

Identifying the Static and Dynamic Relationships Between Rural Population and Settlements in Jiangsu Province, China

ZHU Zhiqing¹, KONG Xuesong^{1,2}, LI Yajing¹

(1. School of Resource and Environmental Sciences, Wuhan University, Wuhan 430079, China; 2. Key Laboratory of Geographic Information System, Ministry of Education, Wuhan University, Wuhan 430079, China)

Abstract: Rapid urbanization has triggered large rural population floating into cities, which in turn affects rural human-land relationships. The actual human-land relationship involves the coupling level of a time point and dynamic change of a time interval. However, few studies have identified the rural human-land relationship from these two perspectives. This study combined static coupling analysis with a dynamic decoupling model to analyze the relationships between rural population and settlements from 2009 to 2018 in Jiangsu Province, China. Although the static coupling degree in Jiangsu Province was relatively high, the decoupling analysis found that the rural human-land relationship in most counties was uncoordinated. There were 11 combination types based on the coupling and decoupling relationships. The most common two types (accounting for 76.74%) were recession decoupling with high-level coupling and strong decoupling with high-level coupling. Although the majority of counties had a high-level coupling degree, an uncoordinated change in rural population and rural settlements was observed in these counties. Counties with relatively reasonable human-land relationships accounted for only 12.79% of the total. The combination features for each type were identified and differential policies were proposed for optimizing human-land relationship in rural areas. This study would contribute to our understanding of the multiple relationships between rural population and settlements involved in different patterns and processes, and expect to provide theoretical and methodological support for promoting rural revitalization and sustainable development in practice.

Keywords: rural settlements; population; human-land relationship; coupling and decoupling; rural revitalization

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1 Introduction

Global urbanization has absorbed a large number of rural laborers and brings regional prosperity (Davis, 2016; Tappe and Nguyen, 2019). However, global urbanization also causes widespread rural decline, and a large area of rural land has been converted into urban land (Huang et al., 2015; Liu, 2018), the population density of rural areas is generally lower than before (Yang et al., 2016), which has led to an increase in idle rural settlements and a serious shortage of high-quality rural labor

resources (Pribadi and Pauleit, 2015; Li and Li, 2017; Zhao and Zou, 2017). The vitality of rural population and community is gradually decreasing. How to address the issues of rural recession and imbalance of human-land relationships in rural areas has become a common challenge around the world (Liu and Li, 2017).

China has achieved great socioeconomic and institutional success since 1978 and now is undergoing a rapid urbanization process (Long et al., 2011; Liu et al., 2013). From 1978 to 2018, the urban population of China increased from 172.45 million to 831.37 million, and the

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Corresponding author: KONG Xuesong. E-mail: xuesongk@whu.edu.cn

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urbanization rate increased from 17.92% to 59.58% (National Bureau of Statistics of China, 2019). Although rapid urbanization has promoted economic development, improved industrial structure and created more employment opportunities, a series of issues should not be overlooked in the process (Zhou and Peng, 2012; Chen et al., 2016). One of the most serious issues is the imbalance human-land relationship in rural areas (Cao and Guan, 2007; Gao and Ma, 2015). On the one hand, a large number of rural laborers are pouring into the city, and the problem of hollow villages is becoming increasingly serious (Sun et al., 2011; Ye, 2018). On the other hand, with rapid economic development, the demand for improving housing condition is gradually increasing, and the total area of rural settlements shows a growth trend inconsistent with the reduction of the rural population (Wang et al., 2018). To effectively improve the rural human-land relationship, China's central government implemented a land use policy of 'increasing vs. decreasing balance' in 2008 (Long et al., 2012; Hui et al., 2015), which played an important role in activating the vacant rural land and provided land supply for urban areas. However, the anabatic disharmonious human-land relationship is still a tough issue in rural China. Balancing rural human-land relationship has been an important political goal in China (Wu et al., 2019). The point is how to formulate differentiated policy based on identifying the actual human-land relationship in different regions.

The human-land relationship has always been the focus of geographical research (Li et al., 2017). In general, the term 'land' broadly refers to natural environment. Natural environment provides living conditions for human beings, and human activities in turn affect nature, or even partially transform nature (Jesse et al., 2018; Chen et al., 2019). In most relevant studies, the human-land relationship is narrowly defined as the balance between population change and land use change. Numerous studies pay more attention to the human-land relationship in urban development (Luo et al., 2018a; Sapena and Ruiz, 2019). It is a worldwide phenomenon that urban land expands faster than urban population increase (Angel et al., 2011). López et al. (2001) proved that linear regression between urban and population growth offered a more robust prediction of urban growth in Morelia, Mexico. Due to the correlation between urban and rural socioeconomic development, rural human-land relationship gradually attract attention in re-

cent years. Existing studies explored the spatiotemporal changes and driving forces of rural settlements. Changes in the natural environment (Zhou et al., 2013), urbanization (Irwin and Bockstael, 2002; Tan and Li, 2013), housing construction (Bański and Wesółowska, 2010; Peng et al., 2013), social transformation (Kiss, 2000), and road traffic accessibility (Yang et al., 2019) have all been identified as the driving forces of rural settlement evolution. The scholars have tried to reveal the relationships between rural settlement change and variation of population size. Shi et al. (2016) analyzed the spatiotemporal changes in rural settlements and their decoupling relationship with rural registered population in the middle basin of the Heihe River in China. Cai et al. (2019) explored the characteristics and coupling types between rural population and rural settlements in 340 prefecture-level cities of China. These studies provided an important window for understanding the change mechanism of rural human-land relationships.

Floating population has an important impact on rural human-land relationship in the process of urbanization (Luo et al., 2018b). The flexibility of population movement increases the uncertainty of human-land relationship. It means that rural human-land relationship could be overstated or understated at a time point. Analogously, the existing proportional relationship between rural population and settlements should not be ignored. Both the status quo and dynamic changes are equally important for understanding the actual human-land relationships in rural areas. However, up until now, the existing studies either focus on the static human-land analysis at a time point, or on dynamic human-land analysis at a given time interval. Little attention was paid on the combination analysis of static and dynamic relationships between rural population and settlements, and the findings are insufficient in providing valuable reference for improving rural human-land relationship.

To fill this research gap, this study combined static coupling analysis with a dynamic decoupling method to analyze the relationships between rural population and settlements from 2009 to 2018 in Jiangsu Province, China. This study intended to address the following key issues: 1) What are the spatiotemporal characteristics between rural population and settlements at different scales during 2009–2018? 2) How do coupling and decoupling occur between rural population and settlements during 2009–2018? 3) What are the linkages between

static coupling and dynamic decoupling and how to improve rural human-land relationship according to the linkages? We believe the findings would contribute to our understanding of the multiple relationships between rural population and settlements, and provide decision supports for governments and rural planners in formulating differentiation policies of rural revitalization.

2 Study Area and Data

2.1 Study area

Jiangsu Province is located on the China's eastern coastal center and the lower reach of the Yangtze River. The terrain is dominated by plains. Jiangsu Province consists of 13 prefecture-level cities, all of which are among the top 100 cities in China. By the end of 2018, the permanent resident population of Jiangsu Province was 80.51 million, with a rural population of 24.47 million. Located in the Yangtze River Economic Zone, Jiangsu Province is prosperous in its economy, education and culture. The total GDP of Jiangsu Province was 9259.54 billion yuan (RMB), and the urbanization rate was 69.61% in 2018. However, there were significant internal differences in Jiangsu Province. In 2018, the per

capital GDP of southern Jiangsu region was 160 747 yuan (RMB), while the per capital GDP of central and northern Jiangsu regions was only 115 360 yuan (RMB) and 70 369 yuan (RMB), respectively, which directly brought about the differences in urban-rural land use (Jiangsu Provincial Bureau of Statistics of China, 2019). Compared with central and northern Jiangsu, the scale of urban settlements in southern Jiangsu was larger; however, the per capita rural settlements in the southern Jiangsu was much lower than that in central and northern Jiangsu (Fig. 1). The area of per capital rural settlements of southern, central and northern Jiangsu were 322.74 m², 491.66 m², and 466.52 m² in 2018, respectively, which exceeded the national standards (no more than 150 m² per capita). It indicated that the rural settlements were inefficiently used in Jiangsu Province. The difference in regional economy brings the imbalance of human-land relationships in rural areas in Jiangsu Province. The significant differentiation among regions means Jiangsu Province is a representative region for identifying the static and dynamic relationships between rural population and settlements, and would provide valuable information for governments in formulating reasonable human-land policies of rural revitalization.

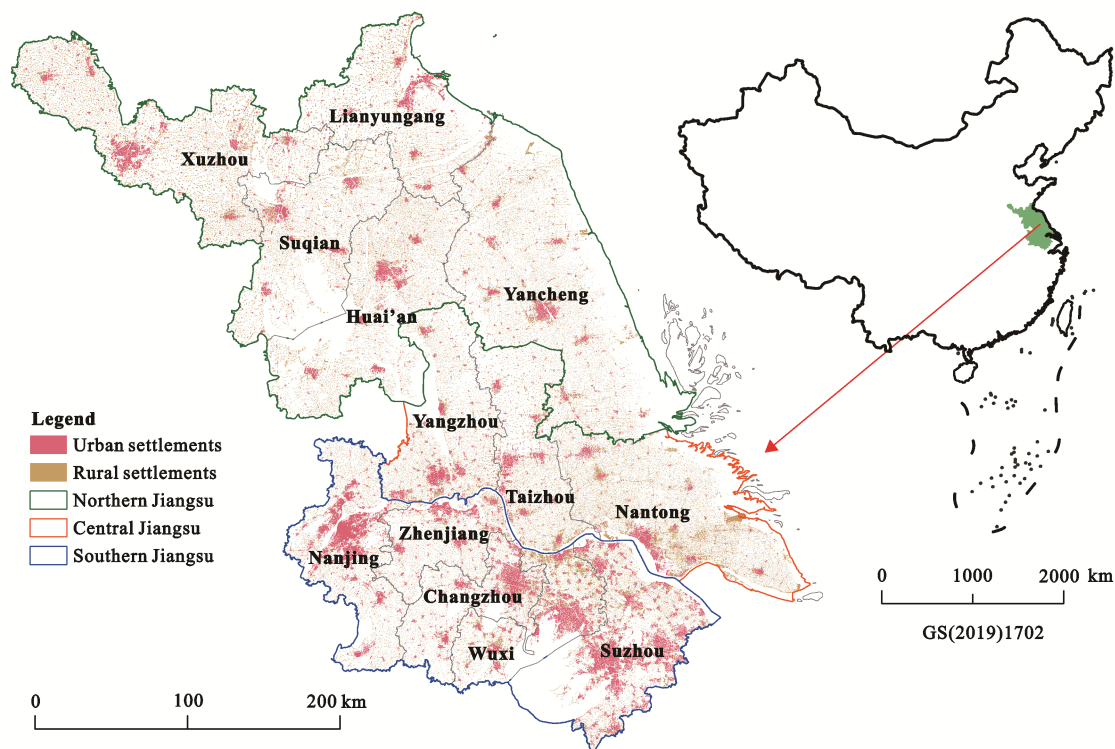


Fig. 1 Location of study area

2.2 Data sources

In consideration of the consistency and accuracy of land use data since the second national land survey in 2009, this study chose 2009 and 2018 as time cut-off points for rural human-land analysis. The land-related data were extracted from the Jiangsu Land Use Change Survey Database (LUCSD) in 2009 and 2018, which were acquired from Jiangsu Provincial Department of Natural Resources. The population-related data were derived from the statistical yearbooks issued by the Jiangsu Provincial Bureau of Statistics and statistical bulletins of the national socioeconomic development of each county (Jiangsu Provincial Bureau of Statistics of China, 2010; 2019). There are 104 counties in Jiangsu Province. After excluding 9 counties with incomplete data, we selected the remaining 95 counties for analyzing the rural human-land relationship. Among the 95 counties, nine counties without rural population in 2009 were excluded in static coupling and dynamic decoupling analysis. Therefore, the remaining 86 counties were identified as study units at the county level.

3 Methodology

A two-level (patch level and county level) analysis was introduced in this study (Fig. 2). At the patch level, the spatiotemporal changes of rural settlements were analyzed to identify the loss and gain of rural settlements, which were further integrated into the county level based on the LUCSD. The static coupling and dynamic decoupling between rural population and settlements were analyzed at the county level. The combination types for coupling and decoupling were identified in 86 counties, and finally we explored the relationship between rural population and settlements involved in

different patterns and processes, which would provide important decision supports for optimizing rural human-land relationship in practice.

3.1 Static coupling analysis between rural population and settlements

The static coupling model is widely used to identify the relationship between two or more interactions (Kong et al., 2019). By using the static coupling model, the state, level and internal synergy of rural population and settlements can be effectively revealed. The coupling evaluation for population and land can be divided into two categories: single factor evaluation, in which a single dimension of indicators is selected for evaluation; and comprehensive factor evaluation, in which multiple factors are selected for weighting evaluation. In this study, the change rates of rural population and settlements are measured by a single dimension index. Based on the existing studies (Yang et al., 2015; Ye et al., 2018), the coupling formulas for rural population and settlements are determined as follows:

$$P_i = \frac{PR_i}{PT_i} \tag{1}$$

$$L_i = \frac{LR_i}{LR_i + LU_i + LT_i} \tag{2}$$

$$C_i = 2 \times \left\{ \frac{P_i \times L_i}{(P_i + L_i)^2} \right\}^{\frac{1}{2}} \tag{3}$$

where P_i and L_i respectively denote the proportion of rural population to total population and rural settlements to total construction land area of administrative unit i ;

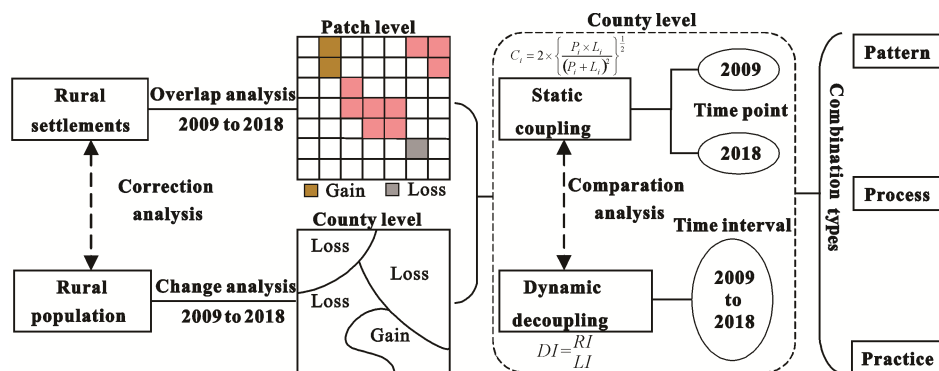


Fig. 2 Framework illustrating the research methodology

PR_i and PT_i represent rural population and total population of administrative unit i , respectively; LR_i , LU_i and LT_i refer to the area of rural settlements, urban land area, and town land area of administrative unit i , respectively; and C_i is the static coupling degree. Referring to relevant studies (Xiong et al., 2014), the coupling degree can be divided into four stages, namely, the low-level coupling stage (0 to 0.3), the antagonistic stage (0.3 to 0.5), the running-in stage (0.5 to 0.8), and the high-level coupling stage (0.8 to 1).

3.2 Decoupling analysis between rural population and settlements

The term ‘decoupling’ comes from the field of physics, meaning that the response relationship between two or more related physical quantities does not exist. Later, the decoupling theory was gradually introduced into other research fields (Camagni et al., 2002; Xu and Yang, 2019). Based on the basic methods and ideas of the decoupling theory, this paper constructed the decoupling relationship model between rural population change and rural settlement change in Jiangsu Province with reference to Tapio’s decoupling mode (Tapio, 2005). The calculation formula of the model is as follows:

$$DI = \frac{RI}{LI} \quad (4)$$

where DI is the elasticity index; RI is the change rate of the rural population; LI is the change rate of rural settlements. According to the characteristics of RI and LI , the decoupling types are clearly delineated in Fig. 3.

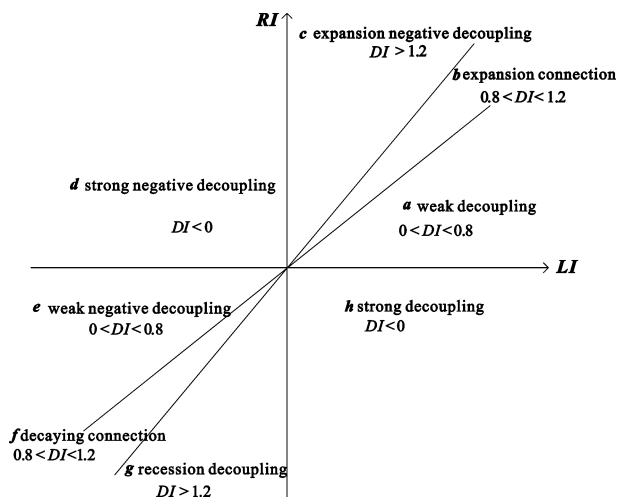


Fig. 3 The decoupling types between the rural population and settlements

When the changes of rural population and settlement reverse, the following results are identified: 1) in the h zone, the changes of rural population and settlements are in an extremely uncoordinated state, and 2) in the d zone, rural population increase coexisting with rural settlements decrease, indicating a trend of intensive and rational use of rural settlements. When the changes of rural population and settlements are coincident in directions, and the values of DI range from 0.8 to 1.2, expansion connection and decaying connection are observed in zone b and f , respectively. Although the values of DI range from 0 to 0.8 in both zones a and e , weak negative decoupling in zone e is superior to weak decoupling in zone a from the perspective of intensive land use. Analogously, expansion negative decoupling in zone c is better than recession decoupling in zone g .

3.3 Identification of combination types for coupling and decoupling

The static coupling between rural population and settlements reflects the status quo of rural human-land relationship, while the dynamic decoupling shows the trend of rural development. A single dimension analysis of static coupling or dynamic decoupling is insufficient to explore the actual rural human-land relationship. In this paper, we combined the static coupling and dynamic decoupling for exploring the relationship between rural population and settlements. The static coupling stage is divided into four stages, and the decoupling relationships are divided into eight types; therefore, a 4×8 combining matrix can be formed theoretically. Due to the lack of some coupling or decoupling types, the final combination types could be different in case study.

4 Results

4.1 Spatiotemporal changes of rural population and settlements

During 2009 to 2018, a discordant relationship was found that the loss of the rural population coexisted with the increase in rural settlement area (Fig. 4). The rural population decreased from 34.68 million in 2009 to 24.47 million in 2018, while the total area of rural settlements increased by 139.00 km² synchronously. Fortunately, a decrease of rural settlements was found during 2016 to 2018, which attributed to the consolidation and reconstruction of rural settlements in recent years.

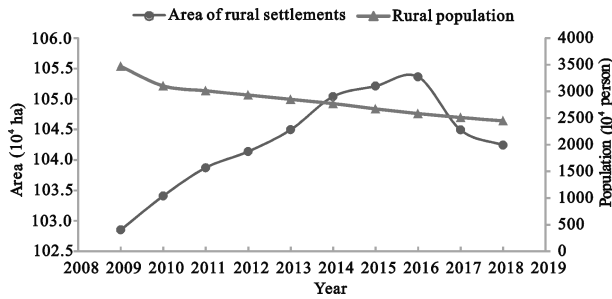


Fig. 4 Changes of rural settlements and rural population during 2009–2018 in Jiangsu Province

Jiangsu Province is undergoing rapid urbanization process. A large number of rural surplus labor flow into the city. Meanwhile, rural residents have strong desire to rebuild or expand their original settlements with the improvement of household income. In the context of urban-rural dual structure, the uncoordinated change between rural population and rural settlements is bound to occur in Jiangsu Province, which is also a common phenomenon in rural China.

Fig. 5 shows the changes in both rural settlements and population during 2009 to 2018 at the county level. It was observed that the amount of counties with rural settlements loss was roughly equal to that of counties with rural settlements gain. However, rural population

loss occurred in the majority of counties, and greater rural population loss was mainly distributed in the southern and central Jiangsu, especially in counties with higher urbanization rates. Additionally, rural population increased in 4 counties locating within the city proper of Nanjing, Yangzhou and Huai'an. The consistent trends of changes in rural population and rural settlements were found in 46 counties; among which, 38 counties were found an expected greater loss rates of rural population than those of rural settlements. Meanwhile, it was important to note that rural population loss coexisted with rural settlements increase in the remaining 40 counties. There was an urgent call for optimizing rural human-land relationship in these counties.

We overlaid the land use map of 2009 and 2018 to acquire the spatiotemporal change of rural settlements at the patch level. The distribution of rural settlements was scattered in space, which led to a chaotic dynamic changes at first glance. To better present the spatial change of rural settlements, we classified the changes into five levels at a 10 km × 10 km grid. It was found that the changes of rural settlements were obvious in areas along the Yangtze River. The expansion of rural settlements presented three main patterns: dot (Fig. 6a), block (Fig. 6b), and band (Fig. 6c). The dot expansion

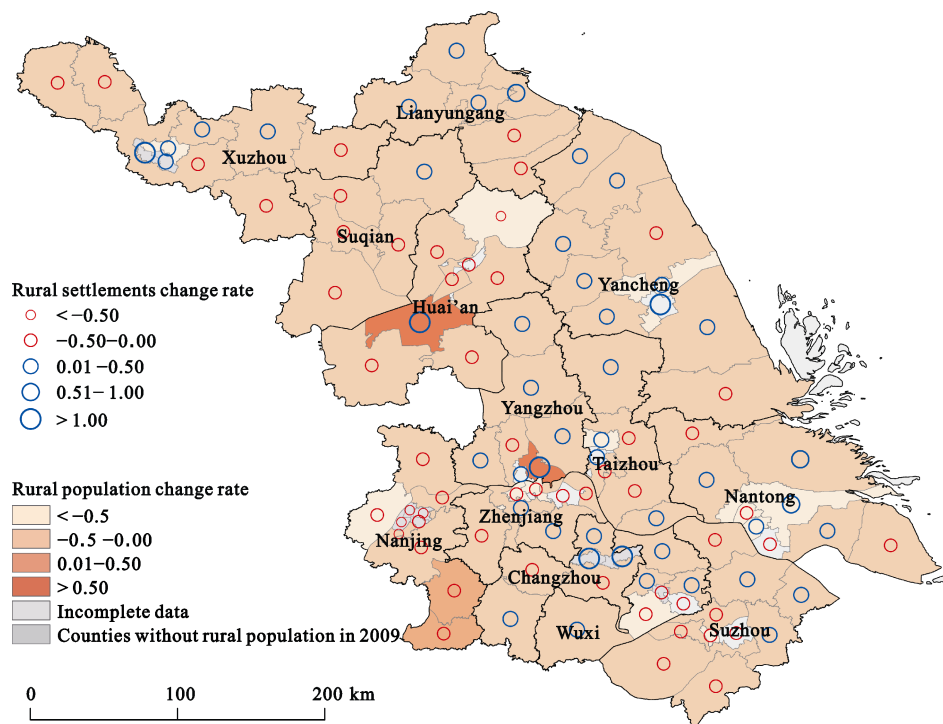


Fig. 5 Changes of rural population and settlement at the county level during 2009–2018

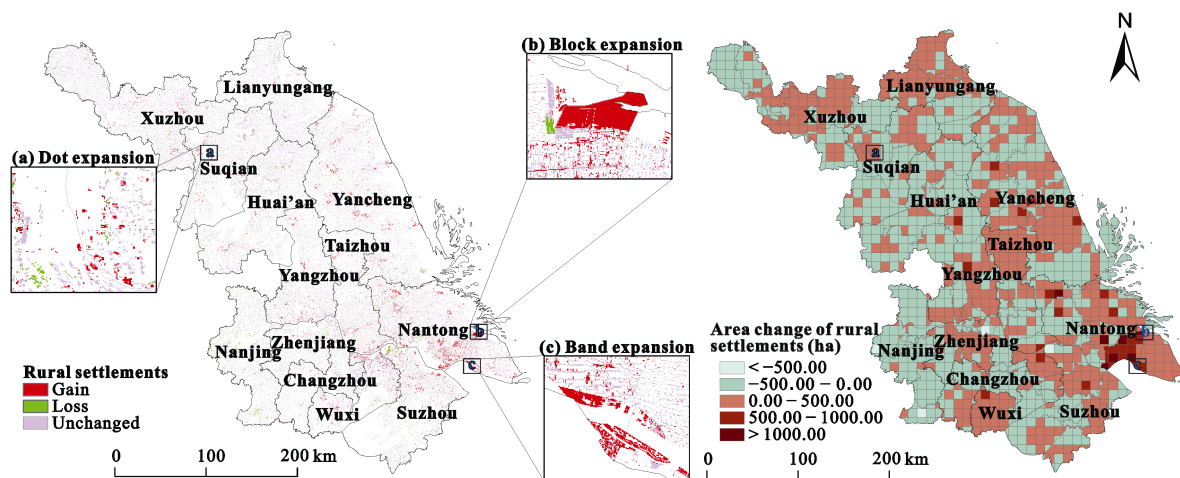


Fig. 6 Spatiotemporal changes of rural settlements at the patch level (left) and the grid level (right) during 2009–2018

was the most typical pattern, which was highly in accord with the overall scatter pattern of rural settlements in Jiangsu Province. The band expansion was mainly distributed in the south of Nantong along the Yangtze River. The block expansion was mainly distributed in the southern Jiangsu, which was characterized by an outward expansion along the original rural settlements and was more likely occurred in the urban fringe areas. At the grid level, the amount of grids with settlements loss was greater than that of grids with settlements gain; however, the grids with settlements gain were more congregated in space, especially in Nantong and Suzhou. Overall, the dynamic loss and gain of rural settlements in southern Jiangsu were more remarkable than those in northern Jiangsu.

4.2 Static coupling and decoupling between rural population and settlements

The static coupling between rural population and settlements at the regional level was presented in Table 1.

The coupling degrees of southern, central, and northern Jiangsu were close to 0.98 in 2009 and 0.95 in 2018. It was hard to identify the regional difference by the static coupling degree, which was in a stage of high-level coupling in both 2009 and 2018. However, a slight decrease of the coupling degree was found during 2009 to 2018. The reason could be that a large number of rural population flowed into the city driven by the urbanization process, whereas their rural settlements did not convert into urban land synchronously, thus leading to a decrease in the level of static coupling. The static coupling degrees of southern Jiangsu in 2009 and 2018 were slightly higher than the other two regions. Both the share of rural settlements and the share of rural population in southern Jiangsu were lowest among the three regions. To some extent, it indicated that there was a good socioeconomic transformation of rural areas and the rural human-land relationship came into a relatively stable period in southern Jiangsu.

Table 1 Static coupling degree of Jiangsu Province in 2009 and 2018

Regions	2009			2018		
	Share of rural population	Share of rural settlements	Coupling degree	Share of rural population	Share of rural settlements	Coupling degree
Southern Jiangsu	0.32	0.45	0.99	0.23	0.39	0.97
Central Jiangsu	0.48	0.73	0.98	0.33	0.69	0.94
Northern Jiangsu	0.55	0.76	0.99	0.37	0.71	0.95
Jiangsu Province	0.44	0.64	0.98	0.30	0.59	0.95

The static coupling degree between rural population and rural settlements of each county in 2009 and 2018 is shown in Fig. 7. The static coupling degree decreased in 59 counties and increased in 10 counties; additionally, there were 17 counties with invariable coupling degrees. The number of counties in the high-level coupling stage decreased from 81 in 2009 to 77 in 2018, while the number of counties in the low-level coupling stage increased three during 2009 to 2018. The changes of static coupling degree indicated that there was a relatively stable rural human-land relationship in the majority of counties. These coupling changes were consistent with the findings in southern, central, and northern Jiangsu. However, there was a discordant trend of the changes of rural population and settlements in some counties within the main urban areas, such as Gusu District in Suzhou and Chongchuan in Nantong. The reason was that rural population decreased even faster than rural settlements loss, which in turn broke the coordination state between rural population and settlements.

The differentiation of decoupling was obvious among counties. It can be found that LI and RI of the most counties in Jiangsu Province were in the domain of $[-0.5, 0.5]$. Due to the general decline in rural population, the majority of counties were located in e to h zones presented in Fig. 3. There were 38 counties locating in h zone, where indicated a worsening relationship between rural population and settlements, and should be given priority in land use consolidation of rural settle-

ments.

To better illustrate the differentiation of decoupling between rural settlements and population at the county level, we calculated the elasticity index according to the decoupling model presented in Formula (4). Six kinds of decoupling relationships were identified in Jiangsu Province (Fig. 8). Among them, strong decoupling (38 counties) and recession decoupling (37 counties) were the most important two types, which accounted for 87.21% in Jiangsu Province. Strong decoupling was featured by rural population decrease and rural settlements increase, which implied the worst state of human-land relationship in current rural China. To some extent, it was totally different from the static coupling at a given time point (2009 or 2018). The type of strong decoupling was widely distributed in Yangzhou, Lianyungang, and Wuxi. Although both population loss and settlement decrease were observed in the type of recession decoupling, the pace of settlements decrease lagged behind the pace of population loss. The type of recession decoupling was observed in Xuzhou, Huai'an, and Suzhou, which meant that the relationship between rural population and settlements became more and more incongruous over time and should be given priorities in rural population return and retreat of homestead. Fortunately, strong negative decoupling was found in two counties located in Nanjing, where featured by rural population increase and rural settlements decrease.

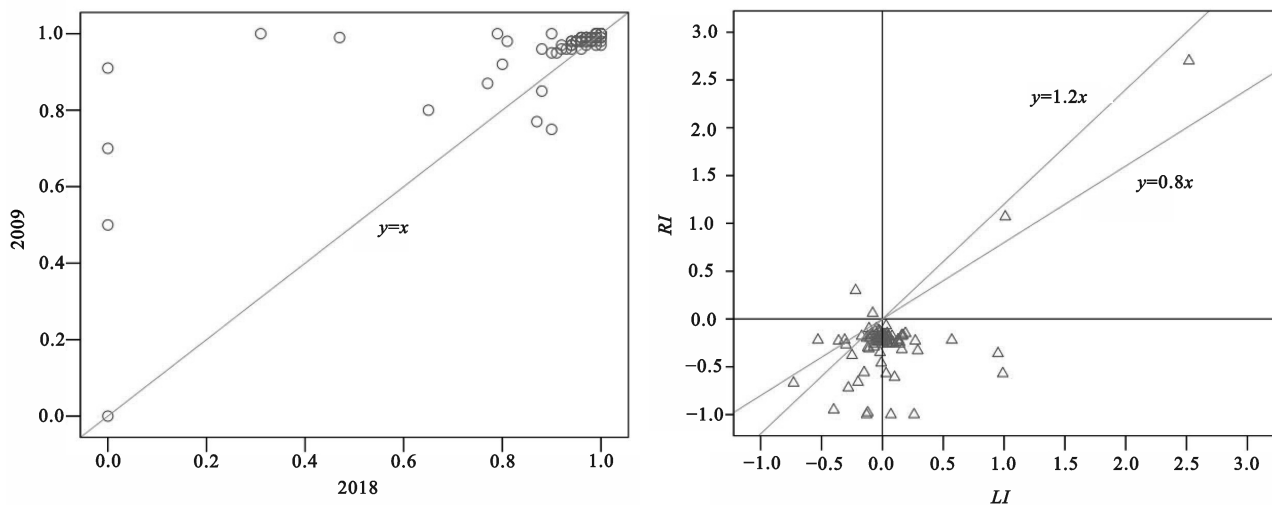


Fig. 7 Scatter diagram of static coupling (left) and decoupling (right) of Jiangsu Province

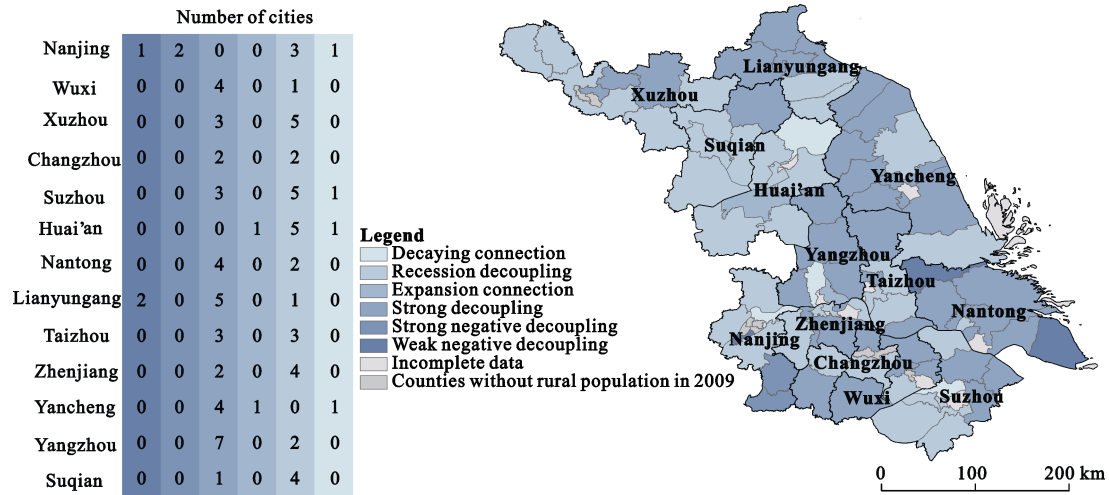


Fig. 8 Decoupling types in Jiangsu Province during 2009–2018

4.3 Combination analysis of coupling and decoupling

We combined the classification of the static coupling degree in 2018 with the decoupling types during 2009–2018 to identify the multiple relationships between rural population and settlements. Eleven combination types were identified at the county level in Jiangsu Province (Fig. 9); among which, recession decoupling and high-level coupling (RH), and strong decoupling and high-level coupling (SH) were two major types. There were 66 counties (accounting for 76.44%) belonging to RH (33) and SH (33), which indicated that the changes in the rural population and settlements in these counties were uncoordinated during 2009 to 2018. However, the static coupling analy-

sis showed a high-level coupling between rural population and settlements in these 66 counties. Rural human-land polices could be misguided if only consider the static coupling analysis. Additionally, the multiple relationships between rural population and settlements were well reflected by the combination analysis. For example, recession decoupling were further classified into 4 sub-types: RH (33), recession decoupling and antagonism (RA, 2), recession decoupling and low-level coupling (RL, 1), and recession decoupling and running-in (RR, 1) in Jiangsu Province. Therefore, we can draw the conclusion that the combination of static coupling and dynamic coupling is superior to the single coupling or decoupling analysis.

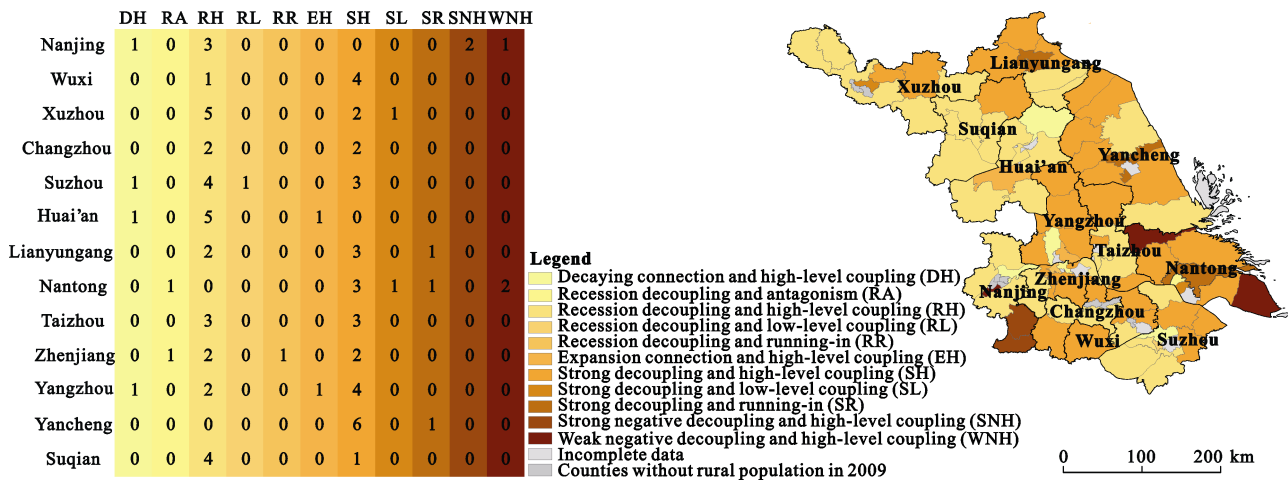


Fig. 9 Combination types of coupling and decoupling in Jiangsu Province

The combination types and features were summarized in Table 2. The 11 combination types were classified into two categories: incoordination and coordination. All the combination types including strong decoupling or recession decoupling indicated an incongruous change relationship between rural population and settlements. There were 75 counties (accounting for 87.21%) in the incongruous process. The remaining 11 counties were all in the high-level coupling stage and showed a harmonious process during 2009 to 2018.

Differentiated policies could be implemented according to different types and features. For the strong decoupling, the policies should focus on developing rural industry to attract rural labor return and promoting intensive utilization of rural settlements, especially in the central and northern Jiangsu with large per capita rural settlements. For the recession decoupling, it was suggested that the government should strengthen village merging and agricultural scale production, and broaden rural employment channels. For the coordination types including decaying connection and high-level (DH), expansion connection and high-level (EH), the strong negative decoupling and high-level (SNH), and weak

negative and high-level (WNH), priorities should be given in improving the habitat environment of village and building beautiful countryside featured by thriving agriculture, intensive land use, and excellent ecological environment. The combination features provide important information for policymaker to implement differential rural revitalization policies.

5 Discussion

5.1 Underlying causes linked to the imbalance human-land relationship in rural China

Rural settlements increase coexisting with population loss is a common phenomenon in rural China. Evidence from Jiangsu Province shows that the changes of rural population and settlements could be totally different among regions. For example, the counties with strong decoupling and running-in (SR) were all distributed in central and northern Jiangsu, while SNH was observed in southern Jiangsu. The imbalance human-land relationship means irrational structure or inconsistent change between rural population and settlements. The high-level coupling degree indicated that there was a

Table 2 Combination types and features of rural human-land relationship

Pattern		NC	Process and feature	Practice
Decoupling	Coupling			
Strong	High-level	33	Rural settlements increase coexisting with population loss, coordination in 2018 & incoordination during 2009–2018	Developing rural industry to attract rural labor return
	Running-in	3	Rural settlements increase coexisting with population loss, preliminary coordination in 2018 & incoordination during 2009–2018	Controlling the construction of new rural settlements and farmland renovation
	Low-level	2	Rural settlements increase coexisting with population loss, incoordination in 2018 & incoordination during 2009–2018	Village demolition and urban village renovation
Recession	High-level	33	Population loss exceeding rural settlements decrease, coordination in 2018 & preliminary incoordination during 2009–2018	Improving the habitat environment and central village construction
	Running-in	1	Population loss exceeding rural settlements decrease, preliminary coordination in 2018 & preliminary incoordination during 2009–2018	Improving the habitat environment and village merging
	Antagonism	2	Population loss exceeding rural settlements decrease, preliminary incoordination in 2018 & preliminary incoordination during 2009–2018	Village merging and agricultural scale production
	Low-level	1	Population loss exceeding rural settlements decrease, incoordination in 2018 & preliminary incoordination during 2009–2018	Village demolition and agricultural scale production
Decaying connection		4	Rural settlements decrease coexisting with population loss in comparable pace, coordination in 2018 & preliminary coordination during 2009–2018	Developing rural industry to attract rural labor return
Expansion connection	High-level	2	Population gain coexisting with rural settlements increase in comparable pace, coordination in 2018 & coordination during 2009–2018	Central village construction
Strong negative		2	Rural settlements decrease coexisting with population gain, coordination in 2018 & coordination during 2009–2018	Improving the habitat environment of village
Weak negative		3	Rural settlements decrease exceeding population loss, coordination in 2018 & coordination during 2009–2018	Urbanization-oriented development in land and industry

Note: NC, Number of counties

reasonable structure between rural population and settlements in Jiangsu Province; however, the inconsistent change between rural population and settlements was observed in the majority of counties. Rapid population loss in rural areas is the fundamental reason for the imbalance human-land relationship. It is known that China has a typical urban-rural dual system (Ye et al., 2018). China's employment system, social security system, education system, and housing system tilt to the urban areas. The urbanization-oriented development strategy impels a large rural population to flow into the city. Meanwhile, the rural household registration system binds farmers to their rural land. Under such circumstances, it is a very natural outgrowth of the inconsistent changes between rural population and settlements. Additionally, the urban-rural dual system has greatly restricted rural land circulation. Rural homesteads cannot be transferred freely like urban real estate, resulting in the inability of some farmers to transfer their existing rural homesteads in markets even if they are able to stand firm in the city (Kong et al., 2018). As a result, rural areas are facing challenges of sustainable land management.

Urban village is the underlying reason for the formation of RL and strong decoupling and low-level coupling (SL) types in Jiangsu Province. The number of counties with RL or SL types accounted for 1.16% and 2.33% in Jiangsu Province, respectively. The RL and SL types were mainly distributed in the main urban districts of Suzhou, Xuzhou and Nantong cities. The changes in rural population and settlements of these two types were at a static low-level coupling. Referring to the static coupling degree of counties in Jiangsu Province in 2009, it can be found that the static coupling degree of the three counties reduced over time, which showed that the changes of the rural population and settlements in these three counties tended to be inconsistent. It should be noted that the urbanization rates of these three counties in 2018 reached 100%, while the area of rural settlements in these three counties in 2018 did not vanish. The findings implied that there were urban villages in these three counties, which was the main reason for the unreasonable changes in their rural population and rural settlements.

In China, there is an obvious gap between urbanization rate of household registered population and urbanization rate of permanent population (Peng, 2011). This

study analyzes the rural human-land relationship based on permanent population statistics. The situation could be different when considering the mass floating population, especially in southern Jiangsu, where attracts a large number of rural workers into the local township enterprises. It could be one of the reasons why rural human-land relationship shows a relatively coordinated state in southern Jiangsu. We believe that the rural human-land relationship could be better reflected by combining resident population statistics with household registered population statistics. However, there lacks of uniform statistical caliber of household registered population (Qi et al., 2017). Accurate population data could be acquired with the help of big data, such as cellular signaling data and smartcard data (Huang et al., 2018). In addition, local urbanization is an important path advancing the urbanization process, which means that rural production and life have transformed to cities in the original location. Actually, there are some villages have been achieved local urbanization in Jiangsu Province, but they are still defined as rural areas in official statistics. Although it is hard to investigate each village at the provincial level, we should recognize that the term of village could have different definitions in different situations, which may have important influence on rural human-land relationship. The local governments should assess local urbanization in a scientific and orderly manner, and the village data should be updated periodically according to the official assessment.

5.2 Implications for the combination of coupling and decoupling

Rural revitalization has been upgraded to one of basic national strategies in China (Liu and Li, 2017). However, it does not mean that all villages will get the chance of development. Inversely, we should keep in mind that the most villages will still in a recession stage under the wave of urbanization. The point is how to identify the differentiation characteristics of villages and orderly optimize the human-land relationships in rural areas. However, the interaction between population and land does not always occur concurrently. There could involve a series of transmission processes (Kong et al., 2019). Although the static coupling degree is high in the majority of counties in Jiangsu Province, the differentiation among regions is identified by the dynamic decoupling analysis. It means that the actual human-land rela-

tionship is usually covered by single static coupling or dynamic decoupling analysis. Population mobility is easier than land urbanization, which can explain the phenomenon of rural population loss exceeding rural settlements decrease in Jiangsu Province. With the further advance of rural land consolidation and reform of the rural land system, the imbalance changes between rural population and settlements could be improved in the future. In other words, the inconsistency changes between rural population and settlements may be temporary, which further demonstrates the necessity of combination analysis between coupling and decoupling.

Therefore, the governments should not be misguided by the superficial disharmony human-land relationship at a given time point; on the contrary, they should focus on both the static structures and dynamic changes during a given period. The proposed combination analysis offers more comprehensive human-land relationship for the governments and rural planners to formulate differentiation policies of rural revitalization. For example, the counties with recession decoupling and low-level coupling should focus on village demolition and agricultural scale production, while the counties with expansion connection and high-level coupling should lay stress on central village construction. An order village-town system could be scientifically formed and beautiful countryside could be built in this way.

Additionally, as one of the most developed provinces in China, Jiangsu is undergoing a rapid socioeconomic transformation. The changes of rural population and settlements in Jiangsu Province present significant regional differences in patterns and processes, which provide important reference for other regions. Extensive use of rural settlements in northern Jiangsu is a microcosm of the developing areas, where should be paid more attention on the change process of rural population and settlements, rather than the structure of them. The rural human-land relationships in southern Jiangsu have good reference and revelation for the developed areas in China. Although structural disequilibrium between rural population and settlements was observed in southern Jiangsu, we believed that it was temporary and the governments should focus on improving the habitat environment and urban-rural integration. Central Jiangsu represents the regions between the developing and developed areas, which is undergoing rapid rural population loss. The policies of rural revitalization should give

priorities in developing rural industry to attract rural labor return in central Jiangsu. These regional differentiation policies could be well formed based on the combination analysis of coupling and decoupling between rural population and settlements.

6 Conclusions

This study proposed a combination analysis method to identify the static and dynamic relationships between rural population and settlements in Jiangsu Province, China. The high-level coupling degree indicated that there was a harmonious human-land relationship in rural areas. However, it was observed that the area of rural settlements increased with rural population loss from 2009 to 2018 in Jiangsu Province. The static coupling model was insufficient in revealing these dynamic changes, which were well reflected by using the decoupling model. We argued that both the states of static coupling and the process of dynamic decoupling were equally important in identifying rural human-land relationship. The relationships between rural population and settlements presented spatial heterogeneity at the county level. We identified 11 combination types with differentiated human-land relationships. Although the most common two types featured by high-level coupling, the dynamic changes in rural population and settlements revealed that these two types were in a disharmonious stage. Only 12.79% of counties had a relatively coordinated static and dynamic relationship between rural population and settlements. Both urbanization-oriented development strategy and socioeconomic development level affected the changing speed and intensity of rural population and settlements. The findings would provide valuable information for governments and planners in formulating reasonable rural development policies and promoting rural revitalization.

It is worth noting that the implications of the proposed combination analysis could be improved by considering population structure, which reflects the population quality and vitality in rural areas. Rural China is facing an aged tendency of population. We believe that the imbalance human-land relationship could be worse when considering the aging population in Jiangsu Province. Improving the quantity and quality of rural population is essential for rural sustainable development. In addition, the uncertainty of rural population mobility

increases the difficulties in rural planning and governance. The combination of top-down rural planning and bottom-up rural governance is vital in rural revitalization.

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