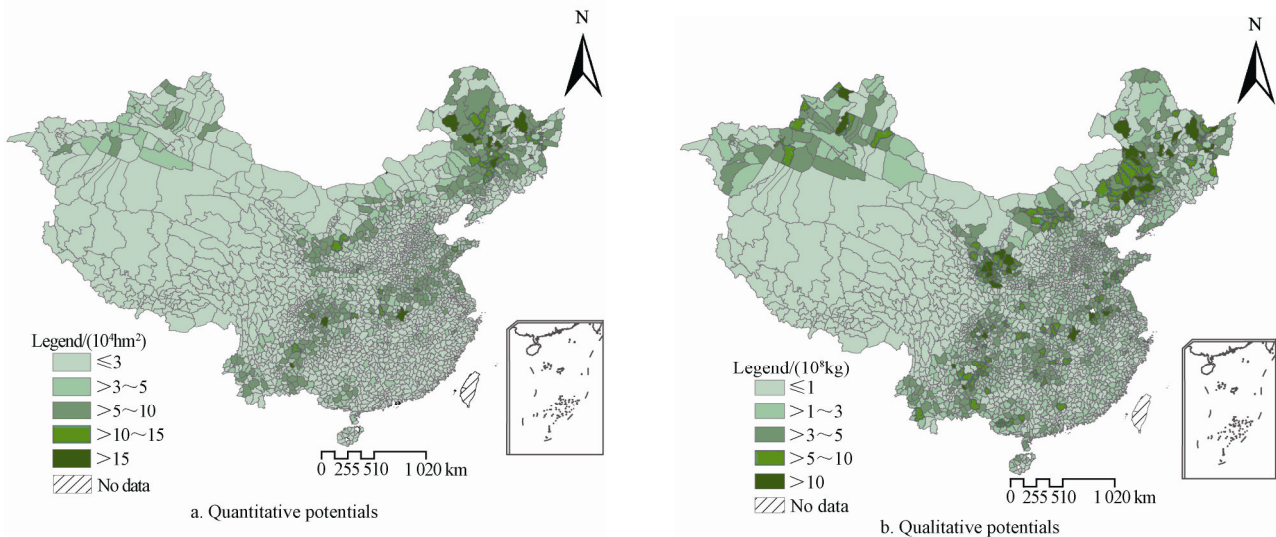


Fig.1 Results of county-level evaluation on quantitative and qualitative potentials in cultivated land consolidation in China

**3.1 General status of cultivated land consolidation potential**

This research proves the huge potential in cultivated land consolidation in China. The total net increase of the cultivated land will reach  $417.93 \times 10^4 \text{ hm}^2$  after the consolidation, and qualitative potential is  $4647.63 \times 10^8 \text{ kg}$ .

In general, the potential points for quantitative and

qualitative increases are distributed in a similar way. In the map of quantitative potential of land consolidation in China, the counties with higher potential concentrate in Heilongjiang and Jilin in northeast China, Henan, Anhui and Hubei in east China, Sichuan, Guizhou and Yunnan in the southwest, Xinjiang in the northwest, as well as the major party of Ningxia. Those with lower potential are located in northwest China, Fujian, Canton, Hainan,

Qinghai and Tibet. And in the map of qualitative potential, the counties with higher potential are mainly distributed in Heilongjiang in the northeast, Xinjiang, Inner Mongolia and Ningxia in the northwest, Sangdong and Anhui in the east, Hubei and Hunan in central China, Guizhou, Sichuan and Yunnan in the southwest. Those with lower qualitative potential are mainly in Gansu, Fujian, Canton, Hainan and Tibet. The northern counties in Sichuan also maintain a lower potential.

### 3.2 Potential of cultivated land consolidation in nine major land use areas

In the *National Layout of Land Use from 2006 to 2020*, there are nine major land use regions, namely the Qinghai-Tibet area, the Southwest area, the Northwest area, the Northeast area, Shanxi-Henan area, the Hunan-Hubei-Anhui-Jiangxi area, the Beijing-Tianjin-Hebei-Shandong area, the Jiangsu-Zhejiang-Shanghai area and the Fujian-Canton-Hainan area.

Table 1 The Potential of Cultivated Land Consolidation in the Nine Major land use areas

Land use areas	Scale/ (10 <sup>4</sup> hm <sup>2</sup> )	Quantitative potentials/ (10 <sup>9</sup> hm <sup>2</sup> )	Qualitative potentials/ (10 <sup>8</sup> kg)	Land use areas	Scale/ (10 <sup>4</sup> hm <sup>2</sup> )	Quantitative potentials/ (10 <sup>9</sup> hm <sup>2</sup> )	Qualitative potentials/ (10 <sup>8</sup> kg)
Total	12709.75	417.93	4647.63	Jiangsu-Zhejiang-Shanghai	692.76	19.99	174.5
Northeast	2727.76	87.39	729.36	Southwest	2081.62	65	1038.43
Beijing-Tianjin-Hebei-Shandong	1449.55	48.34	583.64	Southwest	2299.91	85.57	874.27
Shanxi-Henan	1197	42.06	341.5	Fujian-Canton-Hainan	487.83	13.25	202.37
Hunan-Hubei-Anhui-Jiangxi	1682.39	53.54	692.68	Qinghai-Tibet	90.94	2.78	10.88

Among them, the Northeast area has the highest quantitative potential of cultivated land, followed by the southwest and northwest areas. Their potentials are all beyond 60×10<sup>4</sup>hm<sup>2</sup>. Quantitative potentials between 40×10<sup>4</sup>-60×10<sup>4</sup>hm<sup>2</sup> exist in Hunan-Hubei-Anhui-Jiangxi area, Beijing-Tianjin-Hebei-Shandong area and Shanxi-Henan area. In Jiangsu-Zhejiang-Shanghai area, Fujian-Canton-Hainan area and Qinghai-Tibet area, the potentials are below 20×10<sup>4</sup>hm<sup>2</sup>.

Especially Qinghai-Tibet area claims the lowest 2.78×10<sup>4</sup>hm<sup>2</sup>.

In terms of qualitative potential, the highest comes up in Northwest area, Southwest area and Northeast area. The potential is lower in Hunan-Hubei-Anhui-Jiangxi area, Beijing-Tianjin-Hebei area and Shanxi-Henan area. The lowest may distribute in Fujian-Canton-Hainan area, Jiangsu-Zhejiang-Shanghai area and Qinghai-Tibet area.

### 3.3 Potential in provincial cultivated land consolidation

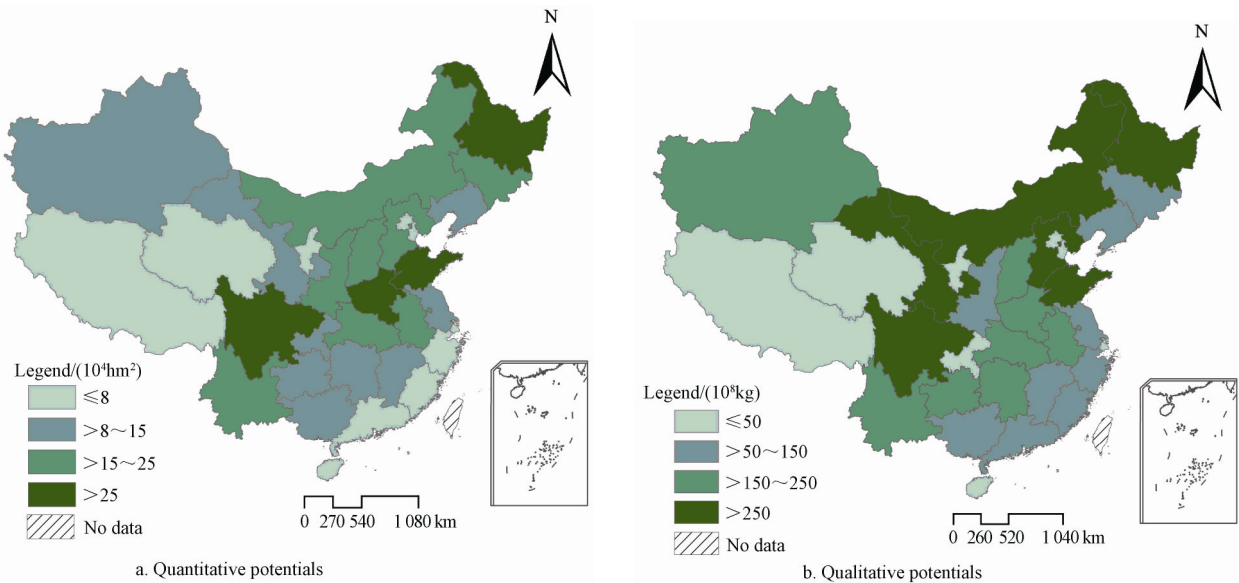


Fig.2 Results of province-level evaluation on quantitative and qualitative potentials in cultivated land consolidation in China

Table 2 The cultivated land consolidation potential in province-level

Province	Scale/ (10 <sup>4</sup> hm <sup>2</sup> )	Quantitative potentials/ (10 <sup>9</sup> hm <sup>2</sup> )	Qualitative potentials/ (10 <sup>8</sup> kg)	Province	Scale/ (10 <sup>4</sup> hm <sup>2</sup> )	Quantitative potentials/ (10 <sup>9</sup> hm <sup>2</sup> )	Qualitative potentials/ (10 <sup>8</sup> kg)
Total	12709.75	417.93	4647.63	Henan	789.6	25.22	175.94
Beijing	23.17	0.59	2.65	Hubei	465.3	16.47	154.47
Tianjin	44.11	1.46	7.61	Hunan	378.94	9.99	247.7
Hebei	630.74	18.29	277.95	Guangzhou	288.57	6.92	110.95
Shanxi	407.4	16.84	165.56	Guangxi	425.84	12.24	132.54
Inner Mongolia	704.2	18.35	371.93	Hainan	66.25	1.71	20.48
Liaoning	408.53	11.45	115.42	Chongqing	223.59	9.82	33.89

				Continuation			
Province	Scale/ ( $10^4 \text{ hm}^2$ )	Quantitative potentials/ ( $10^4 \text{ hm}^2$ )	Qualitative potentials/ ( $10^8 \text{ kg}$ )	Province	Scale/ ( $10^4 \text{ hm}^2$ )	Quantitative potentials/ ( $10^4 \text{ hm}^2$ )	Qualitative potentials/ ( $10^8 \text{ kg}$ )
Jilin	553.46	16.96	98.14	Sichuan	594.74	25.16	304.96
Heilongjiang	1752.83	58.58	514.85	Guizhou	448.53	14.57	168.07
Shanghai	25.38	0.56	3.09	Yunnan	607.21	23.78	234.8
Jiangsu	475.34	13.39	91.73	Xizang	36.16	0.84	3.84
Zhejiang	192.03	6.04	79.68	Shanxi	405.03	16.84	118.68
Anhui	555.79	17.82	198.43	Gansu	465.65	13.57	282.24
Fujian	133.01	4.62	70.95	Qinghai	54.77	1.94	7.04
Jiangxi	282.35	9.25	92.09	Ningxia	107.22	3.57	49.1
Shandong	751.53	28.01	295.42	Xinjiang	412.45	13.08	217.45

The quantitative and qualitative potentials of cultivated land consolidation differ greatly from one another among the 31 provinces (municipalities directly under the central government and autonomous regions). The higher quantitative potentials can be found in the central and east regions. Heilongjiang harbors the largest absolute potential area, because of its vast cultivated land and extensive land use. In Shandong, Henan and Sichuan, the quantitative potentials are also over  $20 \times 10^4 \text{ hm}^2$ . However, the lower potentials are shared by the provinces in the west as well as Fujian, Canton and Hainan. Meanwhile, the higher qualitative potentials are in the central and east parts, especially in Heilongjiang, Inner Mongolia, Sichuan and Shandong. Qinghai and Tibet have lower qualitative potentials, so do the coastal provinces in the south.

#### 4 Conclusion and discussion

This research proposes a new calculation method for cultivated land consolidation potential to accommodate the new situation. It adopts the survey data of land use change in 2008 and the national farmland classification system to measure the quantitative and qualitative potentials of China's cultivated land consolidation at the county level. Based on these results, the potentials of land consolidation in land utilization region and provinces are further estimated, so as to find out the distribution features of the potential capacities and the critical dimensions in future cultivated land consolidation.

Through decades of development, the meaning of cultivated land consolidation potential has largely changed. And the evaluation methods also vary to adapt to different data scale. This research may help to apply the achievements in farmland classification, plan future land consolidation, reasonably assign the responsibilities of basic cultivated land protection, better understand the issues about food security and set up the regulations for proper land development and consolidation. At present, however, the calculation methods only focus on the quantitative and qualitative potentials. In further researches, more approaches need to be developed to measure the environmental, socio-economic and cultural effects triggered by the cultivated land consolidation.

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## 中国耕地整理潜力测算分析

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**摘要:** 耕地整理是增加耕地面积的重要途径, 该研究提出新形势下中国耕地整理潜力的测算方法, 并以 2008 年中国土地利用变更调查数据和农用地分等数据为基础, 结合耕地整理典型项目区的资料等, 以县为单位, 对中国的耕地整理数量潜力和质量潜力进行了测算。结果表明, 中国的耕地整理的数量和质量潜力巨大, 耕地整理的数量潜力和质量潜力呈现较一致的集中分布特点。数量潜力较高的县主要分布在东北地区的黑龙江省和吉林省, 东部地区的河南、安徽、湖北省, 西南地区的四川、贵州、云南省和西北地区的新疆地区; 质量潜力较高的县主要分布在东北地区的黑龙江省, 西北地区的新疆和内蒙古和宁夏地区, 其次是东部的山东省、安徽省和中部的湖北省、湖南省, 西南地区的贵州、四川、云南省的潜力也较高。研究结果对掌握中国耕地整理潜力分布特点和确定中国的耕地整理重点区有指导作用, 并可为编制中国土地综合整治规划提供数据基础。

**关键词:** 土地利用, 土地整理, 测算, 潜力, 评估, 中国