

The poverty dynamics in rural China during 2000–2014:

A multi-scale analysis based on the poverty gap index

REN Qiang^{1,3}, HUANG Qingxu^{1,2}, *HE Chunyang^{1,2}, TU Mengzhao^{1,3},
*LIANG Xiaoying⁴

1. Center for Human-Environment System Sustainability (CHESS), State Key Laboratory of Earth Surface Processes and Resource Ecology (ESPRE), Beijing Normal University, Beijing 100875, China;
2. School of Natural Resources, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China;
3. Academy of Disaster Reduction and Emergency Management, Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China;
4. College of Urban and Environmental Science, Northwest University, Xi'an 710127, China

Abstract: As the largest developing country in the world, China's rural areas face many poverty-related issues. It is imperative to assess poverty dynamics in a timely and effective manner in China's rural areas. Therefore, we used the poverty gap index to investigate the poverty dynamics in China's rural areas during 2000–2014 at the national, contiguous poor areas with particular difficulties and county scales. We found that China made significant achievements in poverty alleviation during 2000–2014. At the national scale, the number of impoverished counties decreased by 1428, a reduction of 97.28%. The rural population in impoverished counties decreased by 493.94 million people or 98.76%. Poverty alleviation was closely associated with economic development, especially with industrial development. Among all 15 socioeconomic indicators, the industrial added value had the highest correlation coefficient with the poverty gap index ($r = -0.458$, $p < 0.01$). Meanwhile, the inequality of income distribution in the out-of-poverty counties has been aggravated. The urban-rural income gap among the out-of-poverty counties increased by 1.67-fold, and the coefficient of variation in rural per-capita income among the out-of-poverty counties also increased by 9.09%. Thus, we argued that special attention should be paid to reducing income inequality for sustainable development in China's rural areas.

Keywords: rural China; poverty; poverty gap index; income inequity; sustainability

1 Introduction

Poverty is a condition characterized by the severe scarcity of basic human needs for food, clothing and shelter (UN, 2017). Obtaining the basic necessities of life is a fundamental as-

Received: 2018-03-05 **Accepted:** 2018-04-13

Foundation: National Basic Research Program of China, No.2014CB954302; National Natural Science Foundation of China, No.41621061, No.41671086

Author: Ren Qiang, PhD Candidate, E-mail: rq_1994@mail.bnu.edu.cn

***Corresponding author:** He Chunyang, Professor, E-mail: hcy@bnu.edu.cn;

Liang Xiaoying, Associate Professor, E-mail: liangxy@nwu.edu.cn

pect of human well-being (Kates, 2011; Wu, 2013). Reducing poverty is the first goal of the 17 Sustainable Development Goals, which were agreed upon by all 193 member states of the United Nations in 2015 (UN, 2015). As the largest developing country in the world, China faces a series of poverty-related problems, such as the large extent of poverty-stricken areas, an enormous rural impoverished population and a high degree of poverty (Liu *et al.*, 2016). China has the world's third largest impoverished population, following India and Nigeria (NBS, 2015). In 2012, the impoverished population in China's rural areas reached 87.34 million, accounting for approximately 10% of the world's impoverished population. In 2016, the Chinese State Council implemented the targeted poverty alleviation to eliminate poverty (TSC, 2016). Therefore, identifying and analyzing the poverty plays a fundamental role in the policy making of the targeted poverty alleviation (Liu *et al.*, 2016; Ren *et al.*, 2018).

Assessing the poverty dynamics in China across scales is of great importance for understanding the characteristics of poverty dynamics comprehensively and formulating targeted policies accordingly (Liu *et al.*, 2017). First, the contiguous poor areas with particular difficulties (CPAPDs) are the main battlefields for poverty alleviation, while the county is the basic unit for assessing and eliminating the poverty (TSC, 2011; TSC, 2016). Analyzing the poverty dynamics among the national, CPAPD and county scales can reveal the full picture and the regional differences of poverty dynamics in China. Second, multi-scale analysis of the poverty dynamics meets the demands of the targeted poverty alleviation in China. The strategy of the targeted poverty alleviation in China requires to assess the poverty dynamics in an accurate manner and establish a hierarchical system for the targeted poverty alleviation (Liu *et al.*, 2016). Thus, a cross-scale analysis will be helpful for the establishment of the hierarchical system.

Two types of measures are currently used to assess poverty dynamics in rural areas. One measure is the multidimensional poverty index, which usually considers the dimensions of economy, education and health. This type of measure can provide a comprehensive evaluation of the poverty dynamics in rural areas (Sen, 1999; Yang *et al.*, 2015; Liu and Xu, 2016). However, there are difficulties in selecting appropriate indicators to represent a given dimension of poverty, also acquiring necessary and comparable data on a long-term basis, and integrating multidimensional indicators in a reasonable way (Liu and Xu, 2016). The other type of measure is the single-dimensional poverty index, such as poverty headcounts and the incidence of poverty, which are recorded in statistical yearbooks. In comparison to the multidimensional poverty index, the single-dimensional poverty index is easier in terms of obtaining the data and is used more widely (Liu and Xu, 2016). Therefore, previous studies primarily used the single-dimensional poverty index to assess the poverty dynamics in China's rural areas on different scales (Glauben *et al.*, 2012; You, 2014). For example, Liu *et al.* (2017) measured the poverty dynamics in China's rural areas at the provincial scale from 1978 to 2014 using poverty headcounts and at the CPAPD scale from 2006 to 2014 using the incidence of poverty. They found that the poverty headcounts and the incidences of poverty decreased substantially during the studied periods. However, the assessment of poverty dynamics in China's rural areas concentrates primarily at the national, provincial or CPAPD scales, and remains inadequate at the county scale due to the difficulties of acquiring long-term data. Nevertheless, the basic unit of poverty assessment and government support in China is the county (Li *et al.*, 2016; Liu and Xu, 2016). Thus, long-term poverty dynamics in China's rural areas should be evaluated comprehensively across different scales using

an effective indicator.

Defined as the difference between the poverty line and per-capita income, the poverty gap index is an effective indicator for assessing poverty dynamics. First, the poverty gap index is one of the most basic indices for assessing poverty in the economic dimension and is widely used in poverty assessment (TSC, 2011; UN, 2015). For example, Ferreira *et al.* (2016) revealed that approximately 890 million people, or 12.7% of the world population, were living in impoverished conditions in 2012 based on the poverty gap index. Ward (2016) found that the incidence of poverty in China's rural areas fell by nearly 60% from 1991 to 2006 based on the \$2/day poverty line. Chen *et al.* (2015) calculated the poverty alleviation performance among the CPAPDs and found that poverty alleviation in the Liupan Mountain area was the highest in 2012. Second, the calculation of the poverty gap index only requires data on per-capita income, which is a basic statistical record that can be obtained at the county level across China. Therefore, the poverty gap index can be used to assess the poverty dynamics in China's rural areas effectively from the county scale to the national scale.

The main objective of this study is to assess the poverty dynamics in China's rural areas from 2000 to 2014 at the national, CPAPD and county scales using the poverty gap index. To achieve this goal, we first calculated the poverty gap index in 2000 and 2014 at the county scale based on the international poverty line. Then, the poverty dynamics in China's rural areas were analyzed on three scales from 2000 to 2014. Finally, we explored the driving forces of poverty alleviation and monitored the changes in the equality of income distribution during the course of poverty alleviation in China's rural areas. Our findings will be helpful for addressing the challenge of poverty alleviation in China.

2 Study area and data

2.1 Study area

The study area is China's mainland, which includes 2217 counties (Figure 1). In 2014, the total population reached 1.45 billion, including rural population of 682 million and urban population of 768 million. The per-capita income in China's rural areas was \$1622.46. The rural impoverished population was 70.17 million, accounting for 7.20% of the total rural population (NBS, 2015).

We analyzed the poverty dynamics in China's rural areas on three scales (i.e., the national, CPAPD and county scales). The CPAPDs are poverty-stricken areas that were identified by the Chinese State Council in 2012 (TSC, 2012). Characterized by concentrated rural impoverished people and a high incidence of poverty, the 14 CPAPDs consist of Liupan Mountain area, Qinba Mountain area, Wuling Mountain area and other 11 areas, which cover 680 counties and involve 21 provincial-level areas, with a total area of $2.84 \times 10^7 \text{ km}^2$. In 2014, there were 248 million people in the CPAPDs, including 161 million people in rural areas, and the per-capita income was \$1177.65 (NBS, 2015). Tibet, Hong Kong, and Macau were excluded from the analysis due to the lack of the population and socioeconomic data at the county scale. Accordingly, we focused on 13 CPAPDs without the CPAPD of Tibet.

2.2 Data

Three types of data were used in this research. First, rural population data at the county scale

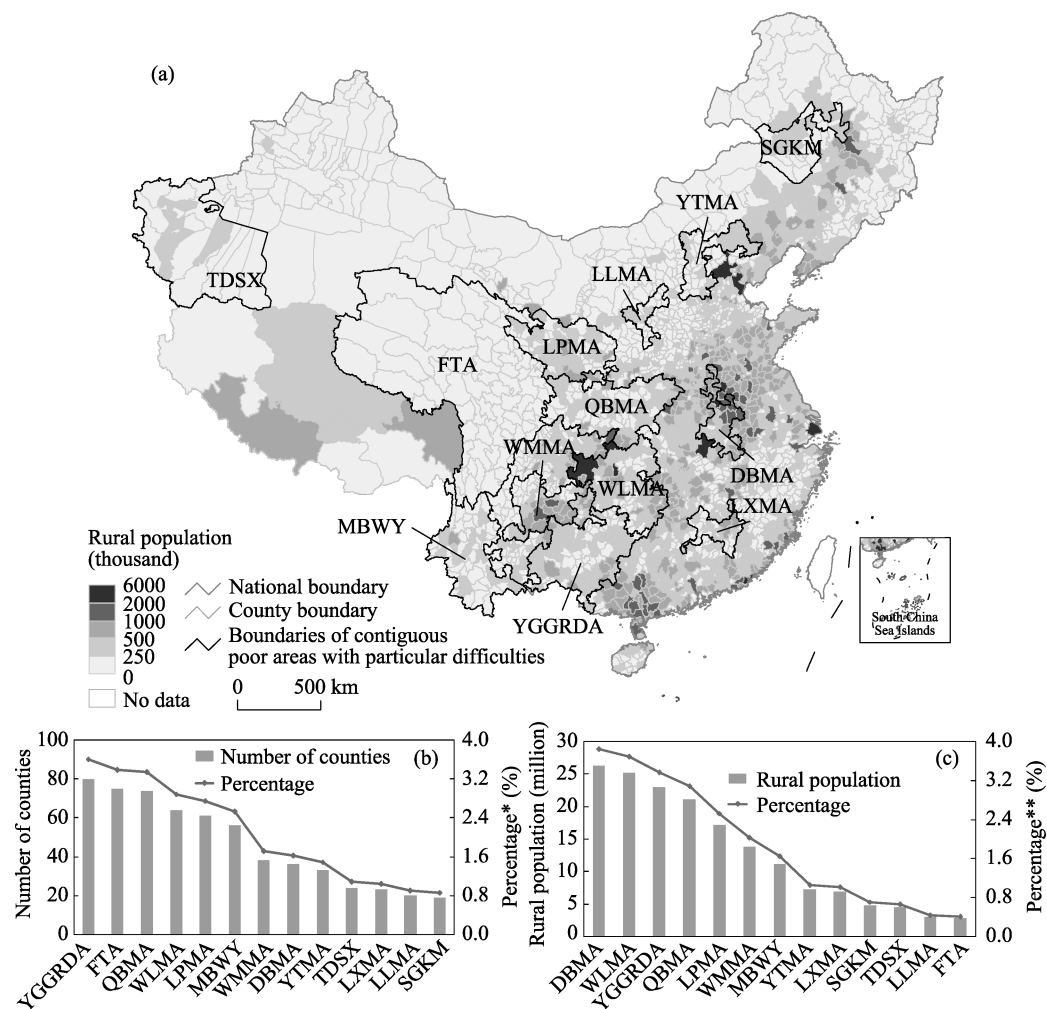


Figure 1 The study area. (a) Spatial pattern of the rural population in China in 2014; (b) The number of counties among the CPAPDs. The percentage is the proportion of the number of counties for each CPAPD to the number of counties in China; (c) Rural population among the CPAPDs. The percentage is the proportion of the rural population for each CPAPD to the rural population in China. Notes: The 13 CPAPDs in China include the three districts of south Xinjiang (TDSX), the four Tibetan-inhabited areas (FTA), the Mountainous borderland of western Yunnan (MBWY), the Liupan Mountain area (LPMA), the Qinba Mountain area (QBMA), the Wuling Mountain area (WLMA), the Wumeng Mountain area (WMMA), the Yunnan-Guizhou-Guangxi rocky desertification area (YGGRDA), the Lvliang Mountain area (LLMA), the Yanshan-Taihang Mountain area (YTMA), the Dabie Mountain area (DBMA), the Luoxiao Mountain area (LXMA), and the south Greater Khingan Mountains (SGKM).

in 2000 and 2014 were obtained from the Statistical Database of Economic and Social Development (SDESD) within the National Knowledge Infrastructure of China (<http://tongji.cnki.net/kns55/>). For the counties with missing rural population data in Heilongjiang, Hebei, Henan, Yunnan and Guizhou in 2014, we estimated the missing data using the rural population projection method developed by the United Nations (UN, 1980; Zhou, 1995). Specifically, we calculated the difference between the urban and rural population growth rates based on the census data in 2000 and 2010 for these counties. Then, with the assumption that the difference between the urban and rural population growth rates remained constant, we estimated the rural population in 2014 based on the total population at the

the county scale. Second, socioeconomic data on the per-capita income of rural households in 2000 and 2014 were collected from the SDESD and county government work reports. Third, auxiliary data, including the administrative boundaries of all CPAPDs and counties in China at a scale of 1:4,000,000, were gathered from the National Geomatics Center of China (<http://ngcc.sbsm.gov.cn>).

3 Methods

3.1 Calculating the poverty gap index

Following the approach developed by Clark *et al.* (1981), we calculated the poverty gap index with the following formula:

$$G^t = Z - I^t \quad (1)$$

where G^t is the poverty gap index in year t . Z refers to the international poverty line. We used the poverty line proposed by the World Bank in 2015, which is \$1.9/day (WB, 2015). I^t is the per-capita income of rural households in year t . We converted the original unit of income, RMB yuan, into US dollars using the exchange rate on January 1, 2014 from the Bank of China (1 US dollar equals 6.0969 RMB yuan) (<http://srh.bankofchina.com/search/whpj/search.jsp>).

To eliminate the impact of price changes on identifying impoverished counties, we applied the price deflator to convert the per-capita income in 2000 to the comparable price in the base year 2014 (Ravallion *et al.*, 2009). The comparable price I_{2014}^{2000} can be expressed as follows:

$$I_{2014}^{2000} = I_{real}^{2000} \cdot D_{2014}^{2000} \quad (2)$$

where I_{real}^{2000} is the price in 2000. D_{2014}^{2000} is the price deflator in the base year 2014. The value of the price deflator can be obtained from the China Statistical Yearbook.

3.2 Analyzing poverty dynamics on multiple scales

According to the Millennium Development Goals of the UN (2015), we divided all counties into groups based on the poverty gap index. When the poverty gap index, G^t , is less than 0, the county is not impoverished. When G^t is equal to or larger than 0, the county is impoverished. Following the methods used by Chen *et al.* (2016), we drew a frequency histogram of the poverty gap indices for all impoverished counties and divided them into three levels (i.e., slight, moderate and extreme poverty) using the equal interval method. The process can be expressed as follows:

$$Class^t = \begin{cases} 1 & 0 \leq G^t < 0.2Z \\ 2 & 0.2Z \leq G^t < 0.4Z \\ 3 & 0.4Z \leq G^t \end{cases} \quad (3)$$

where $Class^t$ is the poverty level in year t . Z refers to the international poverty line. “1,” “2” and “3” represent slight, moderate, and extreme poverty, respectively.

Finally, using the number of identified impoverished counties and the rural populations in

those counties, we analyzed the pattern of impoverished counties in China’s rural areas in 2000 and its changes from 2000 to 2014 at the national, CPAPD, and county scales.

4 Results

4.1 Poverty pattern in 2000

In 2000, nearly two-thirds of counties in China were impoverished (Table 1 and Figure 2a). There were 1468 impoverished counties, accounting for 66.25% of all counties in China. The rural population in the impoverished counties was 500.12 million people, accounting for 64.01% of the total rural population in China. The impoverished counties mainly gathered in the remote mountainous regions, border regions and ethnic minority regions of central and western China, such as the Yunnan-Guizhou-Guangxi rocky desertification area, the four Tibetan-inhabited areas, and the Qinba Mountain area (Table 1 and Figure 2a). The lack of natural endowments, poor geographic condition and fragile ecological environment were the main factors behind the poverty (Liu *et al.*, 2016).

At the national scale, the number of the extremely impoverished counties was the largest, followed by the slightly and moderately impoverished counties. There were 609 extremely impoverished counties, accounting for 41.49% of all impoverished counties. The rural population in the extremely impoverished counties totaled 159.6 million, accounting for 31.92% of the total rural population in those counties. The numbers of slightly and moderately impoverished counties were 490 and 369, respectively, including 183.9 million and 156.6 million people, respectively, for the rural population.

Table 1 The poverty pattern in rural China in 2000

Region	Extremely impoverished counties		Moderately impoverished counties		Slightly impoverished counties		Total	
	Number	Rural population (million)	Number	Rural population (million)	Number	Rural population (million)	Number	Rural population (million)
China	609	159.63	369	156.58	490	183.91	1468	500.12
CPAPDs	444	118.54	108	48.26	46	17.53	598	184.34
YGG RDA	76	19.52	4	1.30	0	0	80	20.83
FTA	57	3.20	11	0.46	6	0.17	74	3.83
QBMA	55	19.04	13	5.20	6	2.97	74	27.21
WLMA	36	13.98	19	13.60	9	4.63	64	32.21
LPMA	54	15.60	5	1.42	1	0.10	60	17.12
MBWY	42	8.95	14	3.68	0	0	56	12.63
WMMA	32	14.00	5	1.66	1	0.53	38	16.19
DBMA	9	5.51	21	16.67	6	3.90	36	26.09
YTMA	19	4.43	6	1.66	7	2.03	32	8.11
TDSX	22	4.36	2	0.29	0	0	24	4.65
LXMA	14	4.52	3	1.07	5	1.75	22	7.34
LLMA	19	3.20	1	0.08	0	0	20	3.28
SGKM	9	2.23	4	1.19	5	1.44	18	4.85

Note: Please refer to Figure 1 for the abbreviations of the CPAPDs in China.

At the CPAPD scale, the percentage of the impoverished counties to all the CPAPD counties was higher than that at the national scale. In 2012, nearly all counties in the CPAPDs were impoverished in 2000 (Table 1 and Figure 2a). There were 598 impoverished counties, accounting for 99.17% of all counties in the CPAPDs. There were 184.34 million people living in impoverished counties, accounting for approximately 99.46% of the total population in the CPAPDs. Among the 13 CPAPDs, the number of impoverished counties exceeded 70 among three CPAPDs (i.e., the Yunnan-Guizhou-Guangxi rocky desertification area, the four Tibetan-inhabited area, and the Qinba mountain area) (Figure 2b). In addition, the rural populations in the four CPAPDs, i.e., the Wuling mountain area, the Qinba mountain area, the Dabie mountain area, and the Yunnan-Guizhou-Guangxi rocky desertification area were larger than 20 million (Figure 2c).

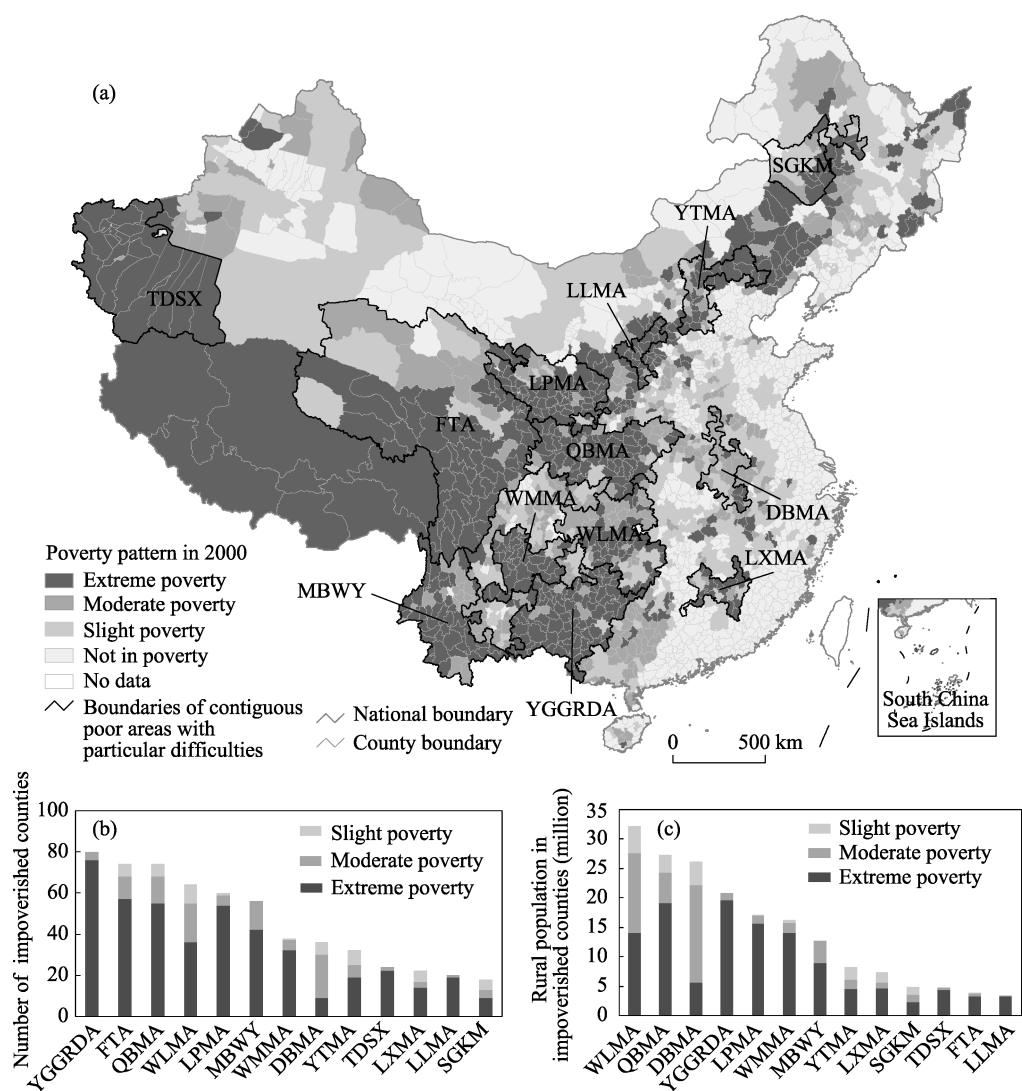


Figure 2 The poverty pattern in China in 2000. (a) The poverty pattern in China; (b) The number of impoverished counties among the CPAPDs; (c) The rural population among the CPAPDs. Notes: Please refer to Figure 1 for the abbreviations of the CPAPDs in China.

At the CPAPD scale, the number of the extremely impoverished counties was the largest, followed by the moderately and slightly impoverished counties. The result also suggested that the degree of poverty was more severe at the CPAPD scale. The number of extremely impoverished counties was 444, accounting for 74.29% of all impoverished counties in the CPAPDs, whereas the proportion of the extremely impoverished counties to the total impoverished counties at the national scale was 41.49%. The rural population in the extremely impoverished counties was 118.54 million. That is to say, 64.31% of the total rural population in the impoverished counties at the CPAPD scale was in the extremely impoverished counties. This number was twice as large as the proportion at the national scale. The numbers of moderately and slightly impoverished counties were 108 and 46, respectively, including 48.26 million and 17.53 million people, respectively, for the rural population.

4.2 Poverty dynamics from 2000 to 2014

China made great strides in poverty alleviation from 2000 to 2014 (Table 2 and Figure 3a). During this period, the number of the impoverished counties declined substantially from 1468 to 40, a 97.28% decrease. The rural population in the impoverished counties decreased from 500.12 million in 2000 to 6.18 million in 2014, with a rate of 98.76%. The out-of-poverty counties were mainly located in southwest China, such as the Yunnan-Guizhou-Guangxi rocky desertification area, the four Tibetan-inhabited areas and the Qinba Mountain area (Table 2 and Figure 3a).

Table 2 The dynamics of poverty alleviation in rural China from 2000 to 2014

Region	Extremely impoverished counties		Moderately impoverished counties		Slightly impoverished counties		Total	
	Number	Rural population (million)	Number	Rural population (million)	Number	Rural population (million)	Number	Rural population (million)
China	608	159.60	362	155.73	458	178.59	1428	493.92
CPAPDs	443	118.51	101	47.41	22	13.12	566	179.04
YGGRA	76	19.52	4	1.30	0	0	80	20.83
FTA	57	3.20	11	0.46	−1	−0.25	67	3.41
QBMA	55	19.04	11	4.88	1	1.27	67	25.19
WLMA	36	13.98	19	13.60	9	4.63	64	32.21
LPMA	54	15.60	4	1.12	−4	−1.10	54	15.62
MBWY	42	8.95	14	3.68	−2	−0.12	54	12.51
WMMA	31	13.97	5	1.66	1	0.53	37	16.16
DBMA	9	5.51	21	16.67	6	3.90	36	26.09
YTMA	19	4.43	6	1.66	7	2.03	32	8.11
TDSX	22	4.36	2	0.29	−1	−0.17	23	4.48
LXMA	14	4.52	3	1.07	5	1.75	22	7.34
SGKM	9	2.23	4	1.19	5	1.44	18	4.85
LLMA	19	3.20	−3	−0.15	−4	−0.80	12	2.25

Note: Please refer to Figure 1 for the abbreviations of the CPAPDs in China.

The numbers of extremely, moderately and slightly impoverished counties decreased at the national scale. The number of extremely impoverished counties decreased by 608, and

their rural population dropped by 159.6 million. The number of moderately and slightly impoverished counties decreased by 362 and 458, respectively, with their rural populations dropping by 155.73 million and 178.59 million, respectively.

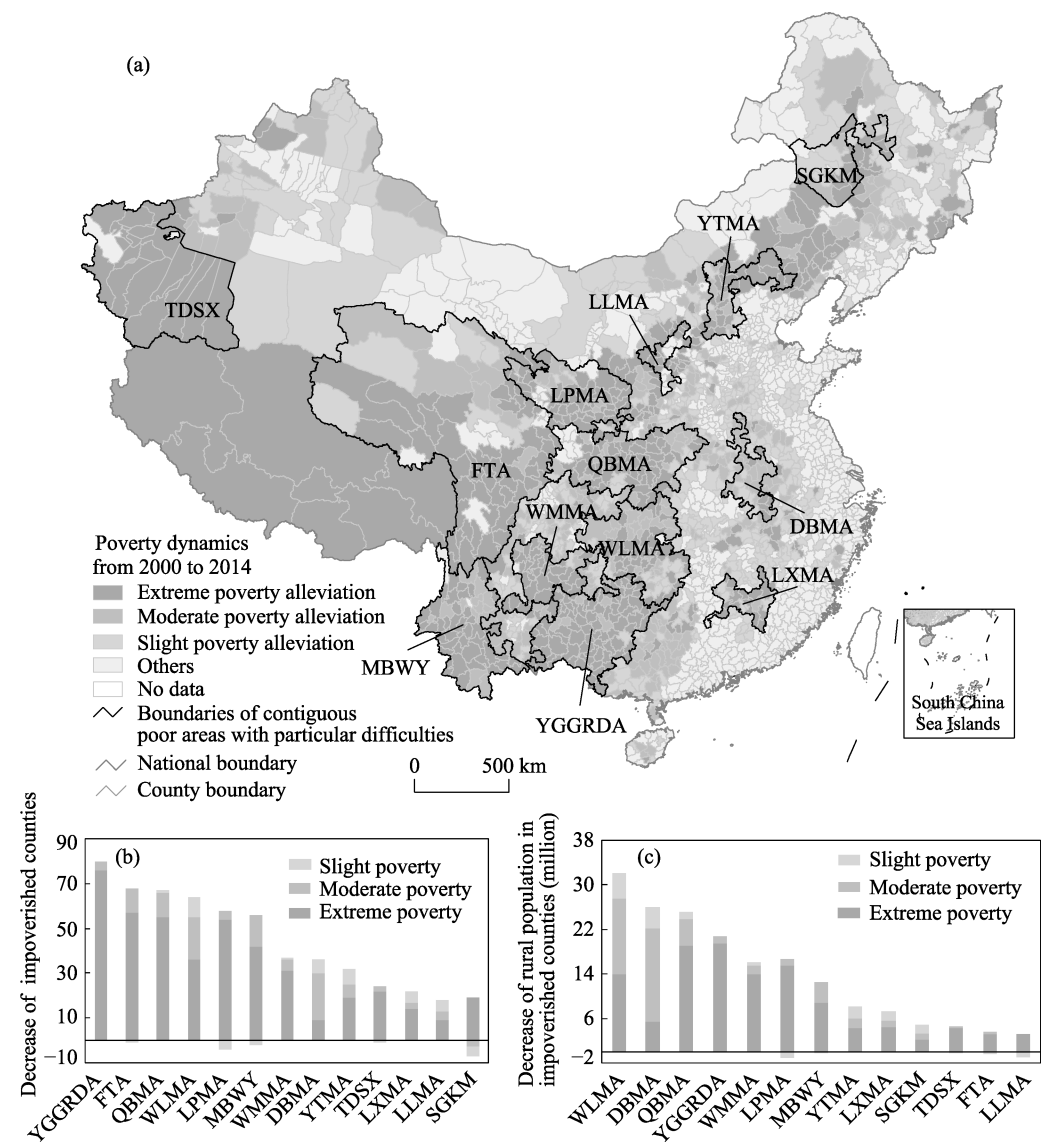


Figure 3 Poverty dynamics in China from 2000 to 2014. (a) Poverty dynamics in China; (b) The decrease in the number of impoverished counties among the CPAPDs; (c) The decrease in the rural population of impoverished counties among the 13 CPAPDs. Note: Please refer to Figure 1 for the abbreviations of the CPAPDs in China.

The number of impoverished counties decreased at the CPAPD scale, although the reduction rate was slightly lower than rate at the national scale. During 2000–2014, the number of impoverished counties declined from 598 in 2000 to 32 in 2014, which represents a 94.65% reduction, nearly 3% lower than the reduction rate at the national scale. During this period, the rural population in the impoverished counties decreased from 184.34 million to 5.30 million, a 97.12% reduction, which was also 1.55% lower than the reduction rate at the national scale. Among the 13 CPAPDs, the number of the out-of-poverty counties reached over

60 among four CPAPDs, i.e., the Yunnan-Guizhou-Guangxi rocky desertification area, the four Tibetan-inhabited areas, the Qinba Mountain area, and the Wuling Mountain area (Table 2 and Figure 3b). Meanwhile, the rural population in the impoverished counties decreased by over 20 million among four CPAPDs, i.e., the Wuling mountain area, the Dabie mountain area, the Qinba mountain area and the Yunnan-Guizhou-Guangxi rocky desertification area (Table 2 and Figure 3c).

The number of extremely, moderately and slightly impoverished counties also decreased at the CPAPD scale, which was similar to the trend at the national scale. The number of extremely impoverished counties decreased by 443, with the rural population dropping by 118.51 million. The numbers of moderately and slightly impoverished counties dropped by 101 and 22, with their rural populations decreasing by 47.41 million and 13.12 million, respectively. However, the number and the rural population of the moderately and slightly impoverished counties increased in some CPAPDs. For example, the number of moderately and slightly impoverished counties in the Lvliang Mountain area increased by 3 and 4. Accordingly, the rural population of the moderately and slightly impoverished counties in this CPAPD increased by 0.15 million and 0.80 million, respectively.

5 Discussion

5.1 The assessment is legitimate based on the poverty gap index

Selecting an appropriate poverty line plays an important role in understanding poverty dynamics (Ravallion *et al.*, 2009). Currently, in addition to the \$1.9/day poverty line we used in this study, there are several widely used poverty lines (Dzanku *et al.*, 2015; Ferreira *et al.*, 2016). For example, the World Bank proposed the \$1/day and \$1.25/day poverty lines in 1990 and 2008, respectively (WB, 1990; Ravallion *et al.*, 2009). The Chinese government also proposed several national poverty lines, which were equivalent to \$0.30/day, \$0.55/day, and \$1.03/day (NBS, 2015). However, when using different poverty lines, assessments of poverty dynamics varied greatly (Table 3). For instance, the difference in the number of impoverished counties between the \$0.30/day poverty line and the \$1.9/day poverty line was 1465 in 2000, and the corresponding difference in rural population was 499.44 million people. Similarly, the difference in the number of the out-of-poverty counties between the two poverty lines was 167 from 2000 to 2014, and the difference in rural population was 45.70 million people. The \$1.9/day poverty line set by the World Bank considers residents' expenditures for meeting their minimum food demands among the world's poorest countries (Klasen *et al.*, 2016). This poverty line was also adopted in the United Nations poverty assessment and the Sustainable Development Goals (Ferreira *et al.*, 2016). Thus, we chose the \$1.9/day poverty line to evaluate poverty dynamics in China.

Meanwhile, following the method proposed by Liu and Xu (2016), we validated our results by comparing the differences in the poverty gap index between the impoverished counties and the non-impoverished counties designated by the Chinese government and between counties within the CPAPDs and counties outside the CPAPDs (Table 4). The results indicated that the impoverished counties identified by the poverty gap index were consistent with the impoverished counties designated by the national government. Specifically, the differences in the poverty gap index between the impoverished counties and the

non-impovertised counties designated by the Chinese government were highly significant. The t-test yielded t values of -38.83 in 2000 and -43.32 in 2014 ($p < 0.01$) between the two groups of counties. The differences in the poverty gap index between the counties within the CPAPDs and the counties outside the CPAPDs were also highly significant ($p < 0.01$) from 2000 to 2014. The t values were -40.51 in 2000 and -38.19 in 2014.

Table 3 The impacts of different poverty lines on poverty evaluation

Poverty lines	Value (\$/day)	Differences between different poverty lines and the \$1.9/day poverty line in evaluating poverty					
		2000		2014		2000–2014	
		Number of impoverished counties	Rural population (million)	Number of impoverished counties	Rural population (million)	Number of impoverished counties	Rural population (million)
The Chinese poverty line (2000–2007)	0.30	1465	499.44	40	6.20	1425	493.15
The Chinese poverty line (2008–2010)	0.55	1443	495.65	40	6.20	1403	488.35
The Chinese poverty line in 2011	1.03	987	381.16	39	6.17	948	349.85
The \$1.00/day international poverty line	1	1033	396.04	39	6.17	994	367.93
The \$1.25/day international poverty line	1.25	753	301.73	36	6.02	717	250.88

Note: We used the average value of the poverty lines from 2000 to 2007 to represent the poverty line during this period because the fluctuation of the poverty lines was small. Similarly, we used the average value of the poverty lines from 2008 to 2010 to represent the poverty line during the corresponding period.

In addition, we also found the rural population in the impoverished counties was significantly correlated with the rural impoverished population recorded in the Poverty Monitoring Report of Rural China at the CPAPD scale (Figure 4). Specifically, the correlation coefficient between the rural population in the impoverished counties and the rural impoverished population in 2010 was 0.79 ($p < 0.01$). The correlation coefficient between the decrease in the rural population in the impoverished counties and the decrease in rural impoverished population from 2010 to 2014 was 0.71 ($p < 0.01$). Thus, the rural population in the impoverished counties can reflect the pattern and dynamics of poverty in China effectively.

Table 4 Validation of the poverty gap index for identifying the impoverished counties designated by the government

Year	Indicators	Poverty gap index			
		Impoverished counties	Non-impovertised counties	Counties within the CPAPDs	Counties outside the CPAPDs
2000	Mean	-2.70	-340.76	-6.27	-344.87
	Standard deviation	785.13	1693.44	688.20	1709.29
	t-value	Significantly different, $t = -38.83^{**}$		Significantly different, $t = -40.51^{**}$	
2014	Mean	-708.56	-1482.68	-744.92	-1481.56
	Standard deviation	1499.10	3615.26	1843.68	3635.89
	t-value	Significantly different, $t = -43.32^{**}$		Significantly different, $t = -38.19^{**}$	

$^{**}p < 0.01$

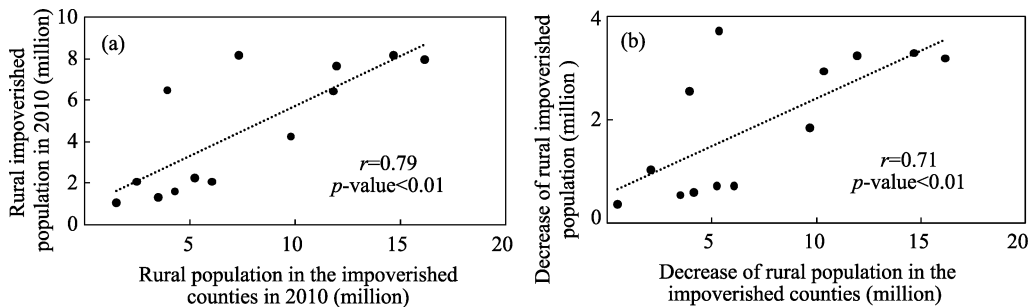


Figure 4 The relationship between the rural population in the impoverished counties and the rural impoverished population recorded in the Poverty Monitoring Report of Rural China. (a) The relationship between the rural population in the impoverished counties and the rural impoverished population in 2010; (b) The relationship between the decrease of the rural population in the impoverished counties and the decrease of rural impoverished population from 2010 to 2014. The dotted lines were the linearly fitted trend lines.

5.2 Economic development was the major factor associated with poverty alleviation in China

Previous studies have confirmed that economic development, infrastructure construction and demographic structure optimization can promote the poverty alleviation effectively. For example, Ravallion *et al.* (2007) revealed that economic development was the major factor of the poverty alleviation in China. Albert *et al.* (2010) found that infrastructure construction was helpful for income growth and poverty alleviation. Chen *et al.* (2016) confirmed that demographic structure optimization had the positive impacts on poverty alleviation. To verify the relationships between poverty alleviation and these factors quantitatively, following the method used by Tao *et al.* (2015) and Li *et al.* (2016), we chose 15 socioeconomic indicators from three dimensions (i.e., economy, infrastructure and population) and analyzed their relationships with the poverty gap index using Pearson's correlation analysis. The results suggested that poverty alleviation was closely associated with economic development, especially with industrial development (Table 5). At the national scale, the correlation coefficients between the poverty gap index and the economic indicators were between -0.340 and -0.458 ($p < 0.01$), which were higher than the correlation coefficients between the poverty gap index and most other indicators. Among all economic indicators, the correlation between the poverty gap index and industrial added value was the highest, with a correlation coefficient of -0.458 ($p < 0.01$).

At the CPAPD scale, the results also showed that the poverty gap index was significantly correlated with most economic indicators. Among all economic indicators, the correlations between the poverty gap index and five indicators (for example, the gross national product, the agricultural added value and the industrial added value) passed the significance test of 0.01, with correlation coefficients ranging from -0.119 to -0.231 . The correlation between the poverty gap index and public finance income passed the significance level of 0.05, with a correlation coefficient of -0.097 . Among all economic indicators, the correlation between the poverty gap index and industrial added value was the highest, with a correlation coefficient of -0.231 ($p < 0.01$). However, the correlation coefficients between the poverty gap index and socioeconomic indicators at the CPAPD scale were smaller than the corresponding correlation coefficients at the national scale. This indicated that the driving factors of poverty alleviation were different among CPAPDs, and place-based poverty alleviation strate-

gies were needed for different CPAPDs.

Table 5 Relationships between the poverty gap index and the selected socioeconomic indicators

Dimension	Indicator	Correlation coefficient at the national scale	Correlation coefficient at the CPAPD scale
Economy	Gross national product	−0.456**	−0.178**
	Agricultural added value	−0.317**	−0.159**
	Industrial added value	−0.458**	−0.231**
	Service added value	−0.367**	−0.060
	Total output value of large-scale industrial enterprises	−0.399**	−0.119**
	Number of large-scale industrial enterprises	−0.340**	−0.164**
	Government revenue	−0.391**	−0.097*
Infrastructure	Fixed asset investment	−0.356**	−0.085**
	Loans of banking system at year end	−0.310**	−0.035
	Government expenditure	−0.216**	−0.065
	Fixed phone subscribers	−0.141**	−0.087*
	The number of hospital beds	−0.082**	−0.003
	The number of social welfare institution beds	−0.136**	−0.134**
Population	Urban population	−0.076**	−0.040
	Rural population	0.103**	0.072**

*significant at the 0.05 level, ** significant at the 0.01 level

5.3 The inequality of income distribution was exacerbated during poverty alleviation in China

The equality of income distribution raises long-term socioeconomic and political concerns and is beneficial for regional sustainable development (Rodríguez-Pose and Hardy, 2015; Chen *et al.*, 2016; Zhou *et al.*, 2016). Following the study performed by You and Zhang (2017), we further evaluated the changes in the equality of income distribution during the course of poverty alleviation in China by using the urban-rural income gap and the coefficient of variation in per-capita rural income among the out-of-poverty counties from 2000 to 2014.

We found that the inequality of income distribution among the out-of-poverty counties was aggravated (Table 6). During poverty alleviation in China from 2000 to 2014, the urban-rural income gap of the out-of-poverty counties widened from \$1025.60 in 2000 to \$2736.47 in 2014, a 1.67-fold increase. The inequality of income distribution was more severe at the CPAPD scale. The urban-rural income gap among the out-of-poverty counties in the CPAPDs increased from \$1061.03 in 2000 to \$2899.83 in 2014, an approximately three-fold increase.

In terms of the coefficient of variation in per-capita rural income, the results also indicated that the inequality of income distribution among the out-of-poverty counties was exacerbated during the course of poverty alleviation from 2000 to 2014. The coefficient of variation in per-capita rural income increased from 0.22 in 2000 to 0.24 in 2014, with an increase of 9.09%. At the CPAPD scale, the coefficients of variation in per-capita rural income among four CPAPDs (i.e., the three districts of south Xinjiang, the Liupan Mountain area, the Yunnan-Guizhou-Guangxi rocky desertification area and the Wuling Mountain area)

increased by 0.21, 0.04, 0.01 and 0.01, respectively, with growth rates of 75.00%, 16.18%, 7.14% and 4.55%, respectively.

Table 6 Changes in the urban-rural income gap among the out-of-poverty counties from 2000 to 2014

Region	Urban-rural income gap		Changes in the urban-rural income gap	
	2000 (US dollar)	2014 (US dollar)	2000–2014 (US dollar)	Rate of change (%)
China	1025.60	2736.47	1710.87	166.83%
CPAPDs	1061.03	2899.83	1838.80	173.29%
TDSX	900.29	3505.22	2604.93	289.33%
FTA	922.93	3362.53	2439.60	264.35%
WLMA	1245.88	4019.26	2773.38	222.59%
LLMA	765.63	2417.95	1652.32	215.79%
LPMA	945.89	2579.67	1633.78	172.71%
WMMA	983.29	2535.22	1551.77	157.81%
YGGRDA	1071.86	2718.59	1646.74	153.63%
DBMA	841.90	2125.34	1283.44	152.44%
QBMA	934.74	2257.38	1322.48	141.48%
MBMA	1191.75	2848.66	1656.91	139.03%
LXMA	991.49	2257.70	1266.22	127.71%
YTMA	988.37	2016.60	1028.23	104.04%
SGKM	805.00	1610.98	805.98	100.12%

Note: Please refer to Figure 1 for the abbreviations of the CPAPDs in China.

5.4 Policy implications

In rural China, national anti-poverty policies play a critical role in poverty alleviation (Liu *et al.*, 2016; Lo *et al.*, 2016; Rogers, 2014) (Table 7). In 2000, the Chinese government implemented “China’s Rural Poverty Alleviation and Development Outline (2000–2010)” (TSC, 2001), which was followed by “China’s Rural Poverty Alleviation and Development Outline (2010–2014)” (TSC, 2011). With the goal of lifting the country’s rural impoverished population out of poverty by 2020, these outlines stressed that the government should reduce poverty by promoting economic development and implementing poverty assessment and government support at the county scale. In accordance with previous studies (Liu *et al.*, 2017), our study showed that China made great strides toward poverty alleviation from 2000 to 2014 under the guidance of these outlines. From 2000 to 2014, the number of impoverished counties decreased from 1468 to 40, representing a reduction of 97.28%. The rural population in impoverished counties also decreased from 500.12 million to 6.18 million, representing a reduction of 98.76%.

From January 2014 onward, the anti-poverty campaign in China started to focus on poverty alleviation at the individual scale and the inequality of income distribution during poverty alleviation. For example, in December 2013, the State Council released “Suggestions for Poverty Alleviation in Rural Areas by the Mechanism Innovation,” which stated that the Chinese government should implement targeted poverty alleviation measures at the village scale. Our results also supported that economic poverty at the county level had been almost

eliminated in rural China, with only 40 counties remaining impoverished in 2014. However, the inequality of income distribution in the out-of-poverty counties was exacerbated. The urban-rural income gap among the out-of-poverty counties increased by 1.67-fold, and the coefficient of variation in per-capita rural income among the out-of-poverty counties also increased by 9.09%. Thus, we suggest that targeted poverty alleviation measures should be implemented at the individual scale. In addition, special attention should be paid to reducing income inequity to realize sustainable development in China’s rural areas.

Table 7 Major poverty alleviation policies in China

Policy	Publication date	Key scale	Targets
China’s Rural Poverty Alleviation and Development Outline (2001–2010)	2001	County	Lifting the rural impoverished population out of poverty at the county scale through economic development
China’s Rural Poverty Alleviation and Development Outline (2010–2020)	2011	County	Lifting the rural impoverished population out of poverty at the county scale through economic development, especially in the impoverished counties designated by the Chinese government and the counties in the CPAPDs
Suggestions about Poverty Alleviation in Rural Areas by the Innovation of Mechanism	2013	Village and household	Lifting the rural impoverished population out of poverty at the individual scale using targeted poverty alleviation measures

5.5 Future perspectives

This study has several limitations. First, the poverty gap index can measure poverty from the economic dimension and cannot be used to measure poverty conditions from other dimensions (e.g., the environmental and social dimensions). Second, we counted the rural population in impoverished counties due to the limitations of the data. We cannot assess poverty status at the individual scale. However, our findings on poverty alleviation dynamics are useful for addressing the poverty challenge in China, considering that they are consistent with previous research (Liu *et al.*, 2017).

In the future, multidimensional poverty indices can be used to assess poverty dynamics from the environmental, economic, and social dimensions (Alkire and Santos, 2014; Alkire and Seth, 2015). Field surveys can be undertaken in the poverty-stricken areas to analyze poverty dynamics at the individual scale. Meanwhile, we can also use remotely sensed images and large-scale data to assess long-term, large-scale poverty dynamics (Jean and Burke, 2016).

6 Conclusions

We used the poverty gap index to investigate the poverty dynamics in China’s rural areas during 2000–2014 at the national, CPAPD and county scales. We found China made great strides in poverty alleviation during this period. In 2000, the number of impoverished counties was 1468, accounting for two-thirds of the counties in China. The rural population in the impoverished counties was 500.12 million, which represented approximately 64% of the total rural population in China. From 2000 to 2014, the number of impoverished counties decreased by 97.28%, while the rural population in the impoverished counties decreased by

98.76%. At the CPAPD scale, the number of impoverished counties declined from 598 in 2000 to 32 in 2014, which represents a 94.65% reduction. During this period, the rural population in the impoverished counties decreased from 184.34 million to 5.30 million, a 97.12% reduction. However, there were still some impoverished counties in some CPAPDs in 2014, such as the Lvliang Mountain area, the Qinba Mountain area and the four Tibetan-inhabited areas, to which special attention should be paid.

The study confirmed that economic development was a major factor that affected poverty alleviation. At the national scale, the correlation coefficients between the poverty gap index and the economic indicators ranged from -0.340 to -0.458 ($p < 0.01$), which were higher than the correlation coefficients between the poverty gap index and most other indicators. Among all economic indicators, the correlation between the poverty gap index and industrial added value was the highest, with a correlation coefficient of -0.458 ($p < 0.01$). At the CPAPD scale, economic development was still the major factor that affected poverty alleviation. The correlation coefficients between the poverty gap index and the economic indicators ranged from -0.060 to -0.231 ($p < 0.01$). However, the correlation coefficients at the CPAPD scale were lower than the corresponding correlation coefficients at the national scale, which indicated that different strategies were needed for the poverty alleviation in a given CPAPD.

The inequality of income distribution was intensified during poverty alleviation between 2000 and 2014 in China. The urban-rural income gap among the out-of-poverty counties increased by 1.67-fold, and the coefficient of variation in per-capita rural income among the out-of-poverty counties also increased by 9.09%. Thus, we suggest that special attention should be paid to reducing income inequity to realize sustainable development in China's rural areas.

References

- Alkire S, Santos M E, 2014. Measuring acute poverty in the developing world: Robustness and scope of the multidimensional poverty index. *World Development*, 59(1): 251–274.
- Alkire S, Seth S, 2015. Multidimensional poverty reduction in India between 1999 and 2006: Where and how? *World Development*, 72: 93–108.
- Chen J, Wang Y, Wen J *et al.*, 2016. The influences of aging population and economic growth on Chinese rural poverty. *Journal of Rural Studies*, 47: 665–676.
- Chen W, Feng D, Chu X, 2015. Study of poverty alleviation effects for Chinese fourteen contiguous destitute areas based on entropy method. *International Journal of Economics and Finance*, 7(4): 89–98.
- Dzanku F M, Jirström M, Marstorp H, 2015. Yield gap-based poverty gaps in rural Sub-Saharan Africa. *World Development*, 67: 336–362.
- Ferreira F H G, Chen S, Dabalen A *et al.*, 2016. A global count of the extreme poor in 2012: Data issues, methodology and initial results. *The Journal of Economic Inequality*, 14(2): 141–172.
- Fu Bojie, Yu Dandan, Lv Nan, 2017. An indicator system for biodiversity and ecosystem services evaluation in China. *Acta Ecologica Sinica*, 32(2): 341–348. (in Chinese)
- Glauben T, Herzfeld T, Rozelle S *et al.*, 2012. Persistent poverty in rural China: Where, why, and how to escape? *World Development*, 40(4): 784–795.
- Jean N, Burke M, Xie M *et al.*, 2016. Combining satellite imagery and machine learning to predict poverty. *Science*: 353(6301): 790.
- Kates R W, 2011. What kind of a science is sustainability science? *Proceedings of the National Academy of Sciences of the United States of America*, 108(49): 19449–19450.
- Klasen S, Krivobokova T, Greb F *et al.*, 2016. International income poverty measurement: Which way now? *The Journal of Economic Inequality*, 14(2): 199–225.
- Li J, Liu Z, He C *et al.*, 2016. Are the drylands in northern China sustainable? A perspective from ecological footprint dynamics from 1990 to 2010. *Science of The Total Environment*, 553: 223–231.

- Li Y, Su B, Liu Y, 2016. Realizing targeted poverty alleviation in China: People's voices, implementation challenges and policy implications. *China Agricultural Economic Review*, 8(3): 443–454.
- Liu Y, Liu J, Zhou Y, 2017. Spatio-temporal patterns of rural poverty in China and targeted poverty alleviation strategies. *Journal of Rural Studies*, 52: 66–75.
- Liu Y, Xu Y, 2016. A geographic identification of multidimensional poverty in rural China under the framework of sustainable livelihoods analysis. *Applied Geography*, 73: 62–76.
- Liu Yansui, Zhou Yang, Liu Jilai, 2016. Regional differentiation characteristics of rural poverty and targeted poverty alleviation strategy in China. *Bulletin of Chinese Academy of Sciences*, 3: 269–278. (in Chinese)
- Lo K, Xue L, Wang M, 2016. Spatial restructuring through poverty alleviation resettlement in rural China. *Journal of Rural Studies*, 47: 496–505.
- NBS (National Bureau of Statistics), 2015. Poverty Monitoring Report of Rural China. Beijing: China Statistics Press. (in Chinese)
- Park A, Wang S, 2010. Community-based development and poverty alleviation: An evaluation of China's poor village investment program. *Journal of Public Economics*, 94(9/10): 790–799.
- Ravallion M, Chen S, 2007. China's (uneven) progress against poverty. *Journal of Development Economics*, 82(1): 1–42.
- Ravallion M, Chen S, Sangraula P, 2009. Dollar a day revisited. *The World Bank Economic Review*, 23(2): 163–184.
- Ren Qiang, He Chunyang, Huang Qingxu *et al.*, 2018. The poverty dynamics in the agro-pastoral transitional zone in northern China: A multiscale perspective based on the poverty gap index. *Resources Science*, 40(2): 404–416. (in Chinese)
- Rodriguez-Pose A, Hardy D, 2015. Addressing poverty and inequality in the rural economy from a global perspective. *Applied Geography*, 61: 11–23.
- Rogers S, 2014. Betting on the strong: Local government resource allocation in China's poverty counties. *Journal of Rural Studies*, 36: 197–206.
- Sen A, 1999. Development as Freedom. Oxford: Oxford University Press.
- Stephen C, Richard H, David U, 1981. On indices for the measurement of poverty. *The Economic Journal*, 91(362): 515–526.
- Tao S, Fang J, Zhao X *et al.*, 2015. Rapid loss of lakes on the Mongolian Plateau. *Proceedings of the National Academy of Sciences of the United States of America*, 112(7): 2281–2286.
- TSC (The State Council), 2001. China's Rural Poverty Alleviation and Development Outline (2001–2010). http://www.gov.cn/gongbao/content/2011/content_2020905.htm. (in Chinese)
- TSC (The State Council), 2011. China's Rural Poverty Alleviation and Development Outline (2011–2020). http://www.gov.cn/gongbao/content/2011/content_2020905.htm. (in Chinese)
- TSC (The State Council), 2012. The List of Counties in the Contiguous Poor Areas with Particular Difficulties. http://www.cpad.gov.cn/art/2012/6/14/art_624_14991.html. (in Chinese)
- TSC (The State Council), 2016. The Conference on Poverty Alleviation and Development Was Held in Beijing. http://www.cpad.gov.cn/art/2011/11/29/art_624_16820.html. (in Chinese)
- UN (United Nations), 1980. Patterns of Urban and Rural Population Growth. New York: Oxford University Press.
- UN (United Nations), 2015. Transforming Our World: The 2030 Agenda for Sustainable Development, United Nations, New York
- UN (United Nations), 2017. Poverty. <http://www.unesco.org/new/en/social-and-human-sciences/themes/international-migration/glossary/poverty/>.
- Ward P S, 2016. Transient poverty, poverty dynamics, and vulnerability to poverty: An empirical analysis using a balanced panel from rural China. *World Development*, 78: 541–553.
- WB, 1990. World Development Report 1990: Poverty. New York: Oxford University Press.
- WB, 2015. Ending Poverty and Sharing Prosperity: Progress and Policies. The World Bank.
- Wu J, 2013. Landscape sustainability science: Ecosystem services and human well-being in changing landscapes. *Landscape Ecology*, 28(6): 999–1023.
- Yang Zhen, Jiang Qi, Liu Minhui *et al.*, 2015. Multi-dimensional poverty measure and spatial pattern of China's rural residents. *Economic Geography*, 35(12): 148–153. (in Chinese)
- You H, Zhang X, 2017. Sustainable livelihoods and rural sustainability in China: Ecologically secure, economically efficient or socially equitable? *Resources, Conservation and Recycling*, 120: 1–13.
- You J, 2014. Poverty dynamics in rural China revisited: Do assets matter? *Journal of Economic Policy Reform*, 17(4): 322–340.
- Zhou S, Liu Y, Kwan M P, 2016. Spatial mismatch in post-reform urban China: A case study of a relocated state-owned enterprise in Guangzhou. *Habitat International*, 58: 1–11.
- Zhou Yixing, 1995. Urban Geography. Beijing: The Commercial Press. (in Chinese)