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Spatiotemporal Evolution and Socioeconomic Impacts of Rainstorms and Droughts in Contiguous Poverty-Stricken Areas of China

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Abstract: To consolidate the achievements in the elimination of absolute poverty in China and prevent rural populations from returning to poverty as a result of meteorological disasters, this study analyzed the spatiotemporal characteristics of rainstorms and droughts and their socioeconomic impacts on China's contiguous poverty-stricken areas (CPSAs) from 1984 to 2019. The annual number of rainstorms and drought days in CPSAs of China reached approximately 1.9 days/year and 44.6 days/year, respectively. It gradually decreased from southeast to northwest. Rainstorms showed a significant increasing trend of 0.075 days/decade, while there is no significant trend in drought days. Due to rainstorms and droughts, the average annual number of people affected and direct economic losses in CPSAs reached 34 million people/year and 29 billion Chinese yuan/year, accounting for 22.9% and 12.6% of China's total amounts, respectively. The average annual loss rate due to disasters in this region reached 1.6%, which is 0.6% higher than the national level. Furthermore, the distinct features and socioeconomic impacts of rainstorms and droughts were identified on the southeastern and northwestern sides of the population density line (PDL) along Tengchong-Aihui in China. Droughts have often impacted the regions located along the PDL, while rainstorms and droughts have occurred more frequently in the regions to the southeast of the PDL than in the regions to the northwest of the PDL. As a result, the affected population and direct economic losses due to rainstorms and droughts in the regions to the southeast of the PDL were 8.8 and 9.2 times and 3.3 and 7.4 times higher, respectively, than those in the regions on the other side of the PDL. Although the losses were greater, the disaster resistance capabilities were significantly improved in these regions. In contrast, the regions to the northwest side of the PDL exhibited a significant increasing trend in losses with a relatively low disaster resistance capabilities. This study revealed that it is necessary to improve the capability of meteorological disaster prevention and reduction in China's CPSAs, especially in the regions to the west of the PDL, which could further contribute to the realization of United Nations Sustainable Development Goals.

Keywords: contiguous poverty-stricken areas; rainstorms and droughts; direct economic losses; disaster-affected population

1. Introduction

The United Nations Sustainable Development Goals (SDGs) clearly state that by 2030, all forms of poverty are to be eradicated worldwide [1]. However, more than 700 million people (10% of the world's population) still live in extreme poverty. The Outline for Poverty Alleviation and Development in Rural China (2011–2020) delineated

14 contiguous poverty-stricken areas (CPSAs) in China based on economic levels and set the net income of farmers to 2300 yuan (constant 2010 prices) as the national standard for poverty alleviation. As of 23 November 2020, all 832 poverty-stricken counties in China have been removed from poverty. The poverty reduction target of the United Nations 2030 Agenda for Sustainable Development has been achieved 10 years ahead of schedule, contributing to more than 70% of the reduction in global poverty [2]. Most of these areas are located in plateau, mountainous and hilly areas with a harsh natural environment, low economic status and relatively lagging social development and represent high-risk areas for meteorological disasters in China [3]. Among these disasters, rainstorms and droughts are the two meteorological disasters with the highest proportion of the total socioeconomic impact, with 24% of the agricultural population endangered by rainstorms and droughts with a long duration and wide range, reaching losses of 67.35 billion yuan in 2016 alone [4,5].

At the global warming level of 1.5 °C, the droughts in CPSAs will change from mild to moderate, which will increase significantly in three prefectures of Southern Xinjiang and the Tibet Region [6]. Meanwhile, the intensity of rainstorms will increase in more than 85% of CPSAs in a 1.5 °C warming scenario [7]. Since the disaster resistance capabilities in poor areas are relatively low, natural hazards like rainstorms and droughts are a major reason why people become and stay poor [8]. Therefore, a comprehensive understanding of the spatiotemporal characteristics and socioeconomic impacts of rainstorms and droughts in CPSAs is important for preventing populations that have been lifted out of poverty from falling back into it again due to meteorological disasters, which further contributes to poverty eradication consolidation processes in China.

Previous studies have found that the frequency and intensity of rainstorms and droughts in China have increased since the 21st century, and the affected population and economic losses due to rainstorms and droughts have significantly increased [9–11]. However, these studies mainly focused on a specific region, such as exploring rainstorms and disaster-induced losses in eastern China [12]. There remains a lack of comprehensive studies of meteorological disaster conditions in CPSAs. In recent years, the demand for natural hazard data has increased, and numerous databases have emerged, e.g., NatCatSERVICE, a global-scale database launched by Munich Re (MUNICH RE), and the Emergency Events Database (EM-DAT) published by the University of Leuven, Belgium. China has also created databases such as the China Meteorological Administration Disaster Database, China Natural Disaster Database and China Meteorological Disaster Yearbook, according to different application needs, which provide a good opportunity to study the socioeconomic impacts of meteorological disasters in specific regions [9,13–16].

Hu Huanyong proposed the well-known population density line (PDL) in 1935, revealing the basic pattern of the population distribution in China. It showed that 64% of the areas northwest of the Aihui-Tengchong line in China is inhabited by only 4% of the population [17,18]. The PDL is strongly correlated with the regional climate, and the PDL coincides closely with the climate dividing line between arid and humid zones in China [19]. This result is very consistent with the 400 mm isohyetal line and the 10 °C annual mean temperature line, and the temperature and precipitation characteristics of the above CPSAs also basically coincide with this dividing line [17]. The divergence of human factors on both sides of the PDL is also significant; CPSAs in China are mainly distributed on both sides of the PDL, and the economy in the regions to the east of the PDL is more developed than that of the regions to the west of the PDL [20,21].

Therefore, based on rainstorm and drought data, direct economic losses and affected population data, this study determined the spatial and temporal evolutionary characteristics of the socioeconomic impacts of rainstorms and droughts and revealed the unique characteristics which distinguish this region from the disaster conditions in China. Furthermore, this study compared and analyzed rainstorm and drought characteristics with the PDL as the boundary. The results of this study can provide a scientific basis for the CPSAs

considered to overcome climate change challenges, prevent a return to poverty resulting from meteorological disasters and further contribute to the realization of SDGs.

2. Data and Methods

2.1. Study Area

CPSAs are mainly located in the mountains, hills and highlands of Central and Western China, with complex and diverse topographic conditions and fragile ecological environments (Figure 1) [22]. For the convenience of description, the regions to the east of the PDL (Regions 5–11, R5–11 for short), the regions along the PDL (Regions 1–4, R1–4 for short) and the regions to the west of the PDL (Regions 12–14, R12–14 for short) were classified. The regions along the PDL (R1–4) include the Southern area of Daxing’anling Mountains, the Yanshan-Taihang Mountain area, the Lvliang Mountain area and Liupanshan area, which have a temperate continental climate, with an average annual precipitation of approximately 500 mm, a mean temperature of approximately 4–8 °C, a maximum temperature of 16 °C, and a minimum temperature of 0 °C, which decreases with increasing latitude. The regions to the west of the PDL (R12–14) include the three prefectures of southern Xinjiang, the Tibet region and Tibetan areas in four provinces which belong to the plateau mountain climate zone of China. The annual precipitation is very low, approximately 300 mm, and the average annual temperature reaches below 4 °C, a maximum temperature of 10 °C, and a minimum temperature of –6 °C. The regions to the east of the PDL (R5–11) have a subtropical monsoon climate, with an average annual precipitation of over 1000 mm and an average annual temperature ranging from approximately 13 to 18 °C, a maximum temperature of 23 °C and a minimum temperature of 10 °C [20].

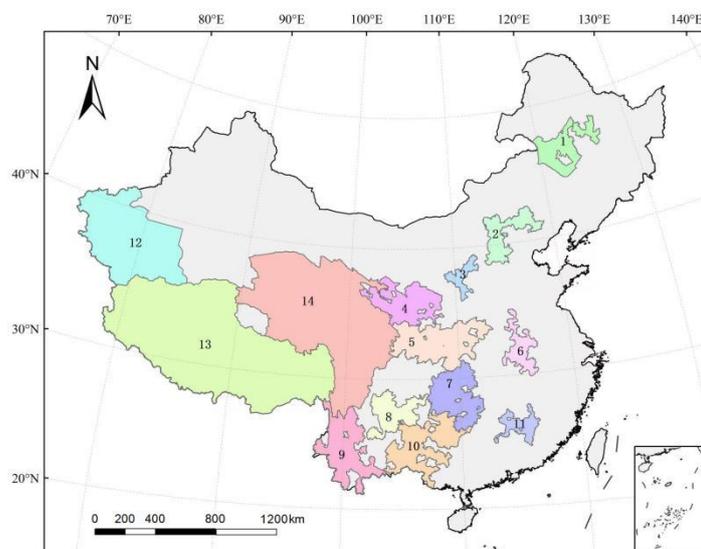


Figure 1. The contiguous poverty-stricken areas (CPSAs) (1. Southern area of Daxing’anling Mountains; 2. Yanshan-Taihang Mountain Area; 3. Lvliang Mountain Area; 4. Liupanshan Area; 5. Qinba Mountain Area; 6. Dabie Mountain Area; 7. Wuling Mountain Area; 8. Wumeng Mountain Area; 9. West Yunnan Border Area; 10. Yunnan, Guangxi and Guizhou rocky desertification area; 11. Luoxiao Mountain Area; 12. Three prefectures of Southern Xinjiang; 13. Tibet Region; 14. Tibetan Areas in Four Provinces).

During 1984–2019, the average annual total population of these CPSAs reached 210 million people, accounting for 16.7% of the total population of China. The average annual total gross domestic product (GDP) reached 1989.3 billion yuan, accounting for only 7.7% of the total GDP of China. The population of the above CPSAs grew from 180 million people to 230 million people, and the total GDP increased from 57.3 billion yuan to 7621.9 billion yuan (Figure 2a,b). The multi-year average GDP per capita in this

region reached RMB 8943 per person, accounting for only 46.9% of China's per capita GDP of RMB 19,079 per person (Figure 2c). This indicates that compared to the entire country, the CPSAs considered, accounting for 40% of the total area of China, contain a relatively small population and are relatively economically under-developed.

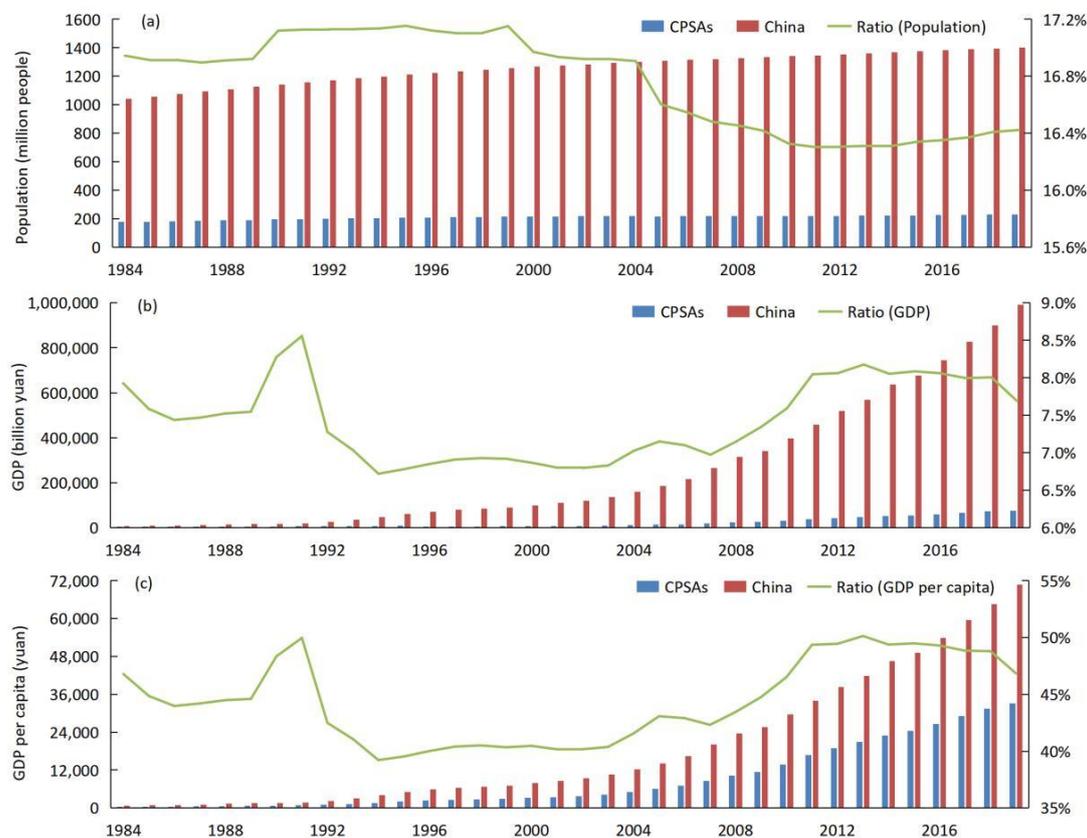


Figure 2. Time series of (a) total population (million people), (b) total GDP (billion yuan), (c) GDP per capita (yuan) in CPSAs, China during 1984–2019. Green lines denote their ratio compared to China's total.

2.2. Datasets

2.2.1. Observational Data

The CN05.1 dataset from the National Climate Center in China with a high spatial resolution (0.25°) for the period of 1984–2019 was used to depict climate regimes and identify rainstorms and droughts, including a daily maximum temperature, a daily minimum temperature, a daily mean temperature, precipitation and wind speed [23,24].

2.2.2. Meteorological Disaster Dataset

The Chinese meteorological disaster dataset with Chinese county units constructed by the National Climate Center based on meteorological disaster data collation standards was used in this study [25]. Two categories of disasters were selected, including rainstorms and floods and mudslides triggered by rainstorms, and droughts. This study mainly focused on the direct economic losses and affected population during the period of 1984–2019. In order to better reflect the situation of the CPSAs, we compared it with the national situation when describing the socioeconomic impacts of rainstorms and droughts. The socioeconomic impacts in CPSAs and China were averaged using the direct economic losses and affected population in the given regions, respectively.

2.2.3. Socio-Economic Data

The GDP and the population of China with a spatial resolution of 1 km were taken from the Geographic Science and Resource Environment Data Center of the Chinese Academy of Sciences [26,27]. The dataset covers the periods of 1990, 1995, 2000, 2005 and 2010. The data of the remaining years within the data range were obtained via cubic spline interpolation to ensure data continuity. Cubic spline interpolation was used to divide the data into several segments. Each segment constructed a cubic function, and each segment function smoothly connected with another [28]. Finally, the linear trend extrapolation method was used to further extrapolate the post-2010 values to 2019 [29]. The CPSAs and national values were calculated as the mean value of the grid points in the regions in which they are located.

2.3. Methods

2.3.1. Definitions of Rainstorms and Droughts

Corresponding to the two categories of disaster from the Chinese meteorological disaster database, the following definitions were used to identify the characteristics of rainstorms and droughts. Since all the socio-economic impact of rainstorm, floods and mudslides were triggered by rainstorms, we mainly focused on the characteristics of rainstorms in this study. The number of rainstorm days was defined as the number of days with a daily precipitation exceeding 50 mm, according to the China Meteorological Administration, which has been widely used in previous studies [30,31]. According to the revised national meteorological drought grade standard, the daily meteorological drought comprehensive index (MCI) was calculated by using the historical daily rainfall, the average temperature, the maximum temperature, the minimum temperature and wind speed [32]. MCI was widely used for monitoring drought and is preferable to other indices in terms of effect and monitoring capacity [33,34]. The number of drought days was defined as the number of days of medium drought conditions or above ($MCI \leq -1.5$) [35,36].

2.3.2. Consumer Price Index (CPI) Standardization

The CPI reflects the movement of prices in economic operations and constitutes an important indicator of the degree of inflation [37]. To eliminate the influence of inflation and ensure comparable direct economic losses due to rainstorms and droughts over time, this study selected 2019 as the base year and converted and standardized the direct economic losses data for other years by the 2019 market value [38].

2.3.3. Assessment of the Disaster Resistance Capability

The disaster resistance capability evaluation index used in this study was the loss-to-GDP rate (the loss-to-GDP rate is the direct economic losses caused by disasters in a certain area compared to the GDP of that area in a given year, referred to as LGR) [39]. The lower the percentage of the direct economic losses in a given region is, the higher its disaster resistance capability.

2.3.4. Linear Trend Detection

In this study, the Mann-Kendall (M-K) nonparametric test method was used to assess the trend of elements, which can reduce the influence of outliers and missing measurements on trend estimation [40,41].

3. Spatiotemporal Characteristics of Rainstorms and Droughts

3.1. Temporal Characteristics

The average number of rainstorm days in CPSAs from 1984 to 2019 was 1.9 days/year, ranging from 1.5 days (1997) to 2.3 days (2016) (Figure 3a). The average number of drought days in CPSAs reached 44.6 days/year, ranging from 21.8 days (1990) to 67.3 days (2011), (Figure 3b). The rainstorm days showed a significant increasing trend of 0.075 days/decade, while there was no significant trend in drought days (Figure 3a,b).

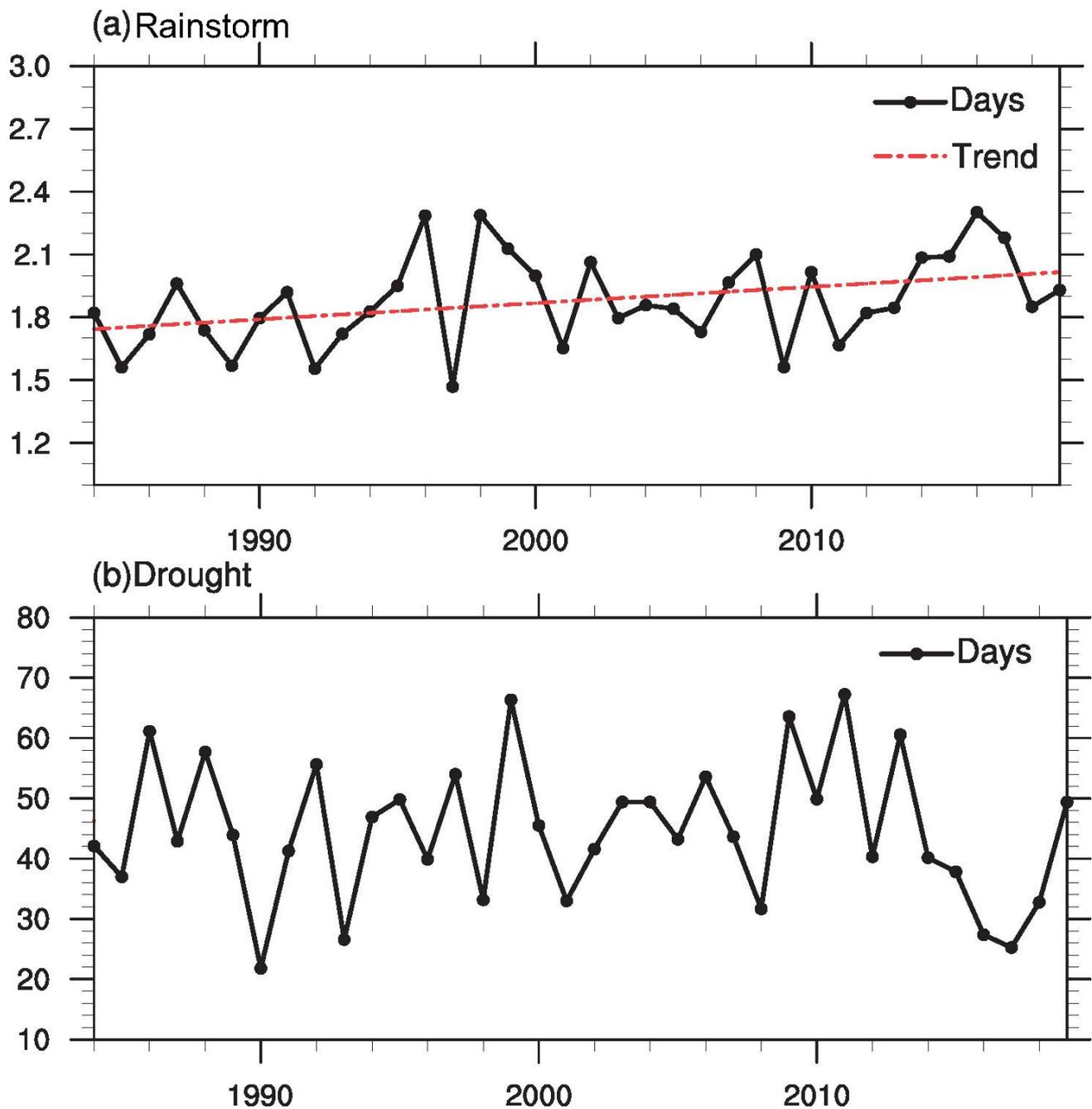


Figure 3. Time series and trend of accumulated (a) rainstorm days (days/year) (daily precipitation ≥ 50 mm) and (b) droughts days ($MCI \leq -1.5$) (days/year) averaged over the CPSAs during 1984–2019.

3.2. Spatial Characteristics

The spatial distribution of rainstorm and drought days in the CPSAs considered revealed distinct characteristics on both sides of the PDL. From 1984 to 2019, the number of rainstorm days in CPSAs gradually decreased from southeast to northwest, with multi-year average values of 3.1 and 0.3 rainstorm days in the regions to the east of the PDL and the regions along and to the west of the PDL, respectively (Figure 4a). The number of drought days in CPSAs also gradually decreased from southeast to northwest, and the multi-year average number of drought days in the regions along and to the east of the PDL and to the west of the PDL reached 50.2 and 25.2 days, respectively (Figure 4b). It could be observed that the number of rainstorm and drought days in the regions to the east of the

PDL decreased from east to west, and only the drought conditions in the regions along the PDL were very severe, while the number of rainstorm and drought days in the regions to the west of the PDL was relatively low.

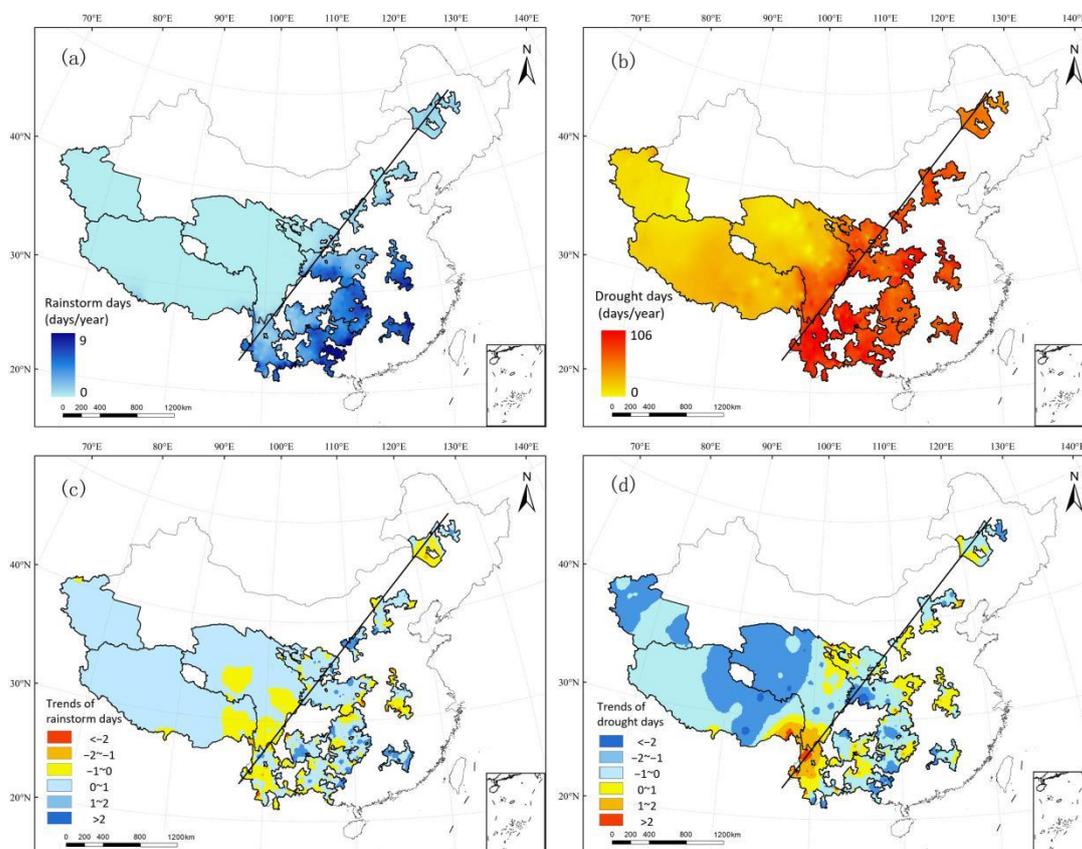


Figure 4. Spatial distribution of (a,b) annual average (days/year) and (c,d) linear trends (days/year) of (a,c) rainstorm days and (b,d) droughts days in CPSAs during 1984–2019.

During 1984–2019, the number of rainstorm days in the Southern area of Daxing’anling Mountains (R1), the Dabie Mountain area (R6), the West Yunnan Border Area (R9) and the Tibetan areas in the four provinces (R14) showed decreasing trends, while the increasing trends of rainstorm days in other regions of CPSAs were not statistically significant (Figure 4c). The number of drought days increased in certain areas of the Dabie Mountain area (R6), the Lvliang Mountain area (R3), the West Yunnan Border Area (R9), the southern Tibetan areas in four provinces (R14) and the eastern Tibet region (R13). In contrast, the drought days in other regions, especially in the three prefectures of southern Xinjiang (R12), the Tibet region (R13) and the Tibetan areas in four provinces (R14), showed a significant decreasing trend (Figure 4d).

4. Socioeconomic Impacts of Rainstorms and Droughts

In order to illustrate the affected population and direct economic losses in CPSAs, comparisons were made between the CPSAs and the whole nation.

4.1. Affected Population

In terms of the total affected population, the average population affected by rainstorms and droughts in CPSAs from 1984–2019 reached 34 million people/year, accounting for 22.9% of the national population affected by rainstorms and droughts, which is higher than the national share of the population in this region (16.7%) (Figure 5a). From 1984 to 2019, both CPSAs and China’s disaster-affected population increased before 2000 and then

decreased. The maximum occurred in 2010, reaching 90 million and 326 million, respectively. Moreover, to identify the affected population, the ratio of the average population affected by rainstorms and droughts to total population in CPSAs and China were 16% and 11.7%, respectively. By contrast, the ratio in CPSAs was 1.6% and 6.8% higher than that in China during 1984–1999 and 2000–2019, respectively. Notably, the affected population in CPSAs increased after 2000.

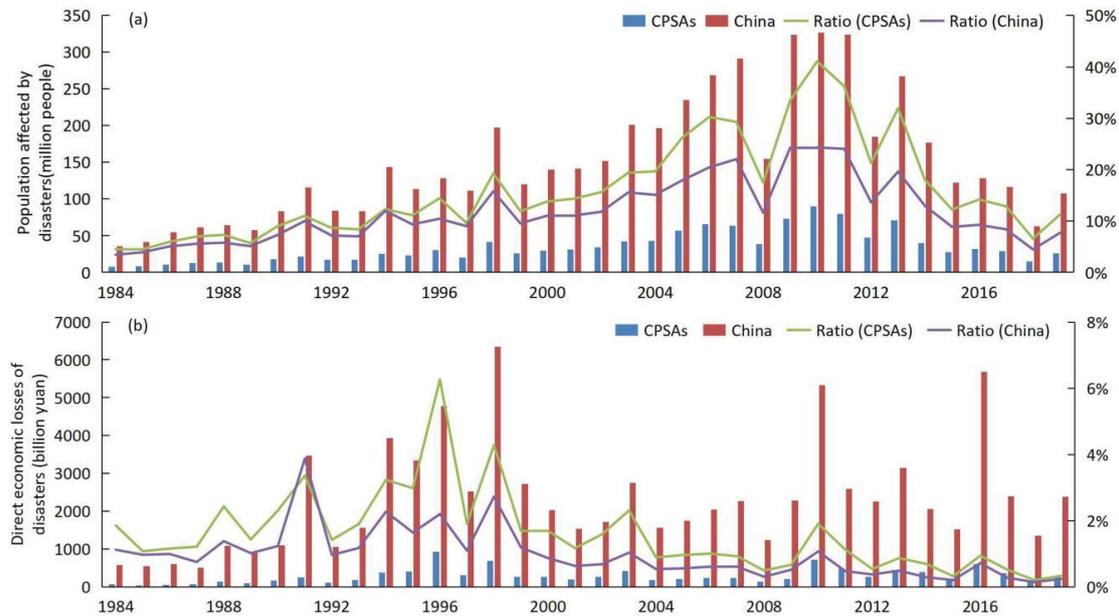


Figure 5. (a) Rainstorm and drought-affected population (million people) and its proportion in total population (%), and (b) direct economic losses caused by rainstorms and droughts (billion yuan) and its proportion in GDP (%) in CPSAs and China during 1984–2019.

As shown in Figure 6, the impact of rainstorms was more serious than droughts. Among the fourteen regions in CPSAs, the Wuling Mountain area (R7) exhibited maximum occurrence of 4.804 million people/year and 2.773 million people/year affected by rainstorms and droughts, respectively. By contrast, the Tibet region (R13) exhibited a minimum occurrence of 0.087 million people/year and 0.048 million people/year, respectively. From 1984 to 2019, the multi-year average of rainstorm and drought-affected population in CPSAs showed different characteristics between the eastern and western sides of the PDL (Figure 6a,b). Divided by PDL, the number of people affected by rainstorms and droughts in the regions to the east of the PDL reached 16.4 million people/year and 12.4 million people/year, which are 8.8 and 3.3 times higher than the population in the regions along and to the west of the PDL, respectively. In particular, the impact of rainstorms and droughts on the population in the regions to the east of the PDL was particularly severe.

4.2. Direct Economic Losses

In terms of total disaster losses, the average direct economic losses resulting from rainstorms and droughts in CPSAs reached 29 billion yuan/year from 1984–2019, accounting for 12.6% of the total national disaster losses, which is higher than the national share of the GDP of the region (7.7%) (Figure 5b). The direct economic losses due to rainstorms and droughts in CPSAs and China reached a peak of 93.1 billion yuan and 633.9 billion yuan in 1996 and 1998, respectively. The disaster-related losses in 1991, 1994, 1996, 1998, 2010, 2013 and 2016 were relatively high. To identify the extent of economic losses, the ratio of the mean direct economic losses due to rainstorms and droughts to GDP in CPSAs and China were 1.6% and 1%, respectively. Except for 1991, the ratio of disaster losses to GDP in CPSAs was higher than that of in China.

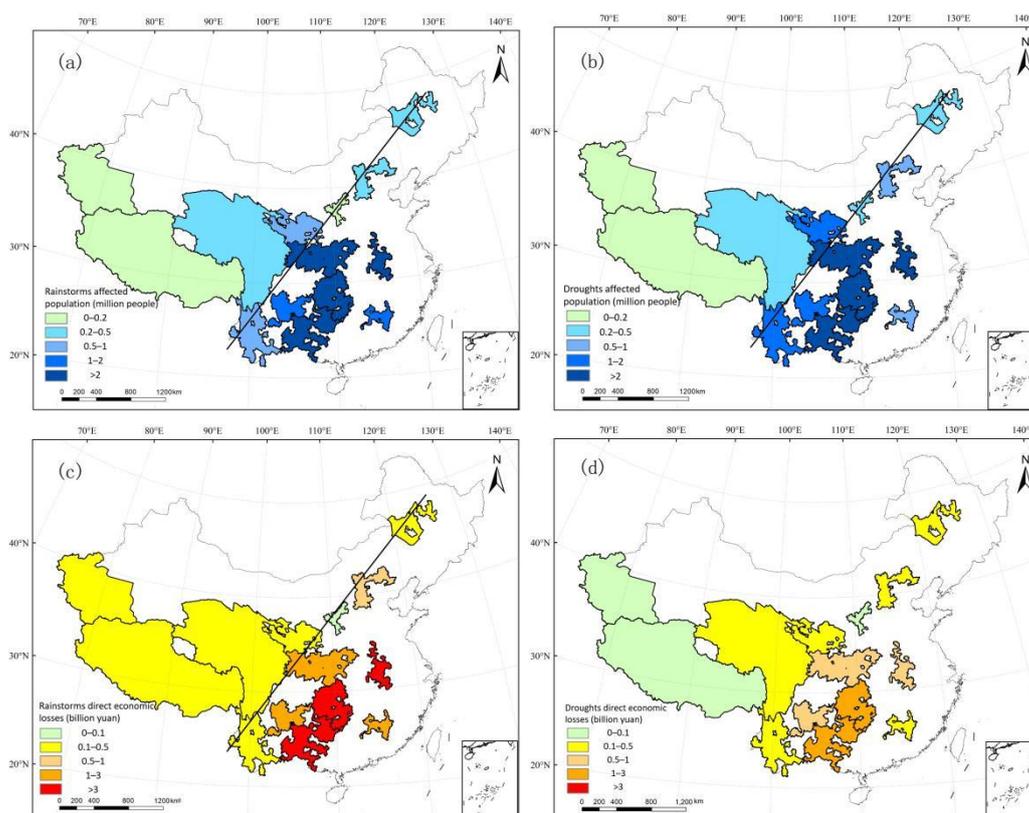


Figure 6. Spatial distribution of (a,b) disasters-affected population (million people) and (c,d) disasters-caused direct economic losses (billion yuan) due to (a,c) rainstorms and (b,d) droughts in CPSAs during 1984–2019.

From 1984 to 2019, the multi-year average direct economic losses resulting from rainstorms in CPSAs also showed significantly distinct characteristics between the eastern and western sides of the PDL. The economic losses caused by rainstorms were higher than those caused by droughts (Figure 6c,d). The region hit hardest by economic losses resulting from rainstorms and droughts was the Wuling Mountain area (R7), with direct economic losses of 7.103 billion yuan/year and 1.445 billion yuan/year resulting from rainstorms and droughts, respectively. The Lvliang Mountain area (R3) and Tibet region (R13) attained the lowest losses resulting from rainstorms and droughts, with losses of 0.098 billion yuan/year and 0.023 billion yuan/year, respectively. Divided by PDL, the direct economic losses due to rainstorms and droughts in the regions to the east of the PDL reached 20.3 billion yuan/year and 5.7 billion yuan/year, which are 9.2 and 7.4 times higher than those in the regions along and to the west of the PDL. Notably, the disaster-related losses in the regions to the east of the PDL were very severe.

As shown in Figure 7a, the trend of the total economic losses attributed to rainstorms and droughts from 1984 to 2019 increased, except in the Dabie Mountain area (R6), which showed a decreasing trend. All 13 other regions showed increasing trends, especially the regions along and to the west of the PDL, where the disaster-related losses increased faster. Among these areas, the Dabie Mountain area (R6), the Wuling Mountain area (R7) and the Luoxiao Mountain area (R11) showed statistically insignificant trends, while the increasing trends in the remaining 11 regions were significant at a confidence level of 95%.

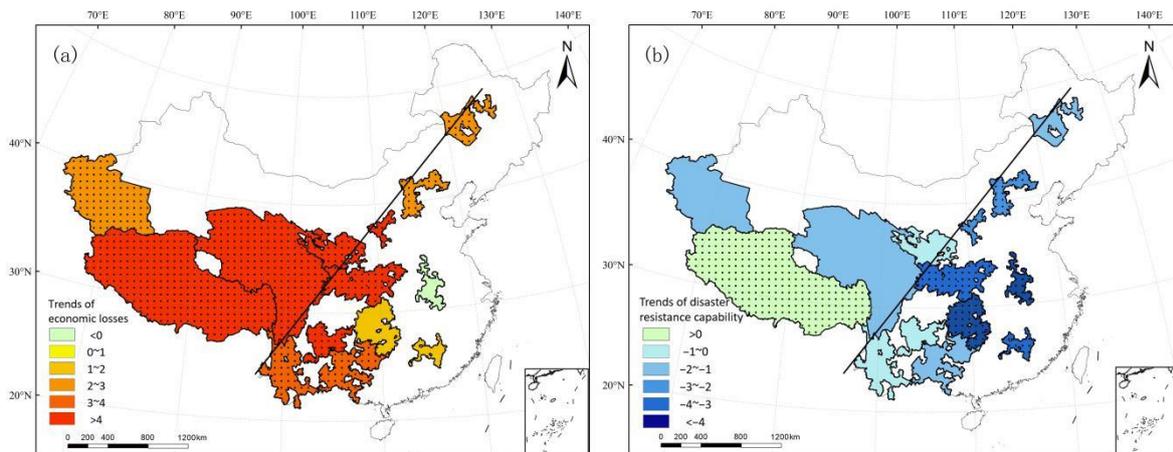


Figure 7. Spatial distribution of linear trends of (a) direct economic losses caused by rainstorms and droughts and (b) disaster resistance capability over CPSAs during 1984–2019. Black dots indicate the results are significant at a confidence level of 95%.

4.3. Disaster Resistance Capability

To identify the disaster resistance capability in each CPSA, average values of the LGR from 1984 to 2019 were calculated in this study (Figure 8). As shown by the solid line in Figure 8, the annual mean LGR in CPSAs is 1.1%. The LGR in the areas to the east of the PDL was generally higher than the average and the disaster resistance capabilities were relatively low. Among these regions, the disaster resistance capabilities in the Wuling Mountain area (R7) and the Luoxiao Mountain area (R11) were the lowest, with the LGR reaching 3% and 2.9%, respectively. The disaster resistance capabilities in the regions along and to the west of the PDL were relatively high.

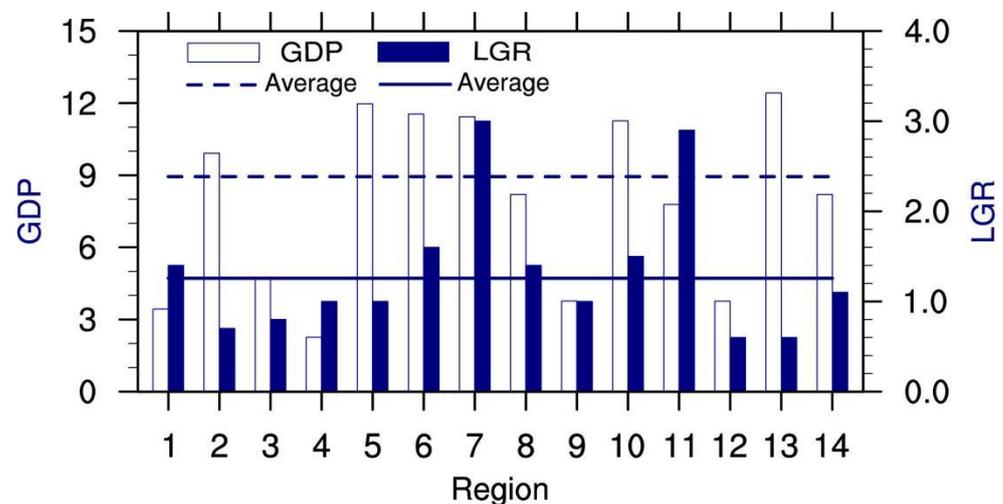


Figure 8. The average GDP per capita (yuan) and loss-to-GDP rate (LGR) (%) in CPSAs during 1984–2019. The serial numbers of CPSAs are the same as Figure 1. (1. Southern area of Daxing’anling Mountains; 2. Yanshan-Taihang Mountain Area; 3. Lvliang Mountain Area; 4. Liupanshan Area; 5. Qinba Mountain Area; 6. Dabie Mountain Area; 7. Wuling Mountain Area; 8. Wumeng Mountain Area; 9. West Yunnan Border Area; 10. Yunnan, Guangxi and Guizhou rocky desertification area; 11. Luoxiao Mountain Area; 12. Three prefectures of Southern Xinjiang; 13. Tibet Region; 14. Tibetan areas in four provinces).

The disaster resistance capabilities in CPSAs increased during 1984–2019, except for the Tibet region (R13) (Figure 7b). Among fourteen regions in CPSAs, the trends in the Yanshan-Taihang Mountain area (R2), the Lvliang Mountain area (R3), the Qinba Mountain

area (R5), the Dabie Mountain area (R6), the Wuling Mountain area (R7) and the Luoxiao Mountain area (R11) are significant at a confidence level of 95%. In the regions to the east of the PDL, for example the Dabie Mountain area (R6) and the Wuling Mountain area (R7), the resistance capabilities increased faster than other regions.

5. Summary and Discussion

5.1. Summary

The population, GDP and GDP per capita in CPSAs reached 210 million people, 1989.3 billion yuan, and 8943 yuan per person, accounting for 16.7%, 7.7%, and 46.9% of China's total amounts, respectively. To consolidate the achievements in the elimination of absolute poverty in China and prevent rural populations from returning to poverty due to meteorological disasters, this study analyzed the spatiotemporal characteristics of rainstorms and droughts and their socioeconomic impacts in China's CPSAs from 1984 to 2019.

The annual average rainstorm and drought days in CPSAs were approximately 1.9 days/year and 44.6 days/year, respectively. It gradually decreased from southeast to northwest. The number of rainstorm days showed a significant increasing trend of 0.075 days/decade, while the decreasing trend of the number of drought days was not significant. Due to rainstorms and droughts, the average annual affected population and direct economic losses in CPSAs reached 34 million people/year and 29 billion yuan/year, accounting for 22.9% and 12.6% of China's total amounts, respectively. The average annual loss rate due to disasters in this region reached 1.6%, which is 0.6% higher than the national level.

Furthermore, distinct features and socioeconomic impacts of rainstorms and droughts were identified on the southeastern and northwestern sides of the PDL along Tengchong-Aihui in China. Droughts often impacted the regions located along the PDL, while rainstorms and droughts occurred more frequently in the regions to the southeast of the PDL than in the regions to the northwest of the PDL. As a result, the affected number of people and direct economic losses due to rainstorms and droughts in the regions to the southeast of the PDL reached 16.4 million people/year and 20.3 billion yuan/year, and 12.4 million people/year and 5.7 billion yuan/year, which were 8.8, 9.2, 3.3 and 7.4 times higher than those in the regions to the northwest of the PDL. Although there were more affected people and higher direct economic losses due to rainstorms and droughts in the regions to the east of the PDL, the disaster resistance capabilities were significantly improved. In contrast, the regions to the northwest side of the PDL showed a significant increasing trend of losses with relatively low disaster resistance capabilities.

5.2. Discussion

From the perspective of rainstorms and droughts, drought conditions were more severe in regions along the PDL, and both rainstorms and droughts were relatively severe in the regions to the east of the PDL. In addition, the number of rainstorm days significantly increased in the entire study area. Rainstorm-induced disasters became increasingly serious, and only the number of rainstorm days in the Southern area of Daxing'anling Mountains (R1), the Dabie Mountain area (R6), the West Yunnan Border Area (R9) and the southern part of the Tibetan areas in four provinces (R14) showed a decreasing trend. The number of drought days decreased in the entire study area, especially the drought conditions in the three prefectures of southern Xinjiang (R12), the Tibet region (R13) and the Tibetan areas in four provinces (R14), whereas the drought conditions in the West Yunnan Border Area (R9) and the southern part of the Tibetan areas in four provinces (R14) and the number of drought days in the West Yunnan Border Area (R9), the southern Tibetan areas in four provinces (R14) and the eastern Tibet region (R13) notably increased.

According to a comprehensive analysis of the direct economic losses, economic level and disaster resistance capabilities in CPSAs, the disaster-related losses significantly increased, and at a higher rate than that of the regions to the east of the PDL, while the

disaster resistance capabilities did not increase significantly. The situation in the regions to the east of the PDL was the opposite, with high disaster losses but at a lower rate, and the disaster resistance capabilities were improving. The disaster resistance capabilities in the Lvliang Mountain area (R3), the Liupan Mountain region and the three prefectures of southern Xinjiang (R12) were satisfactory, although the GDP per capita was slightly lower than that in the other regions. It is worth noting that the disaster resistance capabilities in the Yanshan-Taihang Mountain area (R2), the Wuling Mountain area (R7), Yunnan, the Guangxi and Guizhou rocky desertification area (R10) and the Tibet region (R13) were relatively low. The GDP per capita in these 4 regions is higher than that of other regions, their cost in disaster prevention and reduction might be relatively low (Figure 8). These regions should enhance the disaster prevention consciousness and increase investment in disaster reduction and prevention facilities. Meanwhile, the number of affected population due to rainstorms and droughts in CPSAs showed a remarkable increase after 2000 (Figure 5a). This might be ascribed to the increase in rainstorm days and population exposed to the disasters since the population in CPSAs increased after 2000, with a growth of 39.7% relative to 1984–1999 (Figure 2a). Therefore, the government should take the occurrence of rainstorms and droughts into consideration during urban planning and land use planning in CPSAs to reduce the exposure and risk of population and economy to disasters.

For a long time, the international community has paid great attention to the relationship between poverty and natural disasters. For example, the reduction of rainfall has slowed the economic growth of sub-Saharan Africa [42]. Climate change has plunged 6.5% of the population of Latin America into poverty and vulnerability [43]. Previous studies have reported that disasters will aggravate poverty and recovery is not straightforward for poor people [44]. Under global warming, the frequency and intensity of rainstorms and droughts might increase significantly over CPSAs [6,7]. Correspondingly, the average annual direct economic losses due to rainstorms is expected to be 4 times and 17 times higher than it is currently under global warming of 1.5 °C and 4.0 °C [45]. As the relatively poor area in China, it is necessary to pay close attention to the socio-economic impact and risks of rainstorms and droughts over CPSAs in the future. Hence, the above-mentioned regions with high GDP per capita but low disaster resistance capabilities should strengthen their awareness of disaster prevention and mitigation, enhance early warnings and disaster relief inputs in response to meteorological disasters, and improve the disaster resistance capabilities to meet climate change challenges. This is an important part of consolidating China's gains in poverty eradication and further contributing to the realization of SDGs.

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