

Article

The Impact of Household Dynamics on Land-Use Change in China: Past Experiences and Future Implications

Yaxue Luo ¹, Ruishan Chen ^{1,2,*} , Bo Xiong ³ , Nan Jia ⁴ , Xiaona Guo ², Chenglong Yin ¹ and Wen Song ²

¹ School of Geographical Sciences, East China Normal University, Shanghai 201100, China; luoyaxue11@163.com (Y.L.); yinchenglong95@163.com (C.Y.)

² School of Design, Shanghai Jiaotong University, Shanghai 200040, China; xiaonaguo2018@gmail.com (X.G.); song.wen@sjtu.edu.cn (W.S.)

³ School of Geography and Tourism, Huizhou University, Huizhou 516007, China; cqzk123@163.com

⁴ Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48823, USA

* Correspondence: chenrsh04@gmail.com

Abstract: Population is the main driver of land-system and environmental change. However, population is usually treated as a variable that only considers the population number, and multi-dimensional population structure is largely ignored. There has been a systematic transition of population structure in the past several decades, including changes in household structure, increasing aging populations, increasing divorce rates, and increasing human migration. All of these changes have direct or indirect impacts on land use and environmental issues. Here, taking China as an example and using statistical analysis, namely the Mann–Kendall trend test and a land-use-transition matrix, we examine the relationship between household dynamics and land-use change in China by examining changes in household structure and land-use changes in China between 1980 and 2020. The results show the following three groups of findings. (1) The number of households increased by 130.95% from 1980 to 2020, while the population only increased by 42.83%; the size of households decreased from 4.41 to 2.62 in China from 1982 to 2020; and the household dynamics varied from province to province, which is affected by urbanization rate and economic development. (2) Birth rates, divorce rates, population aging, and migration all affect household structure, which directly or indirectly affect changes in land-use systems. (3) The changes in China's land use are interlinked and interact with changes in household structure, which is evident in the increase in Residential land use and the abandonment of arable land. The rising household number increased the area of urban and rural settlement, leading to the fragmentation of cultivated land and the reduction of ecological land. To regulate land-use change for sustainable development, future land-use planning should take into account the effect of household dynamics and should reduce the negative effects of household dynamics on land systems and environmental change.

Keywords: population structure; household structure; housing demands; land-use change



Citation: Luo, Y.; Chen, R.; Xiong, B.; Jia, N.; Guo, X.; Yin, C.; Song, W. The Impact of Household Dynamics on Land-Use Change in China: Past Experiences and Future Implications.

Land **2024**, *13*, 124. <https://doi.org/10.3390/land13020124>

Received: 3 December 2023

Revised: 31 December 2023

Accepted: 20 January 2024

Published: 23 January 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Land-use change is an important indicator of human–nature interactions and an important component and determinant of global environmental change, and it plays an important role in future development and policy options for climate change, biodiversity, food security, ecosystem services, and sustainable development [1]. A clear analysis and understanding of the drivers of land-use change plays an important role in protecting regional ecosystems, promoting food security, and implementing high-quality development. A large number of studies have shown that land-use change is influenced by a combination of natural and social factors [2], including climate change, urbanization, population growth, and land-use policies [3]. Among them, population is recognized as a main driver of land-system and environmental change [4,5]. It has long been believed that population

growth is potentially exponential while the growth of food supply from the land is linear. Therefore, if population increase is uncontrolled, this will lead to social or environmental catastrophes such as land degradation, hunger, and conflict [6]. The population bomb also painted a gloomy future: overpopulation would cause some people not to be fed by the limited land, and hundreds of millions of people would face food insecurity [7].

Population growth and its impacts on environmental issues have been studied intensively [8,9]. However, in most cases, the population is considered as a single, one-dimensional variable; population numbers, or population density, are used as a variable to explore the population–environment nexus. The multi-dimensional structure of the population, including household number and size, aging population, and divorce rates, was not fully explored [10]. The household is a basic unit in much decision-making, including in the demand for rooms in a house; the use of agricultural land; and the consumption of water, energy, and food, and the role of the household unit in resource demand has not been fully understood. The Land Use and Land Cover Change (LUCC) project and the subsequent Global Land Project (GLP) community have examined the relationship between population growth and land-use change in detail. The rising population will increase the demand for residential and agricultural land, which further causes deforestation and loss of other natural habitats [5]. However, many of these studies have neglected household dynamics, which have more direct impacts on land-use change [11,12]. Even in some countries with decreasing population size, the number of households has increased substantially, which has raised the demand for residential areas and other land uses [8]. Understanding regional and national household dynamics can benefit ecological conservation, real estate development, land-use planning, and resource allocation. There are significant implications to proposing a broader perspective about the demographic characteristics of environmental issues.

Household dynamics are influenced by population migration, education, socioeconomic change, cultural change, and many other factors [13], and it can further cause land-use changes. Studies have explored the impacts of divorce and the aging population on land-use change [14,15]; housing development and its impact on biodiversity [16,17]; deforestation [18]; and protected areas [19] in the U.S., and most of these studies have also concentrated on a local scale [20]. However, similar research in other countries is very limited because of low data availability. In addition, changes in household number and household size can affect the change of land use directly. For example, large-scale rural outmigration within the past 40 years has reduced household size and rural population; however, because of the household registration system, many migrated workers have still kept houses in rural areas or have even enlarged their rural-housing area for security when they are aging, which has further increased rural settlement areas [21,22] and has formed many hollowing villages in China [23]. On the other hand, increasing the urban population and improving living conditions have largely increased urban-housing areas. The average housing area per person changed from 3.6 m² to 40.8 m² in Chinese cities from 1978 to 2018, and in rural areas it increased from 8.1 m² to 48.9 m² during the same period. With nearly every household having at least one suite of a house in China, the increasing household numbers in China have largely increased the amount of construction land and reduced the amount of fertile agricultural land, and have brought cascading effects to other land-use transitions [24]. However, related studies are very limited regarding this issue. Exploring household dynamics and its impacts on land-use change has great implications for urban and rural land-use planning, food, water, and energy demand, and also for contributions to environmental conservation and protection.

In conclusion, it can be seen from the existing results that most of the existing studies emphasize a single population variable, ignoring the integrity of household structure and the relationships between population factors and household structure. In addition, the researched areas are mostly in developed countries, and the research scales are mostly cities and regions. Here, we use the data from the Chinese statistics yearbook, China's population census, land-use surveys, and remote sensing to examine the household dynamics of China

in the past four decades, and to understand how that has affected land-use change in China and the navigation of sustainable land management under changing household dynamics. This study provides a theoretical basis for the sustainable development and utilization of land resources and helps to formulate future land-use policies. The proposed analytic framework can also help to understand the relationship between household dynamics and land-use change in other developing countries and beyond, thus promoting sustainable land-use management.

2. Materials and Methods

2.1. Overview of the Study Area

China ($73^{\circ}33'$ E– $135^{\circ}05'$ E, $3^{\circ}51'$ N– $53^{\circ}33'$ N) is located on the western coast of the Pacific Ocean in eastern Asia (Figure 1). It is a vast country with a total land area of about 9.6 million square kilometers, ranking third in the world. The terrain is high in the west and low in the east, and the terrain is dominated by mountains, plateaus, and hills. The climate type is complex and changeable; the continental monsoon climate is significant, as it brings cold and dry in conditions winter and brings high-temperature and rainy conditions in summer. In 1980, the total population of China was about 981 million, accounting for 22.08% of the global population at that time. As of September 2020, China still ranked first with 1.4 billion people, accounting for 18.45% of the global population. The Chinese population is growing rapidly, with average annual population-growth rates of 0.57% between 2000 and 2010 and 0.53% between 2010 and 2020.



Figure 1. Map of the study area.

As a populous country in the world, China has a fast population-growth rate, rapid urban development, and great demand for agriculture. The huge population has a huge demand-pressure on land use, and the increase in population directly affects urban expansion, agricultural land, and natural resource development. The rapid advance of urbanization has led to the migration of rural populations to cities, which not only leads to the change of urban land-use structures but also increases the demand for commercial, residential, transportation, and infrastructure land types. In addition, China is an agriculture-oriented country with a large demand for agricultural land, and appropriate agricultural land policies are of great importance to national food security. Facing the con-

tradition of population growth, economic development, and land-use imbalance, in-depth analysis of the driving factors of land use and an understanding of the impact of population structure on land use are of great importance for formulating reasonable land-use policies.

2.2. Data Sources

The Chinese census defines a household as family members who live together in the same house and are related by blood, marriage, or adoption [25]. Therefore, the household in this study only refers to family households and does not include collective households that belongs to a certain work unit. A collective household refers to the household account of the collective person, and the address of the household is generally the address of the unit or the address of the police station, which does not have representative significance of a family. In addition, household dynamics refers to the changing number, structure, and composition of a household, including household age-structure, household size, household type, and so on. Here we focus on household size and numbers when we mention household dynamics; because data availability and the patterns of change in the number and size are clear, this makes it easier to understand the impact of changes in household structure on land use. Household dynamics are also influenced by multiple factors, including the birth rate, divorce rate, aging rate, and population migration, etc. [26]. Therefore, we selected these variables as the influence factors for household dynamics. The data sources used in this paper are shown in Table 1.

Table 1. Data sources.

Data Name	Source	Period
Household number	①②③⑧	1980–2020
Population number	⑨⑩	1982–2020
Household size	①③④⑧	1953–2020
Aging rate	①⑧	1982–2020
Divorce rate	①⑤⑧	1980–2020
Birth rate	①⑧	1953–2020
Per-capita-housing area	①③	1980–2020
Migrated population	①	1982–2020
Construction area for housing	①⑥⑦	1980–2020
Completed-housing area	①⑥⑦	1980–2020
Land-use data (1 km)	⑪	1980–2020

Label: ① China Statistical Yearbook (1980–2020) <https://www.stats.gov.cn/sj/ndsj/> (accessed on 15 May 2022); ② China Statistical Yearbook on Health and Household Planning (1980–2020) <http://www.nhc.gov.cn/zwgkzt/tjnj/list.shtml> (accessed on 25 May 2022); ③ China Social Statistics Yearbook (1980–2020) <http://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2021030171?z=Z009> (accessed on 10 June 2022); ④ China Household Survey Yearbook (1980–2020) <http://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2022010292?z=Z033> (accessed on 17 June 2022); ⑤ International Statistical Yearbook (1980–2020) <http://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2021030179?z=Z017> (accessed on 30 June 2022); ⑥ China Financial Yearbook (1980–2020) (<http://www.pbc.gov.cn/yanjiuju/3911332/3911372/3911414/index.html>) (accessed on 5 July 2022); ⑦ China Statistical Abstract (1980–2020) <https://cnki.ctbu.edu.cn/CSYDMirror/area/yearbook/single/N2022070145?z=D26> (accessed on 14 July 2022); ⑧ China Population Census (1980–2020) <https://www.stats.gov.cn/sj/tjgb/rkpcgb/qgrkpcgb/> (accessed on 18 July 2022); ⑨ «Tabulation population census of the people's republic of China» in 1982, 1990, and 2000, <https://www.zgtjnj.org/navibooklist-N2009100047-1.html> (accessed on 24 July 2022); ⑩ «Major figures population census of China» in 2010 and 2020, https://www.gov.cn/govweb/test/2012-04/20/content_2118413_2.htm (accessed on 28 July 2022); and ⑪ Resource and Environment Science and Data Center (<https://www.resdc.cn/>) (accessed on 22 October 2022) [27]. The data accuracy was 1 km. Based on Landsat remote sensing images, the land-use database was constructed using manual visual interpretation, which has been widely used in related research, and the data has high reliability.

The birthrate data from 1953 to 2009 were collected from existing studies [28], and data from 2010 to 2020 were based on China Statistical Yearbook. The household housing size depended on the household's economic status, but per-capita-housing area depended on the household size. Per-capita-housing area was used to reflect the housing demands of residents, and it can show residential-area change due to household dynamics and socioeconomic development. Before 1990, Hainan and Chongqing were not regions in China. Since Chongqing was separated from Sichuan Province as a municipality in 1997,

China's statistics were divided into 30 provinces or regions before 2000 and 31 after 2000. Due to data limitations, household dynamics in Taiwan, Macao, and Hong Kong were not analyzed.

2.3. Materials and Methods

2.3.1. Statistical Analysis of Data

When performing statistical analyses with data describing the factors influencing household dynamics and land use, the data were mainly retrieved using relevant databases and literature, and using EXCEL 2022 to establish a database with relevant data. Finally, data analysis for the demographic factors of land use was completed using Origin 2022 software.

2.3.2. Detection of Trends and Change-Rates in Household Dynamics

The Mann–Kendall (MK) test was used to examine the changing trends of household structure. The MK test method uses a normal-approximate Z test to determine the variable trends of time-series data. If a Z value is greater than 0, it means that the trend shows an increasing trend; if a Z value is less than 0, it means that the trend shows a decreasing trend. In this paper, a value of 0.05 was selected for the confidence interval. When the absolute value of Z is greater than 1.65, 1.96, or 2.58, the corresponding changes are generally significant, relatively significant, or extremely significant, respectively [29].

2.3.3. Analysis of Land-Use Data

There were two parts to these analyses. First of all, based on the land-use data produced by the Resource and Environment Science and Data Center, ArcGIS software was used to classify, process, and generate statistics on land-use data to obtain land-type data for different years. Then, the land transfer matrix method [30] was used to analyze the transition between various land-use types, helping to better identify which types of cultivated land and forest land were occupied, and then analyzing the relationship between land-use types and population factors.

3. Results

3.1. Household Dynamics in China

3.1.1. Changing Household Numbers

The population of China has grown over the last forty years from 987.05 million in 1980 to 1409.78 million in 2020. Comparatively, the household number has increased from 213.96 million to 494.16 million. By comparison, the population increased 42.83%, while the number of households increased dramatically faster, reaching 130.95% between 1980 and 2020. According to Table 2, the proportion of family households and collective households in China changed by year, with fewer households and more collective households in 1982 than in 1990. Between 1990 and 2020, there was a general decline in the number of family households as a percentage of total households, while the number of collective households as a percentage of total households increased.

Table 2. Dynamics of households and population in China from 1982 to 2020.

Year	Family Household		Collective Household	
	Household Number (Million)	Population Number (Million)	Household Number (Million)	Population Number (Million)
1982	222.08	971.09 (96.73%)	1.07	32.82 (3.24%)
1990	276.91	1097.78 (97.10%)	1.71	32.73 (2.90%)
2000	340.49	1178.27 (94.82%)	10.74	64.34 (5.12%)
2010	401.93	1239.98 (93.04%)	15.79	92.83 (6.96%)
2020	494.16	1292.81 (91.70%)	28.53	116.97 (8.3%)

Note: Because data for 1980 were absent, 1982 census data were utilized to provide an example.

The trends of changing household numbers in urban and rural areas were different. In 1980, there were 176.73 million households in rural areas and only 37.23 million in urban areas. The number of households in urban regions climbed to 310.38 million in 2020, compared to 183.77 million in rural areas (Figure 2). More households now reside in cities, resulting from rapid urbanization and population movement from rural to urban areas.

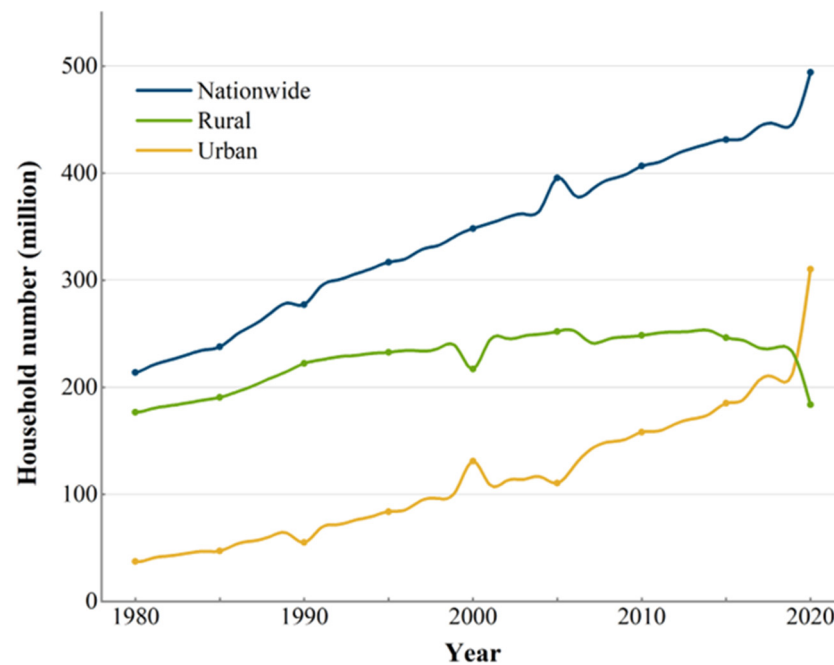


Figure 2. Trends for household numbers in China, 1980–2020.

Although the number of households in urban and rural areas showed an increasing trend, the rate of increase in urban areas was much faster than in rural areas. Over the past four decades, in rural areas excepting the year 2000 the number of households increased slowly, reaching a maximum of 253.13 million in 2014, with only a 3.98% increase in 2020 than 1980. While the number of households in urban areas peaked at 348.30 million in 2000 and increased 733.63% in 2020, it was approximately 8.33 times higher in 2020 than in 1980. As projected, the urbanization rate will increase by 70% in 2030, and by 80% in 2050 due to continuous rural-to-urban migration [31]. The household number in urban areas will increase and that in rural areas will continue to decrease in the following several decades. The MK (Mann–Kendall) test on the number of households showed that all regions had a highly significant upward trend in the number of households, and the significance of the upward trend is shown to be greater in the country as a whole ($Z = 9.1091$) than in the cities ($Z = 8.9294$) or in the countryside ($Z = 5.7395$).

3.1.2. Changing of Household Sizes

Over the past four decades, the size of Chinese households has gradually decreased. The national household size fell to 2.62 people per household in 2020 from 4.41 people per household in 1982 when the third population census was taken. The number of “three-person families” is the minimum threshold, and household size has declined in 2019 to less than three people for the first time (Figure 3).

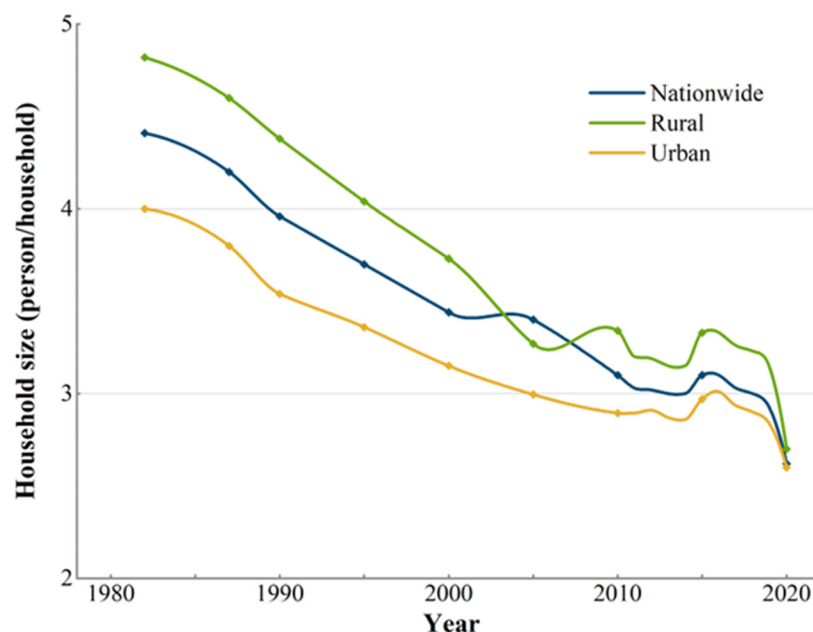


Figure 3. Changing trends for household size in China, 1982–2020.

Although household size showed a diminishing trend in both rural and urban settings, the decline was not the same in each setting (Figure 3). The size of rural households can vary more than urban ones. Until 2016, the household size in rural settings had always been more than four members, whereas the urban household size had only been four members in 1982 and had never had more than four members thereafter. The size in rural areas declined from 4.82 people per household in 1982 to 2.7 people per household in 2020. Urban household sizes decreased from 4.00 people per household to 2.60 people per household during the same period. According to the data, only in 2015 was the national household size larger than the rural one, as in other years the household size was highest in rural areas, which were second highest nationally, and household size was lowest in urban areas. With a high difference of 0.41 people per household in 1982 and a range of only 0.02–0.07 people per household in 2020, the disparity in household size between areas was at its lowest in 2020. The results of the MK (Mann–Kendall) tests comparing household size in the national, urban, and rural areas showed that overall household size in all regions followed a significant downward trend, and that this downward trend as a whole was greater in the national areas ($Z = -4.3644$) than in the rural ($Z = -3.9133$) or urban areas ($Z = -3.6250$), but that the rate of change of the downward trend was smaller in relation to the number of family households.

In addition, changes in household structure were not only seen for household size but were also seen for the intergenerational structure of households. From 1982 to 2020, the number of generations in a single family underwent a significant shift. In 1982, only 13.77% of families had a single generation whereas 67.46% of households had two generations. However, in 2020, nearly half of families had a single generation and only 36.72% of families had two generations, with two generations meaning that there are both parents and children in the family. The families that had three or more generations also changed greatly, decreasing from 18.76% in 1982 to only 13.78% in 2020, with the size of the household tending to decrease. The number of households with only one generation rapidly increased in China, with only 50.50% of families having two generations or greater in 2020 (Table 3).

Table 3. Household type according to number of generations, from 1982 to 2020 (%).

Household Type	1982	1990	2000	2010	2020
One generation	13.77	13.53	21.70	34.18	49.50
Two generations	67.46	68.02	59.32	47.83	36.72
Three generations and above	18.76	18.45	18.98	17.99	13.78
Total	100.00	100.00	100.00	100.00	100.00

3.1.3. Household Size Variation among Provinces of China

The household size was diverse across various provinces in China. From 1990 to 2020, household size declined in all provinces; in 1982, Yunnan had the highest household size in China (5.17 people per household), while Shanghai had the lowest household size (3.6 people per household). By 2020, Heilongjiang was the smallest province in China, with only 2.22 people living in each family, which was below the national average, the and Tibet Autonomous Region was the largest region, with 3.19 people living in each household. The biggest shift in household size between 1980 and 2020 occurred in Ningxia, while the smallest shift occurred in Shanghai.

The spatial distribution of household sizes in China from 1982 to 2020 is shown in Figure 4A. Combination of this data with economic-level zoning data (According to the economic zone division Rules of 2000, China is divided into three regions: East, Central and west) reveals that the household size in the eastern region was the smallest, while that in the western region was the largest. In the eastern regions, the household sizes in Shanghai, Beijing, and Tianjin were much smaller than in other regions. In the western regions, Tibet, Qinghai, and Yunnan always had larger household sizes than the other provinces. This shows that the economic level influences the size of the household.

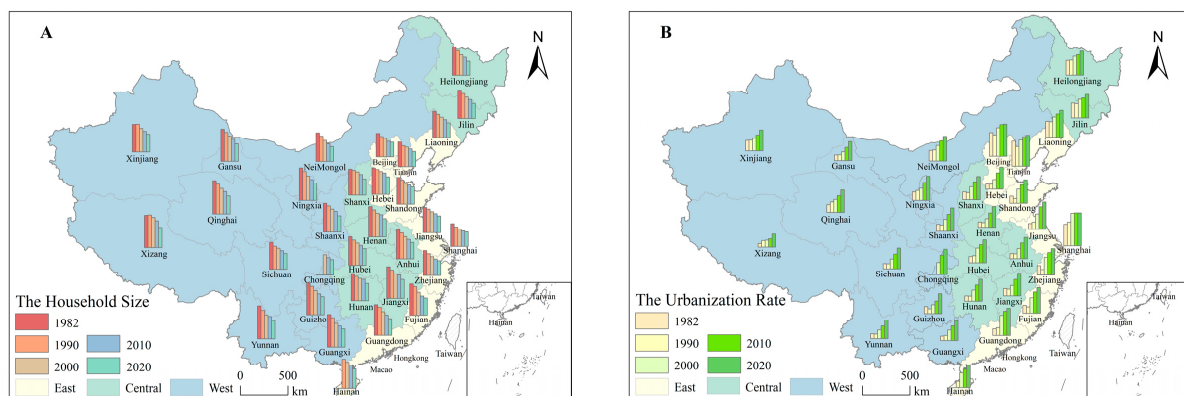


Figure 4. Changes in household sizes and urbanization rates for different provinces, 1982–2020. (A) changes in household size; (B) changes in urbanization rates.

As the urbanization rate is one of the indicators for assessing the level of economic development, the urbanization rate of each province in China from 1982 to 2020 was calculated (Figure 4B). By comparing the rate of urbanization and household size between provinces, it can be shown that the rate of urbanization was inversely connected to the change in household size, meaning that while the size of households was dropping the rate of urbanization was rising. Household sizes were smaller in areas with higher urbanization rates, such as Beijing, Tianjin, and Shanghai. Greater household sizes could be found in areas like Yunnan, Guizhou, and Guangxi, which had lower rates of urbanization. However, not all provinces followed this pattern. For instance, Heilongjiang province, which had an urbanization rate of only 65.61% in 2020, had the lowest household size at 2.22 people per household, suggesting that the urbanization rate was not the only factor affecting household size.

3.1.4. Demographic Drivers for Household Structure in China

The household is an integral unit of the population, and changes in the household structure are influenced by changes in the population structure, such as birth rates, divorce rates, aging populations, and migration, all of which have various effects.

Comparing China's household size and birth rate (Figure 5A), the trends for change were similar. The birthrate in China declined from 40‰ in the 1960s to less than 10‰ in 2020, and the household size shrank from 4.62 people per household in the 1960s to 2.62 people per household in 2020. The birth rate implies the birth of a new child, and if only the birth rate is being considered an increase in the birth rate would indicate that new family members were being added into the household, corresponding to an increase in the size of the household, indicating that the birth rate contributed to the size of the household.

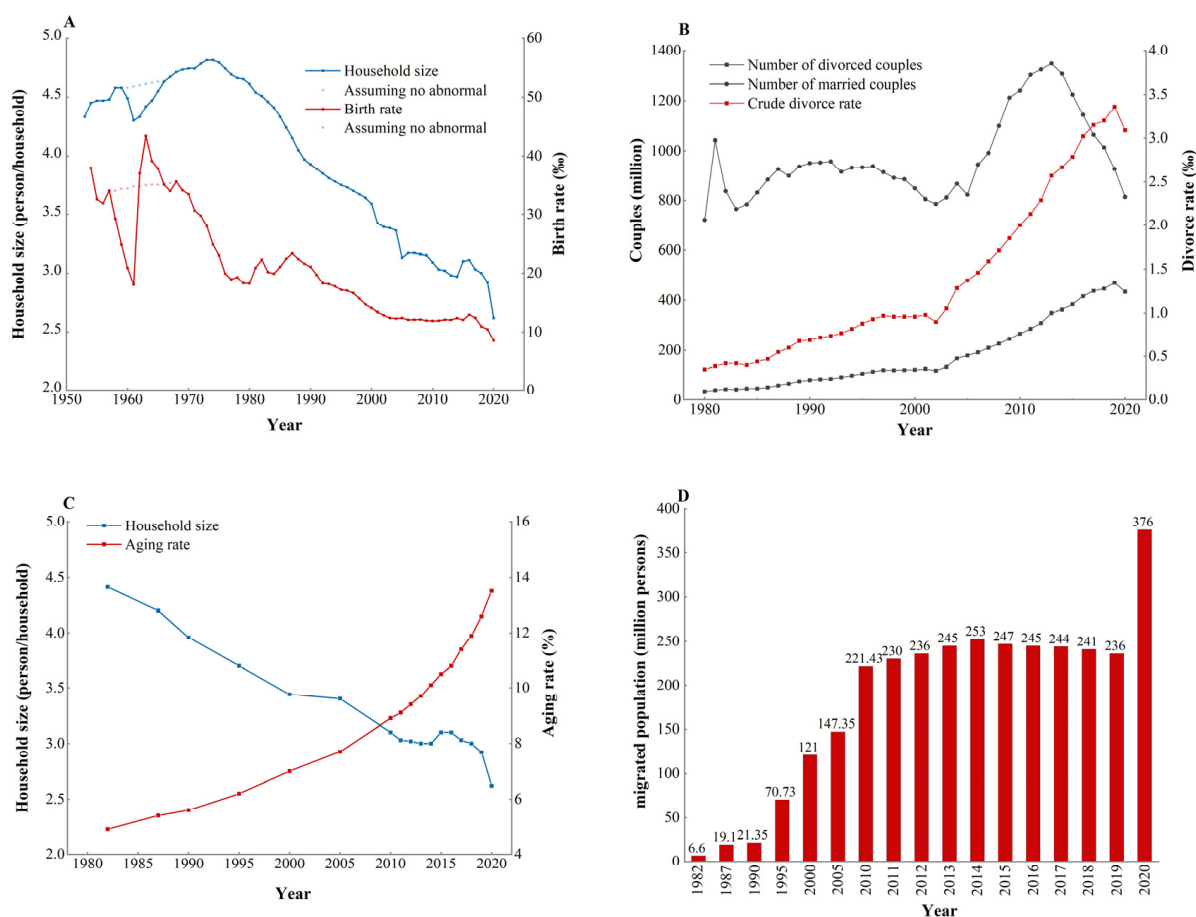


Figure 5. Factors affecting household structure. (A) Changes in household size and birth rate from 1953 to 2020. (B) Changes in the divorce rate and the numbers of married and divorced couples from 1980 to 2020. (C) Changes in the aging population in China from 1982 to 2020. (D) Changes in the migrant population in China from 1982 to 2020.

The divorce rate always affects household numbers and size. Generally, marriage will reduce the household number and increase household size, but divorce will increase the household number and reduce household size. Before a couple divorces, they belong to the same household with their children, but after a divorce they will be separated into two new households, which is a process that reduces the household number and increases the household size. The divorce rate increased from 0.35‰ in 1980 to 3.09‰ in 2020, rising nearly nine-fold (Figure 5B). There were only 0.34 million couples divorced in 1980, and this increased to 4.34 million in 2020 yet the number of couples married only increased from 7.21 million to 8.14 million couples.

Population aging is another indirect driving force of household-size change. The percentage of the aging population older than 65 years increased from 4.9% in 1982 to 13.5% in 2020 (Figure 5C). There was only an aging population of 49.28 million in 1982, which increased to 190.64 million in 2020, showing a total increase of 287% over the past 40 years. In many families, the older generation and the younger generation were not living together, as shown in Table 3, the number of one-generation families was rapidly increasing and the number of two- or three-generation families have declined in the past several decades.

Migration can also significantly affect household size and number. In 1982, there were 6.6 million migrants, which increased to 376 million in 2020 (Figure 5D). Around a quarter of people in China now are migrants or a floating population. With the rapid development of the urban economy, the growing gap between rural and urban incomes shows a continuously increasing trend, which drives greater labor migration flow into metropolitan areas. When these people have new families in urban areas, the original household size in rural areas decreases, increasing the total household number.

3.2. Changes in Housing Demand and Land Use during the Past 40 Years in China

3.2.1. Changes in Per-Capita-Housing Area in Urban and Rural Areas

The per-capita-housing area reflects the demand for housing of the residents. The per-capita-housing area has increased both in urban and rural areas. Specifically, the per-capita-housing area in urban areas was 7.2 m² in 1980, then it increased to 36.52 m² in 2020, while in rural areas it changed from 9.4 m² in 1980 to 51.03 m² in 2020 (Figure 6). The per-capita-housing area in rural areas was always larger than that in urban areas. With the increase in the number of households and the per-capita-housing area, the demand for housing promoted a surge in construction land.

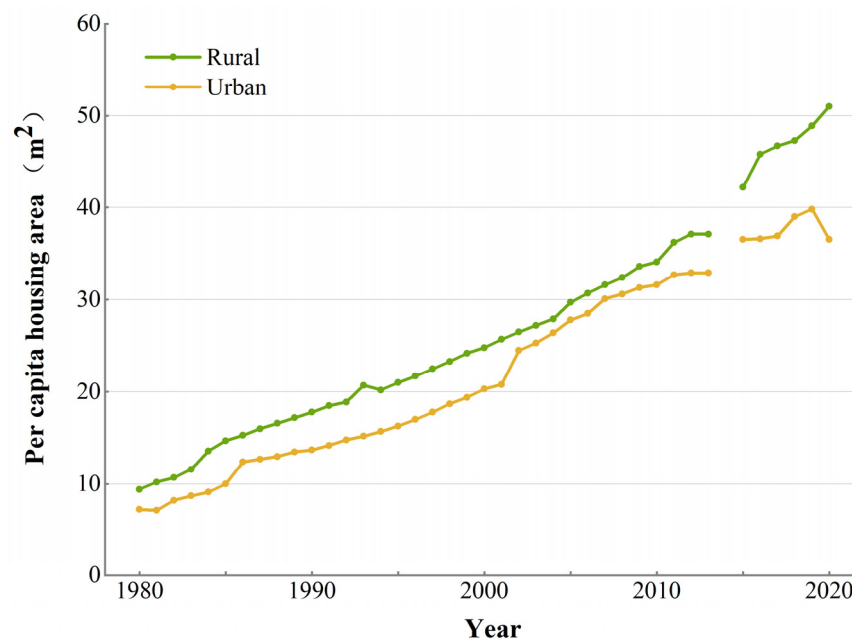


Figure 6. Trends in per-capita-housing area in China, 1980–2020 (Due to lack of data, there was no analysis for 2014).

Combined with China's rural and urban populations, the total housing area can be roughly estimated. According to national statistics, China's urban population was 902.20 million and the rural population is 509.92 million by the end of 2020. The total housing area was 32,948.34 million m² in urban areas and about 26,021.22 million m² in rural areas. To meet the housing needs of residents, China needs at least 58,969.56 million m² of housing space. As the household number was 494.16 million in 2020, the average living area of each household was about 119.3 m².

3.2.2. Changes in Construction Area and Completion Area in China

The construction area and the completed-housing area can also reflect residents' demand for housing. In this connection, construction area, which is the sum of new construction in the current year and the unfinished area in previous years, may indicate the residential requirements of the residents. However, direct use of this data may underestimate total-floor-area requirements. Completed-housing area is the floor area completed in the year, which is the area of housing that can be used directly and indicates the actual use of housing.

The data show (Figure 7) that construction area (Building under Construction) has been increasing, indicating that residents' demand for housing has been growing, with a faster rate of growth between 2014 and a slower but unabated increase in floor area after 2014, with only 275 million m² of housing area under construction in 1980 and 14,947 million m² in 2020. The completed-housing area shows a similar growth trend, with 45,653 million m² of housing area completed from 1980 to 2020, which is less than the 58,969.56 million m² minimum-dwelling area that China was previously thought to require.

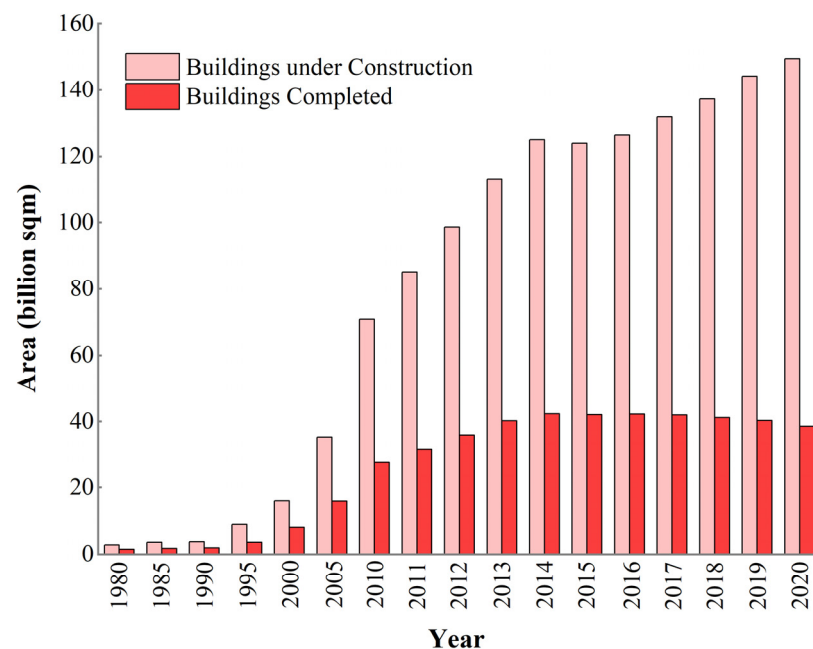


Figure 7. Trends for Building under construction and Completion area in China, 1980–2020.

3.2.3. Changes in Land-Use Transitions in China during the Past 40 Years

Based on the land-use data, we conducted a long time-series analysis of land-use change from 1980 to 2020 (Figure 8). The analysis focuses on four land types, and the reasons for selecting the corresponding land type are indicated in parentheses. The land types include Agricultural (the household structure of rural residents directly affects the amount of Agricultural); Woodland (policies such as “returning farmland to the forest” affect changes in the area of Woodland and Agricultural); Unused land (changes in household structure may lead to an increase in the area of abandoned land); and Residential land (the area that may be occupied by urban land is considered to include only urban land and rural settlements, excluding construction lands such as industrial, mining, and transport) to facilitate understanding of the links between changes in land use and changes in household structure.



Figure 8. Plots of area changes for four land types, 1980–2020.

The area of each land type has changed over time, as shown in Figure 8, with Woodland remaining the largest and Residential land the smallest of the four land types. From 2010 to 2020, China's urbanization expansion accelerated, with a large number of rural emigrants and an increase in the area of rural arable land left fallow. At the same time, this may be accompanied by deforestation and forest clearance activities in mining areas. The area of Unused land reached its maximum in 2020, increased by 0.19×10^8 ha compared to 1980. Agricultural land showed an increase and then a decrease in area, reaching a maximum of 1.80×10^8 ha in 2000. Woodland land showed a decrease and then an increase, reaching a minimum of 2.24×10^8 ha in 2000. Residential land showed a trend of year-on-year increase, and the area of urban Residential land area differed from that of rural Residential land.

The area of urban land was different from that of rural land. It showed a change in urban land and rural settlements, with the area of urban settlements being smaller than that of rural settlements (Figure 9). In 1980, China's urban settlements just were 0.02×10^8 ha, and rural settlements were 0.12×10^8 ha. By 2020, urban land increased to 0.07×10^8 ha, which was an increase of 250% compared to 1980. This result is closely related to rapid urbanization and population movement, with rapid urban development and more and more people moving to cities, increasing urban construction land.

The transformation between land types was analyzed by counting the changes between Agricultural and Woodland types, as well as the area converted to Unused land and Residential land in different periods, reflecting the results of various influencing factors (Figure 10). The results indicated that between 2010 and 2020, the most Agricultural and Woodland land was changed to other land-use types, while between 2000 and 2010 the least Agricultural and Woodland land was converted, and the overall conversion area showed a large gap compared with other periods. From 2000 to 2010, China emphasized the importance of land protection and implemented relevant land protection policies, such as the "policy of returning farmland to forest" in 2002 and the "target of 1.8 billion mu of cultivated land" in 2006. The introduction of these policies and indicators has increased

the rigor of national and local land-use management, resulting in less land-use changes between 2000 and 2010.

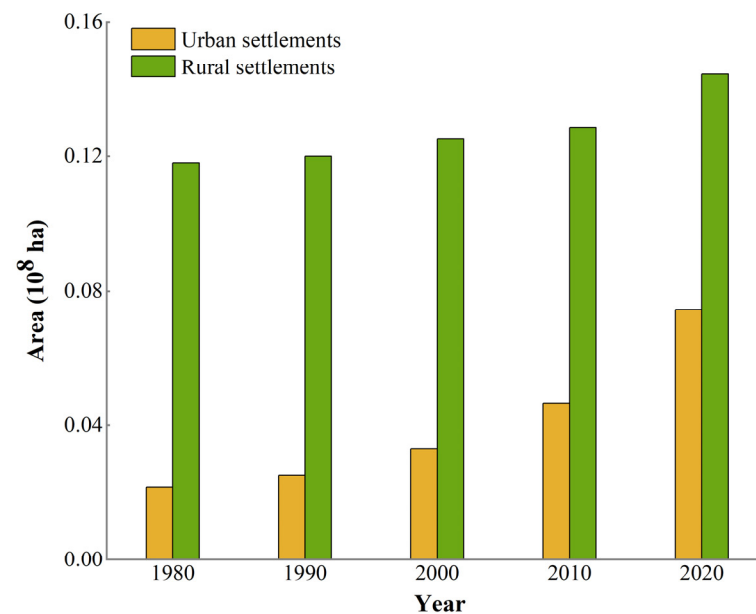


Figure 9. Map of area change for Residential land, 1980–2020.

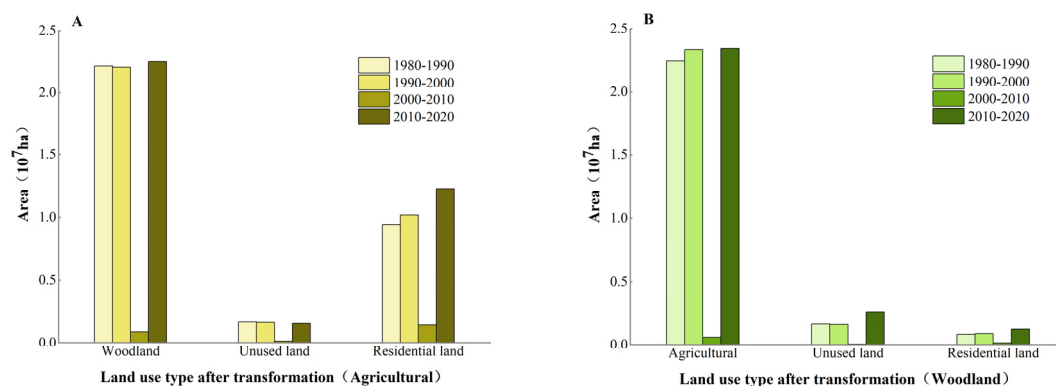


Figure 10. Area changes from land-use transformation, 1980–2020; (A) Agricultural land; and (B) Woodland.

In addition, conversion between Agricultural land and Woodland was examined. Agricultural land was mainly converted to Woodland, with an area greater than 2.20×10^8 ha changing in all periods except for the 2000–2010 period. The area of Agricultural land occupied as Urban land was more than 0.94×10^8 ha, and the area converted to Unused land was greater than 0.15×10^8 ha. The area of Woodland converted to Unused land was greater than 0.16×10^8 ha, the area converted between 2010 and 2020 amounted to 0.26×10^8 ha, and the area occupied for the construction of Residential land was 0.12×10^8 ha.

4. Discussion

4.1. Demographic Transition and Household Dynamics

This paper used long time-series demographic data for China to understand the dynamics of household numbers, size, and driving factors. Throughout human history, family, once a dense cluster of many siblings and extended kin, would separate into ever smaller and more fragile forms [32]. The number of nuclear families has increased while the number of extended families has significantly decreased. Nowadays, families become diversified and new forms of families such as single-parent and dink families (double

income without any kid). Corresponding to the demographic transition that happened in developed countries, China's household dynamics are following the same path, along with urbanization and rural outmigration, the household number is increasing while the size is decreasing. However, the change in household size in China is much faster than that in developed countries like the U.S. and the U.K. In the U.S., household size decreased from 3.33 people per household in 1960 to 2.53 people per household in 2020, with a 24.02% decrease in the past half-dozen decades [33]. In the U.K., the mean household size in 1901 was 4.62 people per household, and this decreased to 2.4 people per household in 2020, with a 48.05% decrease in 120 years [34]. In China, household size decreased from 4.65 people per household in 1979 to 2.62 people per household in 2020, a 43.66% decrease in 40 years.

Many demographic factors affected the changes in household size and number. The decreasing birthrate has a positive relationship with household size, especially because of China's one-child policy, which started in 1980 and ended in 2015. Urbanization causes large-scale rural-to-urban migration, further resulting in a household-size decline. In addition, aspiration for a nuclear family and independence, the increasing aging population, and the divorce rate also contribute to household-size decline. The divorce rate can reflect the changes in household size; however, it is more complex as a divorced couple may marry again later. The effect of urbanization rate on household size is nonlinear, for example, provinces like Heilongjiang and Liaoning have household sizes of 2.22 people per household and 2.29 people per household, smaller than Shanghai, which has 2.32 people per household; however, their urbanization rate is much lower than Shanghai. The urbanization rate in Heilongjiang and Liaoning was 65.61% and 72.14%, respectively, in 2020, compared to 89.30% in Shanghai in the same year. On the national scale, the urbanization rate also follows the same trend. Household sizes in the U.S., U.K., and China in 2020 were 2.53 people per household, 2.4 people per household, and 2.62 people per household, respectively, but the urbanization rates were 82.66%, 83.90%, and 63.89%, respectively, in 2020.

The change in family planning policy in China has affected household size; however, the significance of policy still needs to be observed. Even after the one-child policy was changed in 2015, the birth rate declined and reached 8.52% in 2020, which was the lowest since 1978. Furthermore, with Chinese society becoming an aging population structure, household size may also be affected, so the long-term trend of household size needs to be considered.

4.2. Impact of Household Dynamics on Land-Use Change in China

Changing household numbers and sizes have significant impacts on the environment [8,12]; however, how the household dynamics affect land use is only explored at a local scale. Researchers in [35] have examined the effects of increasing household size on the expansion of land under cultivation and intensification, but research on decreasing household size on rural and urban land use was scarce. Lambin and others (2008) found that declining household size would increase the demand for more housing units, and typically these units would spread horizontally across the landscape, contributing to urban sprawl [36]. Considering this, the households (H) instead of individuals should be recognized as the consuming unit of land (i.e., $I = HAT$ instead of $I = PAT$), as MacKellar and colleagues proposed, where environmental impact (I) is seen as the product of factors: population (P); household (H); affluence (A); and technological efficiency (T) [37]. This paper is the first attempt to understand the relationship between household dynamics and land-use change at the national scale, not only for urban areas but also for rural areas.

Urbanization, rural-to-urban migration, and decreasing household sizes have contributed to increasing housing units in urban areas in China. However, even with the decreasing population in rural areas, housing area or total settlement areas are continually increasing in China. Benefiting from the household registration system in China, many people still keep their houses and cultivated land in rural areas, even enlarging these houses

to ensure that they have places to live when they are too old to find jobs in the cities. This has created many hollowed villages in China, with many properties being abandoned throughout the settlement [24,38].

Per-capita-housing area has largely increased with the rising affluence associated with economic development and the transition from agricultural to urban-industrial societies. In the past four decades, per capita-, urban-, and rural-housing areas have increased from 7.2 m² and 9.4 m² in 1980 to 36.52 m² and 51.03 m², respectively, in 2020. In addition, with the rising affluence, people also tend to have multiple homes in different locations. According to a report published in 2020, the average housing unit per household is 1.5 [39]. Data shows that 96.0% of households in urban areas have houses. About 58.4% of households only have one suite of the house, while 31.0% of households have two suites of a house, and 10.5% have three or more suites of a house.

The effects of household dynamics on rural cultivated land and ecological land are complex. Increasing household numbers and decreasing household size will result in the fragmentation of cultivated land if rural emigration is limited. However, as more younger people moved to cities for off-farm jobs, some of the cultivated lands are abandoned or are transferred to others for large-scale operations. The emigration from remote rural areas or mountainous areas causes many villages to be abandoned, not only for the cultivated land but also for the whole settlement. The population in rural villages decreased from 37.73 million to 23.63 million in 40 years, with more than 80 villages diminishing each day. From a land-use perspective, increasing household number and decreasing household size will reduce cultivated land, increase urban and rural housing areas, and result in land abandonment and low-efficiency land use. Greater housing area usually leads to more demand for building materials, which also translates into less efficient use of various resources [35] and an increase in CO₂ emission and waste generation [40]. Policies should encourage people to live in extended families.

While household structure affects land-use change, land-use policies can also influence the household structure (Figure 11). For instance, the national policy of “returning farmland to the forest” or the “grain for green” policy, has returned sloping lands to forest land for restoration though some incentives that reduced the amount of cultivated land and encouraged rural people to move to cities as migrant workers. This further promoted population mobility and facilitated the change in household dynamics.

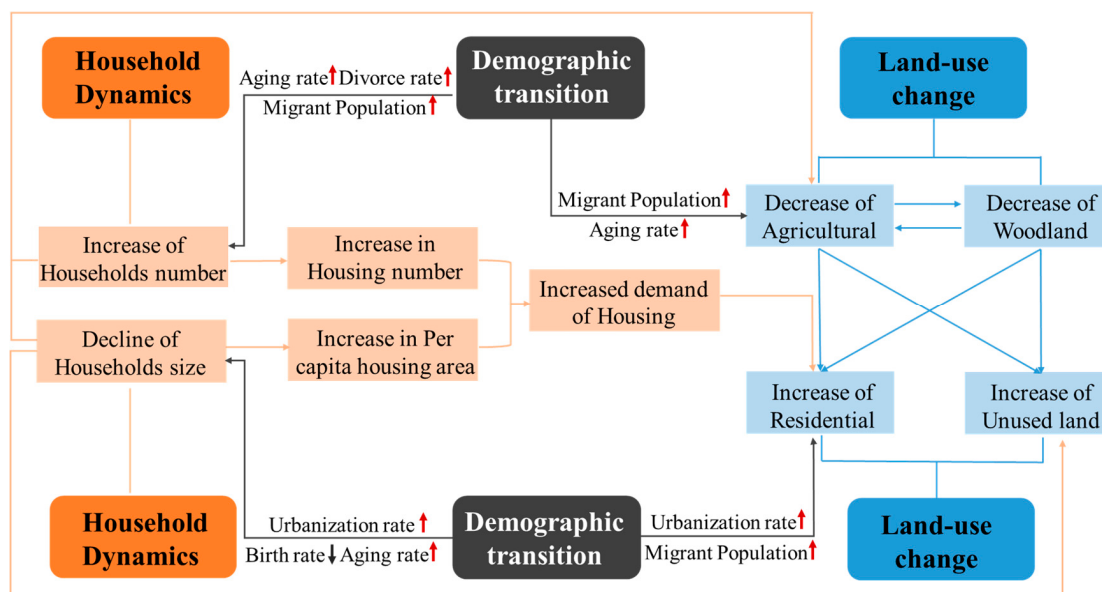


Figure 11. The relationship between household dynamics and land-use change. Note: Red arrows indicate increases and a black arrow represents a reduction.

5. Conclusions

This paper examines a long time-series of changing household number and sizes, and their impacts on land-use change in China. It attempts to understand the complex relationship and helps to address the challenges. Data from statistical yearbooks over the past 40 years shows that household numbers are rapidly increasing, and the size of households is gradually declining. The driving forces of household dynamics are diverse and complex, including decreasing birth rates, increasing migration, rising divorce rates, and aging populations. The relationship between urbanization and household size is nonlinear. Although the decline in household size is a global phenomenon, the speed in China is much more rapid because of certain policies, such as the one-child policy and the green for grain policy.

The change in household number and size has a large impact on land-use change. The declining household size and rising affluence will increase the demand for more housing units, contributing to urban sprawl and rural settlement sprawl. In this regard, decreasing household size will result in the loss of fertile cultivated land in the suburbs and the countryside. In addition, outmigration of the rural population also leads to village hollowing and cultivated land abandonment, which reduces land-use efficiency. The impacts of household dynamics on land-use change should be considered in future policymaking. For instance, limiting the number of houses a household can buy and encouraging households to use the appropriate size per capita. This will slow down the trend of increasing land use for building. Increasing subsidies for arable land will slow rural depopulation and increase the use of rural arable land and will reduce the increase in the area of abandoned land.

The data in this paper are mostly from national statistics, and these data can help to understand the trend of household dynamics and also the relationship with land-use change; however, spatially explicit data are not consistent. Subsequent research can combine remote sensing and statistical data to explore these effects further. Meta-analysis can also be used to integrate the case studies to understand the relationship comprehensively. In addition, this study mainly analyzed the changes of household structure and land use in the past, so we suggest increasing the forecast analysis of household structure and land-use change in the future and formulating relevant protection policies in advance to mitigate the irrational use of land use and its environmental impact in view of possible land-use difficulties.

Author Contributions: Conceptualization, Y.L. and R.C.; formal analysis, Y.L.; investigation, Y.L.; resources, R.C.; data curation, Y.L.; writing—original draft preparation, Y.L. and R.C.; writing—review and editing, B.X., N.J., X.G. and C.Y.; visualization, Y.L. and W.S.; project administration, R.C.; funding acquisition, R.C. All authors have read and agreed to the published version of the manuscript.

Funding: This study was conducted with the support of the National Social Science Fund of China [grant number 20ZDA085], the National Natural Science Foundation of China [grant number 41771119], China Postdoctoral Science Foundation: 2022M722055 and 2022TQ0205.

Data Availability Statement: The data supporting the results of this study can be obtained on public websites, The CNLUCC is available at <http://www.resdc.cn/> (accessed on 22 October 2022).

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

References

1. Stehfest, E.; Van Zeist, W.-J.; Valin, H.; Havlik, P.; Popp, A.; Kyle, P.; Tabeau, A.; Mason-D'Croz, D.; Hasegawa, T.; Bodirsky, B.L.; et al. Key Determinants of Global Land-Use Projections. *Nat. Commun.* **2019**, *10*, 2166. [\[CrossRef\]](#) [\[PubMed\]](#)
2. Hu, Y.; Hu, Y. Land Cover Changes and Their Driving Mechanisms in Central Asia from 2001 to 2017 Supported by Google Earth Engine. *Remote Sens.* **2019**, *11*, 554. [\[CrossRef\]](#)
3. Long, H. Land Use Policy in China: Introduction. *Land Use Policy* **2014**, *40*, 1–5. [\[CrossRef\]](#)
4. Bilsborrow, R.E.; Okoth-Ogendo, H.W.O. Population-Driven Changes in Land Use in Developing Countries. *Ambio J. Hum. Environ.* **1992**, *21*, 37–45.
5. National Research Council. *Population, Land Use, and Environment: Research Directions*; National Academies Press: Washington, DC, USA, 2005.

6. Malthus, T.R.; Winch, D.; James, P. *An Essay on the Principle of Population*; Cambridge Texts in the History of Political Thought; Cambridge University Press: Cambridge, UK; New York, NY, USA, 1992; ISBN 978-0-521-41954-3.
7. Ehrlich, P.R. *The Population Bomb*; Ballantine Books: New York, NY, USA, 1978.
8. Meyer, W.B.; Turner, B.L. Human Population Growth and Global Land-Use/Cover Change. *Annu. Rev. Ecol. Syst.* **1992**, *23*, 39–61. [[CrossRef](#)]
9. Saka, A. Population Growth and Carbon Dioxide Emission: An Investigation of the Africa Perspective. *East Asian J. Bus. Econ. (EAJBE)* **2014**, *2*, 1–8. [[CrossRef](#)]
10. Liu, J.G.; Daily, G.C.; Ehrlich, P.R.; Luck, G.W. Effects of Household Dynamics on Resource Consumption and Biodiversity. *Nature* **2003**, *421*, 530–533. [[CrossRef](#)]
11. Li, A.; Liu, J.G.; Ouyang, Z.Y.; Linderman, M.; Zhou, S.Q.; Zhang, H.M. Simulating Demographic and Socioeconomic Processes on Household Level and Implications for Giant Panda Habitats. *Ecol. Model.* **2001**, *140*, 31–49. [[CrossRef](#)]
12. Bradbury, M.; Peterson, M.N.; Liu, J.G. Long-Term Dynamics of Household Size and Their Environmental Implications. *Popul. Environ.* **2014**, *36*, 73–84. [[CrossRef](#)]
13. Ellsworth-Krebs, K. Implications of Declining Household Sizes and Expectations of Home Comfort for Domestic Energy Demand. *Nat. Energy* **2019**, *5*, 20–25. [[CrossRef](#)]
14. Götmark, F.; Cafaro, P.; O’Sullivan, J. Aging Human Populations: Good for Us, Good for the Earth. *Trends Ecol. Evol.* **2018**, *33*, 851–862. [[CrossRef](#)] [[PubMed](#)]
15. Yu, E.; Liu, J.G. Environmental Impacts of Divorce. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 20629–20634. [[CrossRef](#)] [[PubMed](#)]
16. Pejchar, L.; Reed, S.E.; Bixler, P.; Ex, L.; Mockrin, M.H. Consequences of Residential Development for Biodiversity and Human Well-Being. *Front. Ecol. Environ.* **2015**, *13*, 146–153. [[CrossRef](#)] [[PubMed](#)]
17. Seto, K.C.; Güneralp, B.; Hutyra, L.R. Global Forecasts of Urban Expansion to 2030 and Direct Impacts on Biodiversity and Carbon Pools. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 16083–16088. [[CrossRef](#)] [[PubMed](#)]
18. Kramer, D.B.; Urquhart, G.; Schmitt, K. Globalization and the Connection of Remote Communities: A Review of Household Effects and Their Biodiversity Implications. *Ecol. Econ.* **2009**, *68*, 2897–2909. [[CrossRef](#)]
19. Mockrin, M.H.; Reed, S.E.; Pejchar, L.; Jessica, S. Balancing Housing Growth and Land Conservation: Conservation Development Preserves Private Lands near Protected Areas. *Landsc. Urban Plan.* **2017**, *157*, 598–607. [[CrossRef](#)]
20. Castro-Prieto, J.; Martinuzzi, S.; Radeloff, V.C.; Helmers, D.P.; Quiñones, M.; Gould, W.A. Declining Human Population but Increasing Residential Development around Protected Areas in Puerto Rico. *Biol. Conserv.* **2017**, *209*, 473–481. [[CrossRef](#)]
21. Long, H.L.; Li, Y.R.; Liu, Y.S.; Woods, M.; Zou, J. Accelerated Restructuring in Rural China Fueled by ‘Increasing vs. Decreasing Balance’ Land-Use Policy for Dealing with Hollowed Villages. *Land Use Policy* **2012**, *29*, 11–22. [[CrossRef](#)]
22. Sun, H.; Liu, Y.S.; Xu, K.S. Hollow Villages and Rural Restructuring in Major Rural Regions of China: A Case Study of Yucheng City, Shandong Province. *Chin. Geogr. Sci.* **2011**, *21*, 354–363. [[CrossRef](#)]
23. Li, Y.R.; Liu, Y.S.; Long, H.L. Spatio-Temporal Analysis of Population and Residential Land Change in Rural China. *J. Nat. Resour.* **2010**, *10*, 1629–1638.
24. Long, H.L.; Li, T.T. The Coupling Characteristics and Mechanism of Farmland and Rural Housing Land Transition in China. *J. Geogr. Sci.* **2012**, *22*, 548–562. [[CrossRef](#)]
25. Census Office of the State Council. <<2010 Population Census Of China>>; China Statistical Publishing House: Beijing, China, 2012.
26. Wang, Y.S. An Analysis of Changes in the Chinese Family Structure between Urban and Rural Areas: On the Basis of the 2010 National Census Data. *Soc. Sci. China* **2014**, *35*, 100–116. [[CrossRef](#)]
27. Xu, X.; Liu, J.; Zhang, S.; Li, R.; Yan, C.; Wu, S. *China’s Multi-Period Land Use Land Cover Remote Sensing Monitoring Data Set (CNLUCC)*; Resource and Environment Data Cloud Platform: Beijing, China, 2018.
28. Cui, Z.W. *Population Change and People’s Livelihood*; China Population Publishing House: Beijing, China, 2012.
29. Sicard, P.; Mangin, A.; Hebel, P.; Malléa, P. Detection and Estimation Trends Linked to Air Quality and Mortality on French Riviera over the 1990–2005 Period. *Sci. Total Environ.* **2010**, *408*, 1943–1950. [[CrossRef](#)] [[PubMed](#)]
30. Teferi, E.; Bewket, W.; Uhlenbrook, S.; Wenninger, J. Understanding Recent Land Use and Land Cover Dynamics in the Source Region of the Upper Blue Nile, Ethiopia: Spatially Explicit Statistical Modeling of Systematic Transitions. *Agric. Ecosyst. Environ.* **2013**, *165*, 98–117. [[CrossRef](#)]
31. Bren d’Amour, C.; Reitsma, F.; Baiocchi, G.; Barthel, S.; Güneralp, B.; Erb, K.-H.; Haberl, H.; Creutzig, F.; Seto, K.C. Future Urban Land Expansion and Implications for Global Croplands. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 8939–8944. [[CrossRef](#)] [[PubMed](#)]
32. Brooks, D. The Nuclear Family Was a Mistake. *Atlantic* **2020**, *325*, 54–69.
33. Blake, J. Ideal Family Size among White Americans: A Quarter of a Century’s Evidence. *Demography* **1966**, *3*, 154–173. [[CrossRef](#)]
34. Laslett, P. Size and Structure of the Household in England over Three Centuries. *J. Demogr.* **1969**, *23*, 199–223. [[CrossRef](#)]
35. Rindfuss, R.R.; Turner, B.L.; Entwisle, B.; Walsh, S.J. Land Cover/Use and Population. In *Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth’s Surface*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2004; pp. 351–366. [[CrossRef](#)]
36. Lambin, E.F.; Geist, H.J. *Land-Use and Land-Cover Change: Local Processes and Global Impacts*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2008.
37. MacKellar, L.; Lutz, W.; Prinz, C.; Goujon, A. Population, Households, and CO₂ Emissions. *Popul. Dev. Rev.* **1995**, *21*, 849–865. [[CrossRef](#)]

38. Wang, D.G.; Zhu, Y.J.; Zhao, M.F.; Lv, Q.Y. Multi-Dimensional Hollowing Characteristics of Traditional Villages and Its Influence Mechanism Based on the Micro-Scale: A Case Study of Dongcun Village in Suzhou, China. *Land Use Policy* **2021**, *101*, 105146. [[CrossRef](#)]
39. He, S. The Central Bank's Survey Shows: Two Suites in 30% of Urban Households with Average Household Assets of 3.18 Million. *China Econ. Wkly.* **2020**, *9*, 36–37.
40. MacKellar, L.; Lutz, W.; Munn, R.E.; Wexler, L.; O'Neill, B.; McMichael, A.; Suhrkre, A. *Population and Global Warming*; Book Manuscript; International Institute for Applied Systems Analysis: Laxenburg, Austria, 1996.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.