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Is Cultivated Land Increased by Land Consolidation Sustainably Used in Mountainous Areas?

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Abstract: Land consolidation (LC) in China is an important means by which we can increase the quantity and improve the quality of cultivated land. At present, large areas of cultivated land are abandoned in mountainous areas. It is unclear whether the increased cultivated land from LC in mountainous areas is sustainably used. Data from 64 land consolidation zones completed in 2016 in the Qinba Mountain Area were collected. The land-use status was obtained from high-resolution remote sensing images by the method of visual interpretation, and land-use changes were analyzed. According to our results, the increased cultivated land by LC is mainly terrace, accounting for 92.22% of the total area of increased cultivated land. The increased cultivated land is mainly distributed in the Qinba Mountainous Area, and terrace is the main type of increased cultivated land in both the Hanzhong Basin Area and Qinba Mountainous Area. The transformation rate of cultivated land from LC, especially terrace, is small. The transformation rates of terrace in the Hanzhong Basin Area and Qinba Mountainous Area are 0.36% and 0.09%, respectively. The socioeconomic development in mountainous areas is relatively lagging, and the per capita cultivated land area is small. Many farmers are still engaged in agricultural production and earn a basic income. Thus, high-quality cultivated land with convenient transportation is sustainably used. LC remains a key avenue for increasing cultivated land area, improving agricultural productivity, increasing farmers' incomes, and promoting rural development in the mountainous areas.

Keywords: increased cultivated land; cultivated land transformation; land consolidation; Qinba Mountain

Citation: Zhou, J.; Li, C.; Chu, X.; Luo, C. Is Cultivated Land Increased by Land Consolidation Sustainably Used in Mountainous Areas? *Land* **2022**, *11*, 2236. https://doi.org/10.3390/land11122236

Academic Editor: Marta Debolini

Received: 5 November 2022
Accepted: 6 December 2022
Published: 8 December 2022

1. Introduction

Land consolidation (LC) is an important means with which to increase the quantity and improve the quality of cultivated land to ensure food security around the world [1–3]. LC in China includes land reclamation, cropland consolidation, and land rehabilitation [4]. Land reclamation refers to the transformation of non-cultivated lands, such as grassland, into cultivated land. Land rehabilitation is the conversion of cultivated land damaged by construction, disasters, and other incidents into cultivated land. Cropland consolidation seeks to enhance the agricultural productivity of existing cultivated land by improving cultivated land quality [5]. The practices of land leveling engineering, irrigation and drainage engineering, field road engineering, and eco-environment engineering are conducted in LC. From 1999 to 2017, LC increased by 9.0×10^8 hm^2 of cultivated land in China, accounting for 70% of the total increased cultivated land area and exceeding the 7.8×10^8 hm^2 of cultivated land occupied by construction [6]. Therefore, apart from using LC to increase the cultivated land area, China also deploys LC under its comprehensive rural vitalization strategy aimed at increasing farmers' incomes by reducing agricultural production costs and increasing grain yields [7,8], coordinating urban and rural development [9], and promoting the modernization of agriculture and rural areas [10,11].

The potential of using LC to increase cultivated land area has been extensively studied. Studies in Poland show that LC has increased the area of cadastral plots by 17% [12]. A set of criteria showing the potential for LC at the municipal level and project level were established in Europe [13]. Vegetation cover was used to reflect the dilapidated degree of rural residential areas to estimate the potential for rural residential areas to be consolidated into cultivated land [14]. The distribution of increased cultivated land has gradually moved to the ecologically fragile western areas of China, which has hindered the sustainable utilization of cultivated land [15]. To understand the potential of increasing cultivated land area, China conducted surveys on reserved land resources for cultivation in 2000, 2015, and 2021. The survey of reserved land resources for cultivation mainly investigated the natural and ecological conditions of land resources. In addition, the natural potential of LC to increase cultivated land area was revised from the perspectives of government management, farmer participation, and economic conditions [16–18]. In a study of LC to enhance the quality of cultivated land, eliminating the limiting factor of cultivated land quality was an important research aspect [19,20]. Soil quality, land fragmentation, parcel shape and area, farm structure, the accessibility of roads, and terrain difficulty were identified as factors affecting agricultural production, and the land consolidation sequence was determined according to these factors [21]. The effects of LC on soil pH, soil organic matter, total N, available P, and available K were studied [22]. The change in cultivated land quality after LC was also explored [23]. The improvement of agricultural production efficiency by LC mainly occurred through the optimization of cultivated land plot shapes and the adjustment of landownership [24–26]. From the aspects of average cultivated land parcel size, the number of cultivated land parcels, and the average number of cultivated land parcels per landowner, two different models were used to study the allocation of newly increased cultivated land parcels in LC in Turkey [27]. A cultivated land plot exchange halved the number of plots per household, increased the size of plots, and boosted labor productivity in Vietnam [28]. LC increased farmers' income and reduced rural poverty by increasing the area of cultivated land, enhancing the quality of cultivated land, and improving the efficiency of agricultural production [29,30]. LC is an important means of promoting rural vitalization [31]. It should be noted that the above-mentioned functions of LC largely depend on the sustainable use of increased cultivated land. Mountainous areas are a special geographical system featuring a human–land relationship [32]. With the advancement of China's urbanization, the rural population in mountainous areas is decreasing substantially [33,34], and large areas of cultivated land have been abandoned [35–38]. From 2000 to 2020, the rural population in China decreased from 808.37 million to 509.92 million. The proportion of the rural population to the total population dropped from 63.78% to 36.11%. A survey in China showed that 13.5% and 15% of cultivated land was abandoned in 2011 and 2013, respectively [39]. In 2015, more than 30% of the cultivated land area was abandoned and not used for cultivation in mountainous areas [40]. Cultivated land abandonment in mountainous areas is becoming increasingly severe [41]. The abandonment rate of low-quality cultivated land in Wulong County, Chongqing City, reached 46.25% in 2010 [42]. The maximum abandonment rate of villages in Sichuan Province was 44.64% in 2016–2018 [43]. From 2001 to 2010, 2.76×10^6 hm^2 of cultivated land was increased by LC in China. From 2011 to 2015, 1.84×10^6 hm^2 of cultivated land was increased by LC in China. During 2006–2012 and 2011–2015, the government invested more than USD 30.74 billion and USD 76.71 billion in LC, respectively. Under rural vitalization and food security strategies, more funds will be spent on LC. However, it is unclear whether or not the increased cultivated land from LC in mountainous areas is sustainably used (Figure 1). Experts have also called for a halt to LC in mountainous areas due to the severe abandonment of cultivated land in these regions. If the increased cultivated land by LC is not sustainably used in mountainous areas, the investment will not be able to play its role. Therefore, under the background of cultivated land abandonment in mountainous areas, it is urgent to study the sustainable use of cultivated land by LC, to guide the development of LC in mountainous areas.

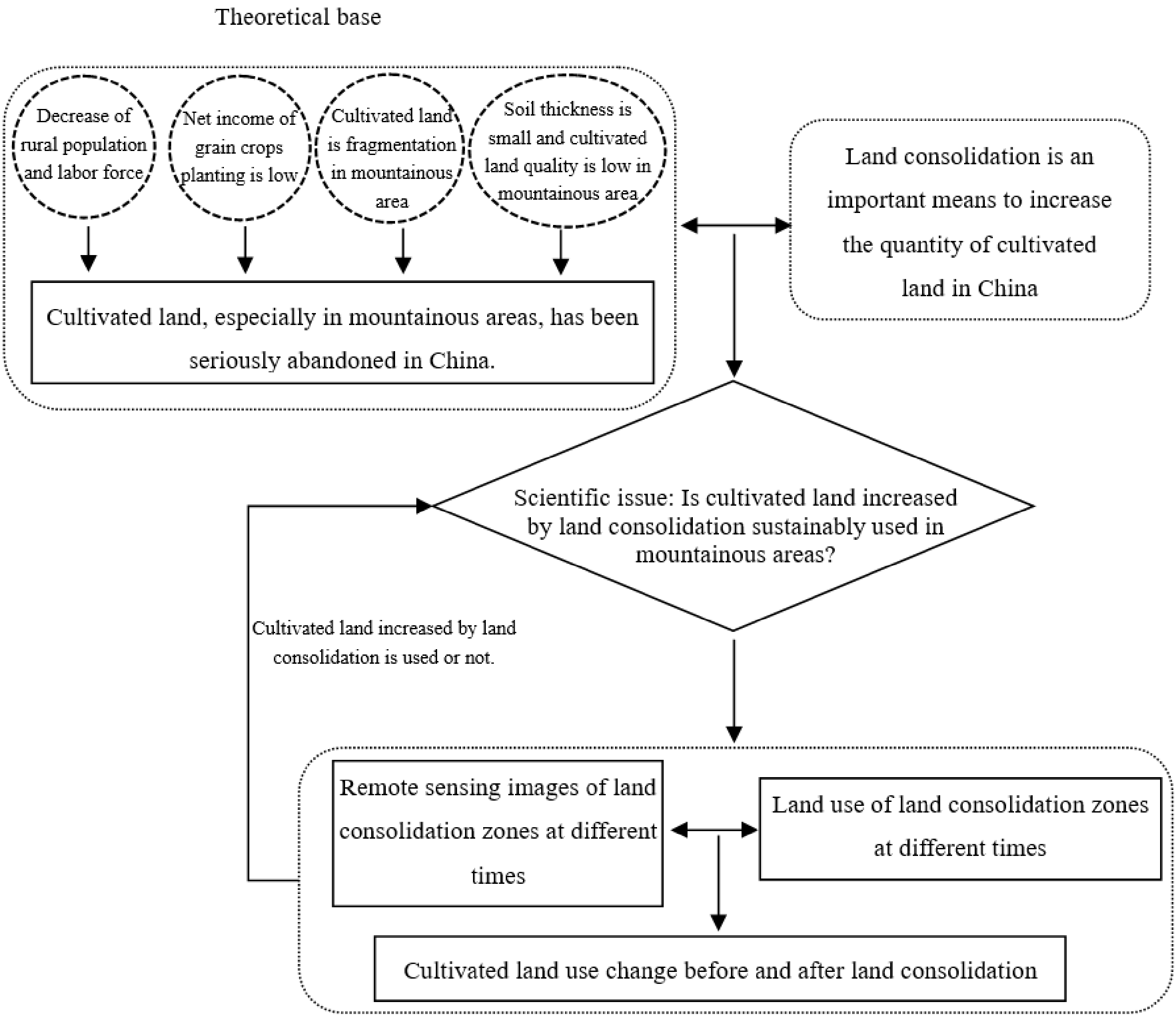

Figure 1. Theoretical analysis framework.

Thus, taking 64 land consolidation zones completed in 2016 in the Qinba Mountain Area as research samples, this article (1) analyzes the increased cultivated land by LC, (2) calculates the transformation rate of cultivated land after LC, and (3) puts forward a suggestion for the future development of LC in mountainous areas.

2. Materials and Methods

2.1. Study Area

Hanzhong City is located at 105°30′50″ E–108°16′45″ E, 32°08′54″ N–33°53′16″ N. It is a prefecture-level city in Shaanxi Province (Figure 2). The total area is 27,000 km^2. The Han River, the largest tributary of the Yangtze River, passes through the middle of Hanzhong City. Hanzhong City is an important water conservation area for China's South-to-North Water Diversion Project. The geomorphic types of Hanzhong City are Hanzhong Basin Area (HZBA) and Qinba Mountainous Area (QBMA). Areas of HZBA and QBMA account for 6.03% and 93.97% of the total area of Hanzhong City, respectively.

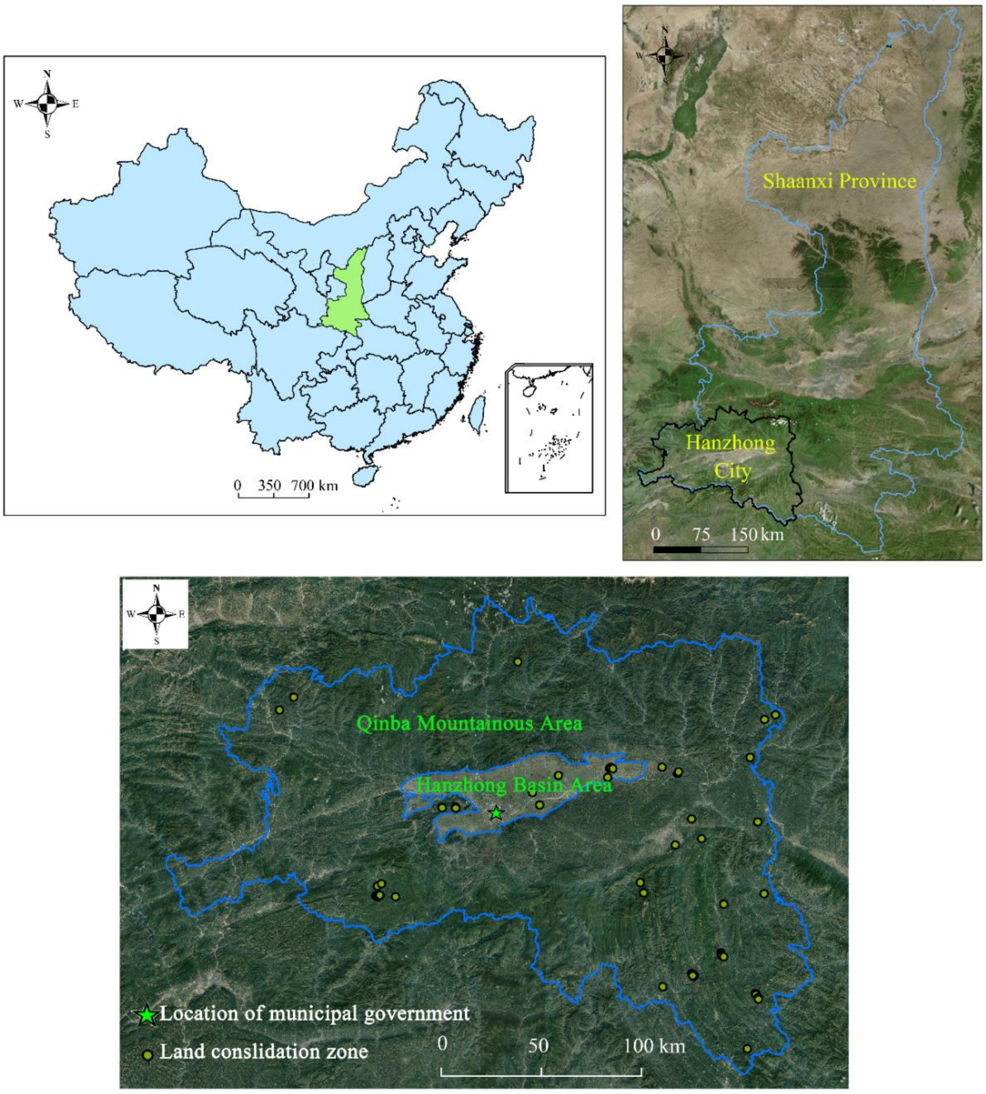

Figure 2. The location and geomorphy of Hanzhong City and land consolidation zones are indicated by points.

At the end of 2019, Hanzhong City had a total population of 3.44 million, and the per capita land area was 0.79 hm^2. The cultivated land area was 212,370 hm^2, and the per capita cultivated land area was only 0.07 hm^2 in rural areas. The per capita GDP was RMB 45,027, which was lower than the per capita GDP of RMB 66,545 for Shaanxi Province and the per capita GDP of RMB 69,765 for China. According to the results of the Seventh National Population Census in 2020, the urbanization rate was 50.96%. Thus, the per capita cultivated land area is small and socioeconomic development is relatively backward in Hanzhong City.

2.2. Data and Methods

The data from 64 land consolidation zones (LCZs) completed in Hanzhong City in 2016 were collected. (1) To obtain land use in the land consolidation zone (LCZ) before LC, a remote sensing image of LCZ before 2016 was downloaded using BigMap software. The spatial resolution was 0.5 m. Land use of LCZs before LC was obtained by visual interpretation. The land use at this phase was defined as first-phase land use (FPLU). (2) To analyze increased cultivated land by LC, remote sensing images of LCZs after 2016 were also downloaded. The spatial resolution was also 0.5 m, and land use of LCZs after LC was obtained by visual interpretation. The land use at this phase was defined as mid-term land use (MTLU). Increased cultivated land by LC was analyzed using FPLU and MTLU. (3) To analyze the transformation of cultivated land by LC, a remote sensing image with a spatial resolution of 0.5 m after mid-term land use was downloaded and interpreted by visual interpretation. The land use at this phase was defined as the third-phase land use (TPLU). Acquisition times of all remote sensing images were between 2013 and 2021 (Table 1). The number of LCZs with the time intervals of MTLU and TPLU, or of less than 1 year, 1–2 years, and greater than 2 years, were 10, 26, and 28, respectively. The area of LCZs with time intervals of less than 1 year, 1–2 years, and greater than 2 years was 115,709 m^2, 783,883 m^2, and 111,0581 m^2, accounting for 5%, 36%, and 59%, respectively. Transformed cultivated land refers to the conversion of cultivated land to non-cultivated land after LC. The land-use type in MTLU is cultivated land, and the land-use type in TPLU is non-cultivated land. The transformation rate of cultivated land was calculated:

$$AR = \frac{E}{A}$$

where AR is the transformation rate of cultivated land or terrace; E is the area of transformed cultivated land or terrace after LC; and A is the area of cultivated land or terrace of MTLU.

Table 1. Acquisition time of remote sensing images of land consolidation zones.

Number of LCZ	Acquisition Time of Remote Sensing Image			Number of LCZ	Acquisition Time of Remote Sensing Image		
	FPLU	MTLU	TPLU		FPLU	MTLU	TPLU
1	14 January 2014	5 December 2017	10 February 2020	33	4 December 2013	17 December 2018	19 July 2020
2	6 August 2015	2 November 2018	20 December 2020	34	27 January 2013	19 January 2018	20 December 2020
3	6 August 2015	2 November 2018	20 December 2020	35	27 January 2013	19 January 2018	20 December 2020
4	6 May 2015	2 November 2018	20 December 2020	36	27 January 2013	19 January 2018	20 December 2020
5	31 August 2015	5 December 2017	20 December 2020	37	6 August 2015	9 January 2018	20 December 2020
6	22 January 2015	5 December 2017	20 December 2020	38	14 August 2014	17 May 2017	13 July 2019
7	28 June 2011	19 February 2016	25 February 2020	39	14 August 2014	17 May 2017	19 February 2020
8	21 December 2014	28 November 2017	11 March 2019	40	14 August 2014	17 May 2017	19 February 2020
9	21 December 2014	23 May 2017	11 March 2019	41	14 August 2014	17 May 2017	19 February 2020
10	24 July 2015	11 May 2018	9 December 2019	42	14 August 2014	17 May 2017	19 February 2020
11	16 December 2013	11 May 2018	22 January 2020	43	14 August 2014	17 May 2017	19 February 2020
12	16 December 2013	11 May 2018	22 January 2020	44	25 October 2013	1 March 2017	20 January 2018
13	12 October 2013	7 June 2016	2 November 2017	45	6 October 2013	1 March 2017	16 January 2018
14	12 October 2013	7 June 2016	2 November 2017	46	6 October 2013	1 March 2017	16 January 2018
15	12 October 2013	7 June 2016	2 November 2017	47	6 October 2013	1 March 2017	16 January 2018
16	12 October 2013	7 June 2016	2 November 2017	48	6 October 2013	1 March 2017	16 January 2018
17	12 October 2013	7 June 2016	2 November 2017	49	6 October 2013	1 March 2017	16 January 2018
18	12 October 2013	7 June 2016	2 November 2017	50	6 October 2013	1 March 2017	16 January 2018
19	12 October 2013	7 June 2016	2 November 2017	51	6 October 2013	1 March 2017	16 January 2018
20	12 October 2013	7 June 2016	2 November 2017	52	28 March 2015	1 March 2017	8 February 2021
21	12 October 2013	7 June 2016	2 November 2017	53	28 March 2015	1 March 2017	8 February 2021
22	12 October 2013	7 June 2016	2 November 2017	54	28 March 2015	1 March 2017	18 March 2019
23	12 October 2013	7 June 2016	2 November 2017	55	28 March 2015	1 March 2017	18 March 2019
24	12 October 2013	26 March 2016	14 August 2019	56	28 March 2015	1 March 2017	18 March 2019
25	12 October 2013	1 July 2016	2 November 2017	57	28 March 2015	1 March 2017	18 March 2019
26	27 January 2013	19 January 2018	26 October 2018	58	28 March 2015	11 March 2017	18 March 2019
27	28 March 2015	8 January 2018	26 October 2018	59	28 March 2015	11 March 2017	18 March 2019
28	14 August 2014	1 March 2017	26 October 2018	60	3 September 2014	12 May 2017	15 August 2019
29	3 September 2014	8 April 2018	15 August 2019	61	3 September 2014	12 May 2017	18 March 2019
30	7 February 2015	9 August 2017	8 March 2019	62	3 September 2014	12 May 2017	15 August 2019
31	18 December 2014	9 August 2017	26 October 2018	63	3 September 2014	12 May 2017	15 August 2019
32	6 October 2013	1 March 2017	26 October 2018	64	9 October 2013	1 March 2017	15 August 2019

Land-use types included cultivated land, forest land, shrubland, grassland, inland beach, land for roads, land for ditches, land for rural settlements, water bodies, and spare land. The terrace was separated from cultivated land.

3. Results

3.1. Scale of Land Consolidation Zone

The number of LCZs gradually decreases with the increase in the area of LCZ. When the area of the LCZs was less than 1.7 hm^2, the number of LCZs in the different area groups was between 9 and 16 (Figure 3). When the area of the LCZs was between 1.7 hm^2 and 6.7 hm^2, the number of LCZs of the different area groups was between 2 and 5. The number of LCZs of the different area groups was all 1, as the area of LCZs was greater than 8.2 hm^2. Thus, as the scale of LCZs increases, the number of LCZs decreases.

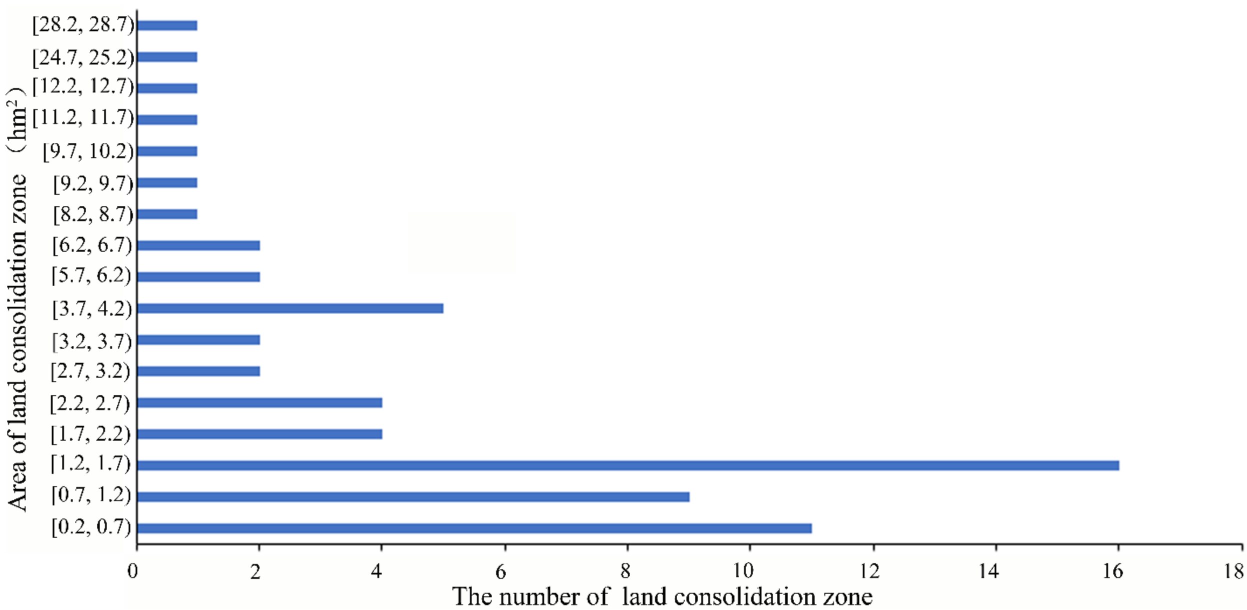

Figure 3. The number of LCZs with different scales.

3.2. Increased Cultivated Land by Land Consolidation

3.2.1. Type and Source of Increased Cultivated Land by Land Consolidation

Increased cultivated land by LC is dominated by terrace. According to the FPLU and MTLU, the area of increased cultivated land by LC was 952,527 m^2 (Table 2). The area of terrace land increased by 878,433 m^2, accounting for 92.22% of the total area of increased cultivated land (Figure 4).

Table 2. Land use of LCZ before and after LC.

Land-Use Type	Area in FPLU (m^2)	Area in MTLU (m^2)	Area Change (m^2)
Cultivated land	546,069	1,498,596	952,527
Forest land	360,911	289,761	−71,150
Shrubland	257,965	160,657	−97,308
Grassland	928,548	172,013	−756,535
Inland beach	41,159	1625	−39,534
Land for roads	24,230	34,174	9944
Land for ditches	54	2097	2043
Land for rural settlements	6581	6581	0
Water body	1811	325	−1486
Spare land	0	1499	1499

Figure 4. Increased terrace by land consolidation.

The increased cultivated land is mainly derived from grassland, shrubland, and forest land. Their areas accounted for 71.284%, 14.177%, and 10.656% of the total area of increased cultivated land, respectively (Table 3). Some inefficient forest land has been reclaimed for cultivation by LC in China. The increased terrace mainly comes from grassland, shrubland, forest land, and non-terraced cultivated land. The proportions of each of their areas to the total area of the increased terrace were 65.320%, 13.005%, 11.172%, and 10.500%, respectively (Table 3).

Thus, the increased cultivated land is mainly terrace. The increased cultivated land and increased terrace are mainly derived from grassland, shrubland, forest land, and non-terraced cultivated land.

Table 3. Sources of increased cultivated land and increased terrace.

Land-Use Type in FPLU	Increased Cultivated Land (m^2)	Proportion (%)	Increased Terrace (m^2)	Proportion (%)
Non-terraced cultivated land	0	0	92,424	10.500
Forest land	102,749	10.656	98,343	11.172
Shrubland	136,703	14.177	114,472	13.005
Grassland	687,376	71.284	574,986	65.320
Inland beach	35,906	3.724	0	0.000
Land for roads	46	0.005	23	0.003
Water body	1486	0.154	0	0

3.2.2. Increased Cultivated Land by Land Consolidation in Different Geomorphic Regions

The QBMA is the main distribution area for increased cultivated land. The increased cultivated land in the QBMA was 881,943 m^2, accounting for 91.46% of the total increased cultivated land area. For the QBMA, an average of 34.76 m^2 of cultivated land was added per 100 km^2. The increased cultivated land in the QBMA was mainly from grassland, shrubland, and forest land (Table 4). The increased cultivated land in the HZBA was 82,323 m^2, accounting for 8.54% of the total increased cultivated land area. An average of 50.56 m^2 of cultivated land was added per 100 km^2 in the HZBA. The increased cultivated land in the HZBA was mainly from grassland and shrubland.

Table 4. Sources of increased cultivated land in different geomorphic regions.

Land-Use Type in FPLU	HZBA		QBMA	
	Area (m^2)	Proportion (%)	Area (m^2)	Proportion (%)
Forest land	2769	3.364	99,980	11.336
Shrubland	10,885	13.222	125,818	14.266
Grassland	68,669	83.414	618,707	70.154
Inland beach	0	0	35,906	4.071
Land for roads	0	0	46	0.005
Water body	0	0	1486	0.168
Total	82,323	100	881,943	100

The terrace is the main type of increased cultivated land in the QBMA and HZBA. The increased terrace area in the QBMA was 816,979 m^2, accounting for 92.63% of the total area of the increased cultivated land in the QBMA. The increased terrace was mainly from grassland, shrubland, and forest land (Table 5). The increased terrace area in the HZBA was 63,269 m^2, accounting for 76.85% of the total area of the increased cultivated land in the HZBA. The increased terrace area is mainly derived from grassland and non-terraced cultivated land.

Table 5. Sources of increased terrace in different geomorphic regions.

Land-Use Type in FPLU	HZBA		QBMA	
	Area (m^2)	Proportion (%)	Area (m^2)	Proportion (%)
Non-terraced cultivated land	10,885	17.204	81,539	9.981
Forest land	2769	4.377	95,574	11.697
Shrubland	0	0	114,472	14.012
Grassland	49,615	78.419	525,371	64.307
Land for roads	0	0	23	0.003
Total	63,269	100	816,979	100

Thus, the increased cultivated land by LC is mainly distributed in the QBMA, and terrace is the main type of increased cultivated land in both the QBMA and HZBA.

3.3. Transformation of Cultivated Land after Land Consolidation

The transformation rate of cultivated land by LC is small, but the transformation rate in the HZBA is larger than that in the QBMA. According to the MTLU and TPLU, 46,207 m^2 of cultivated land was transformed after LC, accounting for 3.08% of the total cultivated area in the MTLU. The transformed cultivated land in the HZBA was 23,440 m^2, accounting for 9.38% of the total cultivated land area of the MTLU in this region (Table 6). The transformed cultivated land in the QBMA was 22,767 m^2, accounting for 1.82% of the total cultivated land area of the MTLU in this region.

Table 6. Transformed cultivated land and terrace after land consolidation.

Geomorphic Region	Land-Use Type in TPLU	Land-Use Type in MTLU	
		Cultivated Land (m^2)	Terrace (m^2)
HZBA	Grassland (m^2)	23,215	0
	Land for roads (m^2)	225	225
	Total	23,440	225
QBMA	Grassland (m^2)	22,686	670
	Land for roads (m^2)	81	0
	Total	22,767	670

The transformation rate of terrace by LC is also small. The area of transformed terrace was 895 m^2, accounting for 0.09% of the total area of terrace in the MTLU. The transformed terrace in the HZBA was 225 m^2, accounting for 0.36% of the total area of terrace in the MTLU in this region (Table 6). The transformed terrace in the QBMA was 670 m^2, accounting for 0.07% of the total area of terrace in the MTLU in this region.

Cultivated land is mainly transformed into grassland. The areas of cultivated land converted into grassland or land for roads were 45,901 m^2 and 306 m^2, respectively, accounting for 99.34% and 0.66% of the total transformed cultivated land area. The conversion of cultivated land into roads existed in two LCZs, which was the consequence of roads being widened. In the HZBA, the areas of cultivated land converted into grassland or land for roads were 23,215 m^2 and 225 m^2 (Table 6), respectively, accounting for 99.04% and 0.96% of the total transformed cultivated land area in this region. In the QBMA, the areas of cultivated land converted into grassland or land for roads were 22,686 m^2 and 81 m^2, respectively, accounting for 99.64% and 0.36% of the total transformed cultivated land area in this region.

4. Discussion

The transformation rate of cultivated land, especially terrace, is much less than the abandonment rate of currently cultivated land. A survey of rural households in 262 counties in 29 provinces in China found that 13.5% and 15% of cultivated land was abandoned in 2011 and 2013, respectively [39]. According to the results of an investigation into the abandoned cultivated land in 142 mountainous counties of China, the abandonment rate of cultivated land in Jiangxi Province and Chongqing City reached 34.03% and 32.49% in 2015, respectively [40]. In addition, relevant studies have shown that cultivated land abandonment in mountainous areas is becoming increasingly severe [41]. The abandonment rate of villages in Sichuan Province reached 44.64% during 2016–2018 [43]. However, the transformation rate of cultivated land by LC was 3.08% but that of terrace was only 0.09%. The transformation rate of cultivated land in the HZBA and QBMA was 9.38% and 1.82%, respectively. The transformation rate of terrace in the HZBA and QBMA was 0.36% and 0.07%, respectively.

Firstly, the infrastructure of cultivated land by LC is much better than that of currently cultivated land. Related research has demonstrated that the accessibility of cultivated land was an important factor affecting the abandonment of cultivated land in mountainous areas [44–46]. With the increase in farmland-to-housing distance, the abandonment rate increased. When the distance was greater than 3 km, the abandonment rate was greater than 50% [42]. The "Acceptance specification for land consolidation and rehabilitation projects (TD/T 1013-2013)" stipulates that the accessibility of increased cultivated land is an important aspect of the acceptance of LC [47]. Thus, cultivated land by LC has very good accessibility by road (Figure 5).

Figure 5. Remote sensing images of land consolidation zone before and after land consolidation in Hanzhong City.

Secondly, the quality of cultivated land by LC is much better than that of currently cultivated land. Terrace is the main type of increased cultivated land by LC. Terrace accounted for 92.22% of the total area of increased cultivated land. The soil thickness of terrace is much greater than that of cultivated land. In addition, terrace has functions of soil conservation, water storage, and increasing crop yield [48]. The abandonment rate increased as the quality of cultivated land declined, and the abandonment rate of low-quality cultivated land in Wulong County, Chongqing City, reached more than 46% in 2010 [42]. The high quality of cultivated land by LC prevents cultivated land abandonment.

Thirdly, socioeconomic development in mountainous areas is relatively lagging, and per capita cultivated land area is small. (1) Although China has been promoting urbanization for decades, the urbanization rate in mountainous areas is relatively low. In 2020, the urbanization rates in Hanzhong City, Shaanxi Province, and China were 50.96%, 62.65%, and 63.89%, respectively. From 2010 to 2020, the urbanization rate of Hanzhong City was much smaller than that of Shaanxi Province and China (Figure 6). (2) Young people are moving to cities because of the low incomes earned from farming. According to monitoring reports of China's migrant workers, young people earn about 21% more in cities than in rural areas. In China, more than 50% of people in their 20s and 30s moved to cities from rural areas in 2016 [33]. (3) Women and elderly people are the main labor force in agricultural production. In 2020, the average age of the labor force in agricultural production was about 55 years old in China [49]. There are few off-farm employment opportunities in mountainous areas, especially for the elderly. In other words, many farmers are still engaged in agricultural production and earn a basic income in mountainous areas. (4) Cultivated land is scarce in mountainous areas. For Hanzhong City, the per capita cultivated land area of the rural population at the end of 2011 and 2019 was 1.77 mu and 1.05 mu (1 mu ≈ 666.7 m^2), respectively [50]. That of China's rural population in 2019 was 3.67 mu [51]; and that of the global rural population in 2019 was 6.84 mu, while the per capita cultivated land area was 3.06 mu. Despite the scarcity of cultivated land resources in mountainous areas, the per capita area of cultivated land has not increased due to the abandonment of cultivated land. This is mainly attributed to the poor quality and infrastructure of abandoned cultivated land and its low grain yield. Therefore, high-quality cultivated land after LC with convenient transportation is sustainably used in mountainous areas.

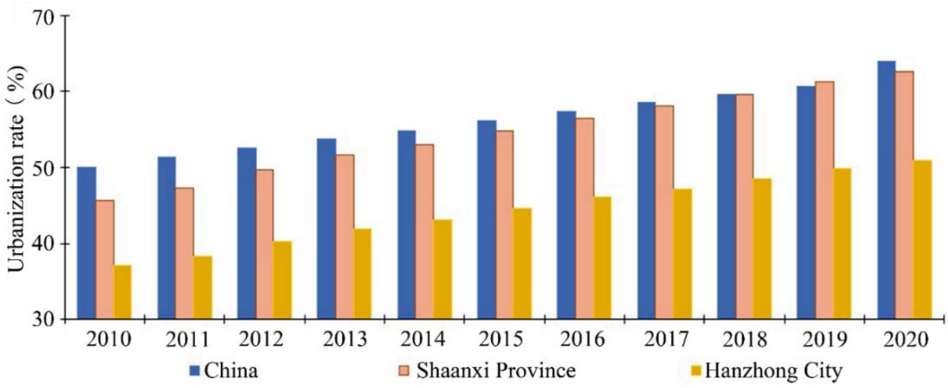

Figure 6. Urbanization rate of China, Shaanxi Province, and Hanzhong City from 2010 to 2020.

Under the background of the abandonment of currently cultivated land in mountainous areas, LC is still a key way for increasing cultivated land area, improving agricultural productivity, increasing farmers' incomes, and promoting rural development in this region.

The socioeconomic development of the HZBA makes the transformation rate of the cultivated land of this region larger than that of the QBMA. The municipal government of Hanzhong City is in the HZBA (Figure 2). In addition, the HZBA is relatively developed within the socio-economy of Hanzhong City. Farmers have more off-farm employment opportunities. The income from off-farm employment is higher than that of crop farming. Thus, the transformation rate of the cultivated land of the HZBA is larger than that of the QBMA.

Cultivated land abandonment is widespread throughout the world [52,53]. Cultivated land abandonment is severe in Europe, and significant differences are found among different countries. For example, in Poland, cultivated land abandonment is 13.9%, and in Portugal, it is 40% [47]. Flooding was an important factor that led to the abandonment of cultivated land in Vietnam [54]. From 2001 to 2012, the abandoned cultivated land in Turkey was mainly distributed in northern mountainous areas, and mountainous areas were the hotspot areas of cultivated land abandonment in Europe [55]. This article found that the transformation rate of cultivated land after LC in mountainous areas, especially for terrace, is very low. Therefore, terrace can be added by LC in mountainous areas to prevent cultivated land abandonment around the world.

The numbers of LCZs with a time interval of MTLU and TPLU of less than 1 year, 1–2 years, and greater than 2 years were 10, 26, and 28, respectively. Their areas of transformed cultivated land after LC were 3775 m^2, 16,306 m^2, and 26,126 m^2, respectively. Their cultivated land areas were 64,374 m^2, 510,372 m^2, and 923,850 m^2, respectively. Thus, their transformation rates were 5.86%, 3.19%, and 2.83%, respectively. This indicates that the transformation rate is decreasing with the extension of time. Further research will be carried out on the use of cultivated land after a longer period in the future.

5. Conclusions

Land consolidation is a vital measure to increase cultivated land in China. The cultivated land in mountainous areas has been severely abandoned. During 2016–2018, the abandonment rate of villages in Sichuan Province reached 44.64%. The abandonment rate increased with the increase in farmland-to-housing distance and more than 50% of cultivated land was abandoned when the farmland-to-housing distance was greater than 3 km. As a result, some experts suggested that LC should be stopped in mountainous areas. Taking 64 land consolidation zones completed in 2016 in the Qinba Mountain Area as research samples, this paper studies the land-use condition of cultivated land by LC. The number of LCZs gradually decreases with the increase in the LCZs' area. The increased cultivated land by LC is mainly distributed in the QBMA, and the increased cultivated land in the QBMA and HZBA is mainly terrace. The increased terrace area accounts for 92.63% and 76.85% of the increased cultivated land area in the QBMA and HZBA, respectively. The transformation rate of cultivated land by LC, especially terrace, is small. The transformation rates of terrace in the HZBA and QBMA are 0.36% and 0.09%, respectively.

Under the background of the abandonment of currently cultivated land in mountainous areas, LC remains an important way to increase cultivated land area and improve the agricultural production condition to increase farmers' income and promote rural development in this region. In the mountainous areas of the world, terrace can be added by LC to prevent cultivated land abandonment.

Author Contributions: Methodology, data curation, writing—original draft preparation, writing—review and editing, J.Z.; conceptualization, supervision, writing—review and editing, C.L. (Chao Li); visualization, X.C.; validation, C.L. (Chenying Luo). All authors have read and agreed to the published version of the manuscript.

Funding: This work was funded by the Social Science Foundation of Shaanxi Province (2022R065), the Major Theoretical and Practical Problems of Philosophy and Social Sciences in Shaanxi Province (2022ND0381), the Fundamental Research Funds for the Central Universities (GK202103126), and the National Natural Science Foundation of China (41801067).

Data Availability Statement: Not applicable.

Acknowledgments: We thank the reviewers and editors for their insightful comments.

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

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