Analysis of Dry-Wet Climate Change Characteristics and Main Influencing Factors in Main Grain Producing Area of Tibet from 1980 to 2021

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Abstract Based on the daily meteorological observation data of seven meteorological stations in southern Tibet from 1980 to 2021 (April - October), the temporal and spatial variation characteristics and influencing factors of aridity index (*AI*) in the growing season of major grain producing areas in Tibet were studied by using climate tendency rate, Mann-Kendal test, Morlet wavelet analysis, GIS hybrid interpolation method, Pearson correlation coefficient, contribution rate analysis and other methods. The results showed that the average *AI* in the main grain producing areas of Tibet was 1.7, which belonged to the semi-arid area, and the overall trend was decreasing (humidifying) (-0.036/10 a). The linear decreasing trend was different in different regions, and the area around Lhatse County was the most significant (-0.26/10 a). *AI* had no obvious abrupt change, and had long- and medium-term fluctuation characteristics of 24 years, 6 years. The spatial distribution was uneven, and had the characteristics of 'shrinking arid area and expanding humid area'. The contribution rates of the main climate influencing factors of AI varied in different regions. In general, the contribution rates after quantification was as follows: precipitation (34.9%) > relative humidity (28.4%) > sunshine (19.9%) > maximum temperature (12.4%).

Key words Tibet; Main production area; Climate; Aridity; Contribution rate

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Under the background of global climate change characterized by global warming, the natural factors of water cycle and the temporal and spatial distribution of water resources have changed obviously. Some areas are getting humid, while others are getting arid, that is, the dry-wet climate pattern has evolved to varying degrees[1-2]. The non-uniformity of this evolution is manifested in the increased uncertainty of seasonal and regional drought disasters in Tibet. Drought disaster has become one of the most serious agro-meteorological disasters in Tibet, and it is also the most serious meteorological disaster in this region except snow disaster[3-4]. The dry-wet climate pattern not only determines the quality of crop water conditions in this region, but also directly affects the local agricultural production types and crop layout[1,5]. Under this background, the research on dry-wet climate change has attracted more and more attention from academic circles, and many scholars at home and abroad have also carried out a lot of research in areas with obvious dry-wet changes[6-13]. The research method mainly uses Penman-Monteith model recommended by Food and Agriculture Organization of the United Nations (FAO) to calculate the maximum potential evapotranspiration ET_0, and then obtains the surface dry-wet index (moisture index MI, aridity index AI), analyzes its interannual variation trend, interdecadal variation characteristics, seasonal differences and abrupt changes, and discusses its relationship with influencing factors such as precipitation, humidity, sunshine, temperature and wind speed. However, in Tibet, Du *et al.* [11-12] mainly conducted in-depth research in northern Tibet[11] and Yajiang River Basin[12] with the moisture index MI in the early years. Since 2015, Shi *et al.* [13] perfected ET_0 abrupt change and periodic fluctuation characteristics in Tibet. Previous studies mainly focused on watershed desertification and grassland degradation, and the breakthrough point was mainly potential evapotranspiration. However, there are relatively few studies on identifying disaster risks, drawing the potential impact to agriculture and putting forward adaptive countermeasures based on the quantitative analysis on the change of dry-wet climate pattern and the contribution of its influencing factors in main grain producing areas of the plateau. From 2020 to 2021, the calculation methods of sensitivity coefficient and contribution rate were introduced by Duan *et al.* [14] and Qiao *et al.* [15] in the analysis of the dominant meteorological factors of plateau potential evapotranspiration in Yarlung Zangbo River basin[14] and Lhasa River basin[15]. Meanwhile, Yang *et al.* [16] applied this method to complete a meteorological factor response analysis on the aridity index (AI) in the Yangtze River basin. It can be seen the quantitative contribution rate can be applied not only in the influencing factor response analysis in plain areas and potential evapotranspiration (ET_0), but also in plateau areas and aridity index (AI). Therefore, in this study, focusing on taking the crop growing season as

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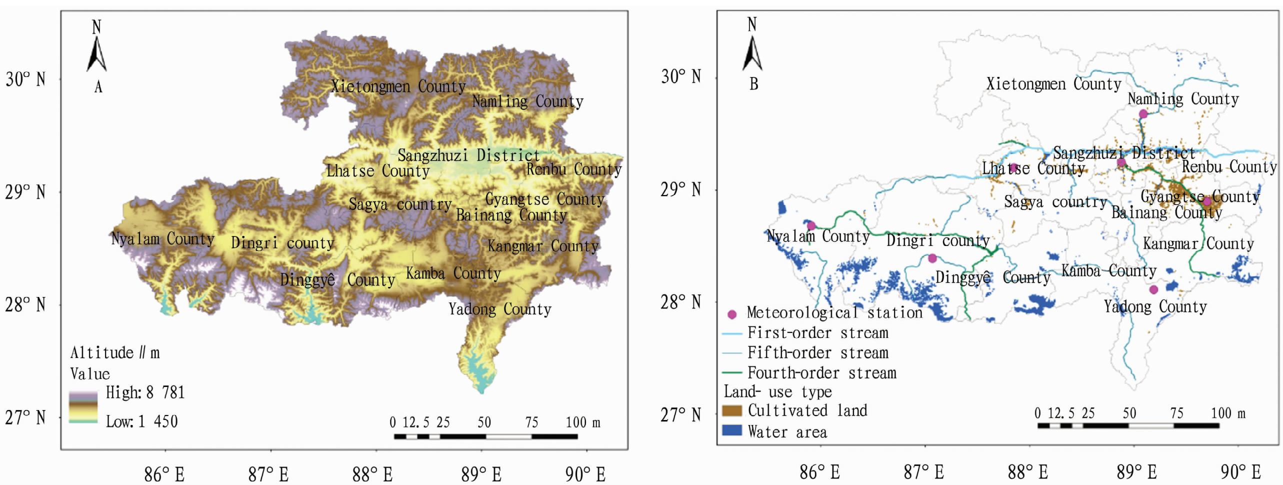
the time scale and the main grain producing areas in Tibet (southern Tibet) as the research area, the temporal and spatial changes of the aridity index (AI) from 1980 to 2021 and the sensitivity coefficients and contribution rates of its main influencing factors were calculated to discuss the characteristics of dry-wet climate change in the growing season in main crop producing areas of the plateau in depth and expound the quantitative contribution of key meteorological factors, aiming to provide some theoretical references for local agricultural climate services and agricultural adaptation to climate change.

Data and Methods

General situation of study area

Main grain producing areas in Tibet (southern Tibet) was chosen as the study area, which is known as the "Tibet granary" and includes the middle reaches of the Yarlung Zangbo River. Meanwhile, most of the counties within the jurisdiction are distributed with fourth or fifth order streams as the mother river, and the lower reaches of the river system are open fields with relatively low altitude, which provides natural water and soil advantages for the main crop producing areas of the plateau. The daily precipitation, average temperature, average highest temperature, average lowest temperature, sunshine hours, average wind speed and air relative humidity from April to October, 1980 – 2021 (that is, the crop growing season) in seven surrounding meteorological stations with long data series in this area were selected, and meanwhile, with reference to the basic topographic resource data such as the administrative vector boundary (1 : 10 000) and DEM digital elevation throughout Tibet, the location of the study area was cut out from the geographical information data of Tibet through GIS as the basic data for regional analysis. The topography of the study area and the distribution of selected meteorological stations, river systems, cultivated land and water areas (snow-capped mountains and lakes) are shown in Fig. 1.



A. Relief map; B. Distribution map of water system, cultivated land and stations; This map is drawn based on the standard map with the approval number of Zang S(2021)007, and the base map has not been modified. The same below.

Fig. 1 Schematic diagram of location of the study area

Research methods

Calculation of aridity index The aridity index[1] was calculated by using the calculation method commonly used in the dry-wet analysis in the production of previous climate zoning atlas in China, as shown in Formula (1).

$$AI = \frac{ET_0}{P} \tag{1}$$

In the formula, AI stands for aridity; ET_0 represents potential evapotranspiration in crop growing season calculated by the Penman-Monteith method recommended by FAO; and P is the precipitation in crop growing season.

Calculation of potential evapotranspiration Penman-Monteith formula is a P-M model recommended and revised by FAO in 1998. Based on the theory of energy balance, water vapor diffusion and aerodynamics, it uses water vapor pressure, net radiation, air drying power at a certain temperature and wind speed to determine the potential evapotranspiration, taking into account not only the physiological characteristics of crops, but also the changes of aerodynamic parameters. This model is suitable for humid and arid areas, and has a solid theoretical foundation and clear physical significance, and it is widely used in the classification and analysis of climate and vegetation, as well as climate zoning in China[2,11,13]. It is specifically shown in formula (2).

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \tag{2}$$

In the formula, ET_0 is the potential evapotranspiration; R_n is the surface net radiation; G is the soil heat flux; γ is the hygrometer constant, e_s is the average saturated vapor pressure; e_a is the actual vapor pressure; U_2 is the average wind speed at a height of 2 m; and $\triangle$ is the slope of the saturated vapor pressure curve. The calculation methods of R_n, $\triangle$, G, e_s, e_a and U_2 referred to Zhang *et al.*[9,11,13,17–18], which will not be expanded in detail here.

Contribution rate of meteorological factors In previous studies[14-16], the changes of ET_0, AI and other parameters caused by a meteorological factor is quantitatively calculated by multiplying the sensitivity coefficient of the meteorological factor by the multi-year relative change rate, that is, the contribution of the factor to the change of ET_0, AI, *etc*. The positive (negative) contribution rate indicates the increase (decrease) in AI caused by the factor, and a large (small) absolute value indicates that the influence of the meteorological factor on AI change is large (small). The calculation of contribution rate[14-16] is shown in formulas (3) to (5).

$$Con_{v_i} = S_{v_i} \times RC_{v_i} \quad (3)$$

$$S_{v_i} = \lim_{\Delta v_i \to 0}\left[\frac{\Delta AI/AI}{\Delta v_i/v_i}\right] = \frac{\partial AI}{\partial v_i} \times \frac{v_i}{AI} \quad (4)$$

$$RC_{v_i} = \frac{\Delta v_i}{\overline{v_i}} = \frac{n \times Trend_{v_i}}{|v_i|} \times 100\% \quad (5)$$

In the formulas, Con_{v_i} is the contribution rate; S_{v_i} is the sensitivity coefficient of meteorological factor v_i, and RC_{v_i} is the relative change rate of the meteorological factor for many years during the research period. The calculation method of sensitivity coefficient adopted the method of Duan *et al.* [14], in which one of the main influencing factors determined by the correlation coefficient test results was changed by −1 to 1 in turn, and the amplitude of each change was 0.1 times that of the factor, and the average value of $\frac{\Delta AI}{\Delta v_i}$ after each change was obtained as a coefficient, and the final result was obtained after nondimensionalization by multiplying the coefficient by $\frac{v_i}{AI}$. In the calculation of relative change rate, $Trend_{v_i}$ is the climate tendency rate of the meteorological factor, $|v_i|$ is the multi-year average value of the meteorological factor, and n is the study period (years).

Other methods Mann-Kendall test was used for trend diagnosis and abrupt change test of 42-year long series aridity index, and the specific algorithm referred to Zhang *et al.* [18-19]. Morlet wavelet analysis is very suitable for indicating the periodic change of aridity index in a long historical series, which can not only accurately identify the characteristics of main periods and periodic change, but also predict the future periodic trend, and the algorithm referred to references [20-21]. The mixed interpolation method (three-dimensional quadratic trend surface + residual interpolation) was adopted in the dry-wet zoning. This method builds an interpolation model by stepwise regression of macro-geographical environmental factors such as latitude and longitude and altitude with aridity index, and realizes the spatial interpolation of grid points through ArcGIS technology. This method is often used to simulate the spatial distribution law of resources, environment and other elements. The specific algorithm referred to Shabiti *et al.* [22-23], and other spatial interpolation adopted the Inverse Distance Weighted Method (IDW).

Results and Analysis

Interdecadal variation characteristics of climatic aridity and humidity

Under the global climate change with the background of global warming, the aridity index in the growing season of major grain producing areas in Tibet experienced various changes on the interdecadal scale from 1980 to 2021. According to the temporal variation trend of aridity index in the growing season of the main grain producing areas in Tibet shown in Fig. 2, the multi-year average value of aridity index was 1.7 (semi-arid); the maximum value was 3.2 (semi-arid), which appeared in 2015; and the minimum value was 1.0 (semi-humid), which appeared in 2000. Overall, the aridity index showed a decreasing (humidifying) trend with time, and the decreasing trend was −0.036/10 a, which failed the significance test. Judging from the multi-year average value, the aridity index was above the average value in 1980s and 1990s, and decreased to below the multi-year average value since the 21st century, that is, the climate became obviously wet in the 21st century. In 28 of the 42 years, the aridity was below the average (1.67), accounting for 66%, that is, more than half of the years showed values below the average. Meanwhile, we could also see that the aridity had been lower than the average since 2010, except for the extreme maximum in 2015, that is, the climate was relatively wetter than before. According to the 10 a moving average, the aridity index in the growing season of the main grain producing areas in Tibet experienced two decreasing (humidifying) trends from 1980s to 2000, and the two valleys respectively corresponded to 1986−1992 and 1996−2005.

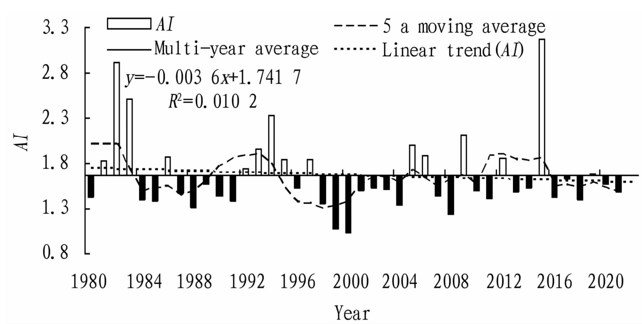


Fig. 2 Temporal variation trend of aridity index in the growing season of main grain producing areas in Tibet

Abrupt change and periodic characteristics of climatic aridity and humidity

The Mann-Kendall method was applied to conduct a 42-year long series change trend analysis and abrupt change test on the aridity index in the growing season of major grain producing areas in Tibet, and two statistical curves of UF and UB were drawn on the same graph under the condition of significance level a = 0.05. As can be seen from Fig. 3, there were obvious intersections between UF and UB curves in 1983 and 1994. After the intersections, the UF curve was less than 0 in both 1983−1993 and 1998−2021, but did not break through the critical line of 0.05 (significant), indicating that AI did not have a turning point. Specifically, after 1983, the AI sequence generally showed a downward (humidifying) trend, and after experiencing a short-term increase (short-term drying) in the early 1990s, it showed a continuous downward (humidifying) trend from 1994. Since 2004, the decreasing range (humidifying range) began to decrease, but it was still in a decreasing state (humidifying state).

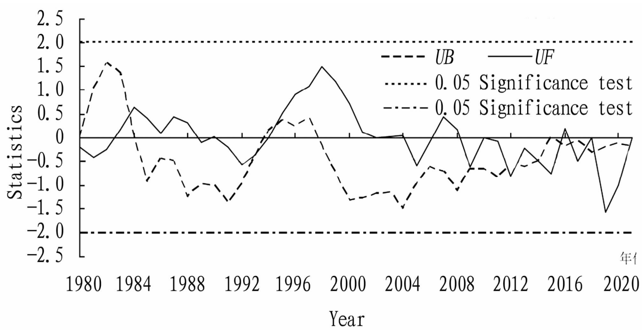


Fig. 3 Mann-Kendall variation trend and abrupt change test of aridity index in the growing season of main grain producing areas in Tibet

At the same time, Morlet wavelet analysis was adopted for a 40-year periodic test on the aridity index in the growing season of main grain producing areas in Tibet. From the wavelet real part distribution and wavelet variance analysis in Fig. 4, it was concluded that there are two main periods, of which the first main period of aridity index was 24 years, and there was a periodic change of 16 – 18 years under the condition of 24-year time scale. The second main period of aridity index was 6 years, and there was a periodic change of 3 – 4 years under the condition of 6-year time scale. Judging from the overall fluctuation trend, in the long-term and medium-term fluctuation which 2021 was involved in, the isoline of wavelet transform was not closed, and it is speculated that the aridity index will maintain a decreasing trend (humidifying trend) after 2021.

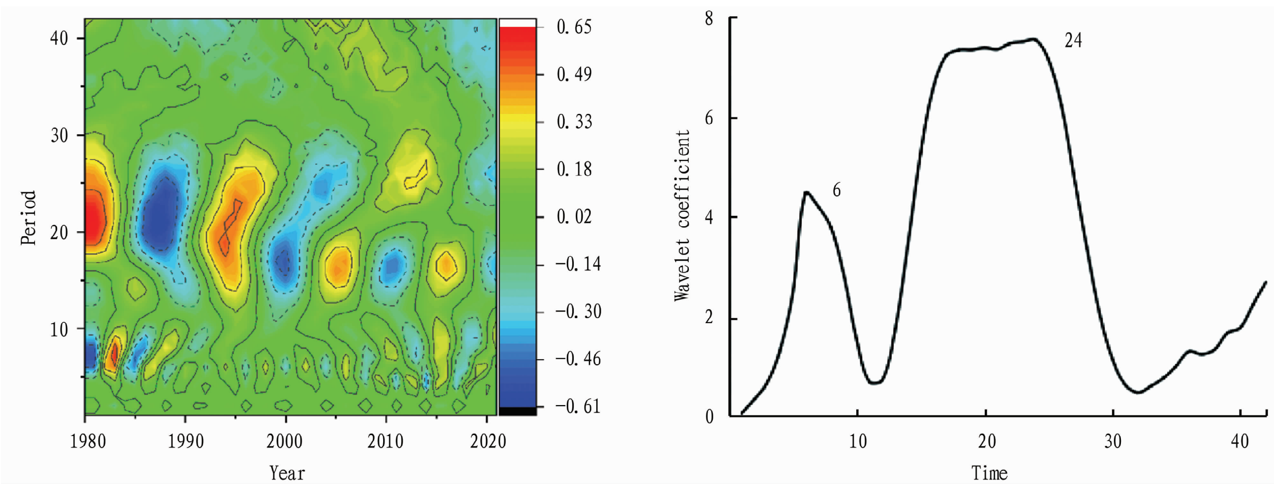


Fig. 4 Morlet wavelet real part distribution and wavelet variance of aridity index in the growing season of main grain producing areas in Tibet

Spatial pattern characteristics of climatic aridity and humidity

The spatial pattern of aridity index in major producing counties was analyzed, and the above-mentioned mixed interpolation method was adopted to comprehensively consider topographic factors for zoning. It could be seen from Fig. 5 that the main grain producing areas in Tibet were generally at the semi-arid climate level, which is consistent with previous research results. The subdivided low-aridity zones (humid zones) were located in Nyalam and Yadong in the western and southern marginal areas, Sangzhuzi in the north-central part, southern namling county and other areas, with aridity ranging from 0.5 to 1.5. The high-aridity zones (arid zones) were located in most parts of Dingri and parts of Gyangtse, Kangmar and Renbu counties, with aridity ranging from 2.5 to 3.5. The aridity in other areas was 1.8 – 2.5.

Spatial distribution characteristics of linear variation trend in climatic aridity and humidity

The aridity and humidity of climate fluctuate from decade to decade, and the major producing counties also experience an increase or a decrease in aridity (a humidifying or drying trend). It can be seen from Fig. 6 showing the spatial distribution of the linear variation trend in aridity index in the growing season of main grain producing areas in Tibet that the aridity exhibited a decreasing (humidifying) tend mostly, especially in the area of Lhatse County, with a decreasing rate reaching –0.26/10 a. Meanwhile, it showed a slight increasing (drying) trend around Nyalam County, with an increasing rate of 0.09/10 a, and there was no obvious change in the zone from Yadong to Sangzhuzi. However, in the past 42 years, the climate aridity index of major grain-producing counties showed a relatively stable decrease (stable humidifying trend).

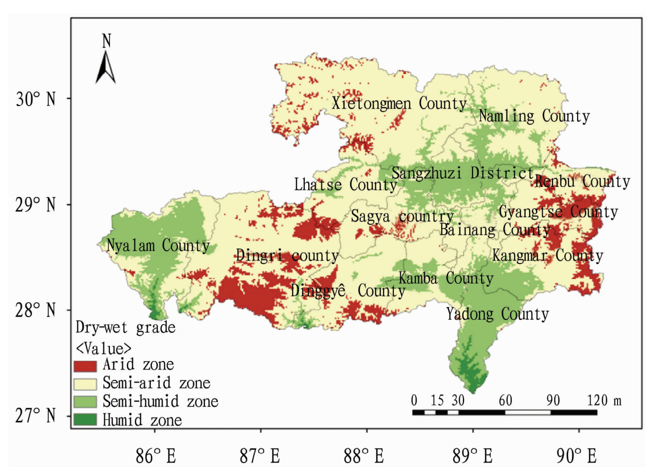


Fig. 5 Spatial pattern and dry-wet grade zoning map of aridity index in the growing season of main grain producing areas in Tibet (1980 – 2021)

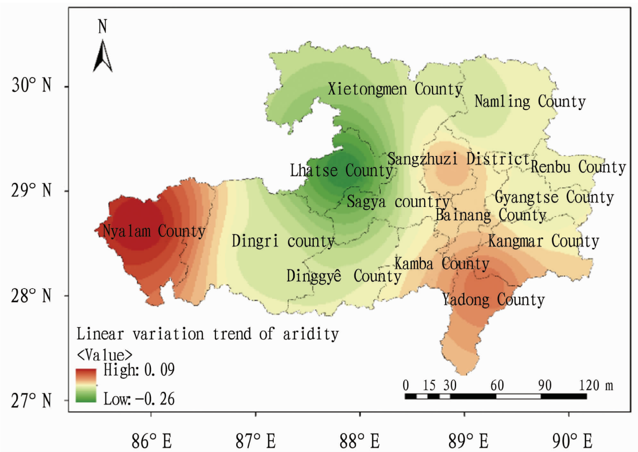


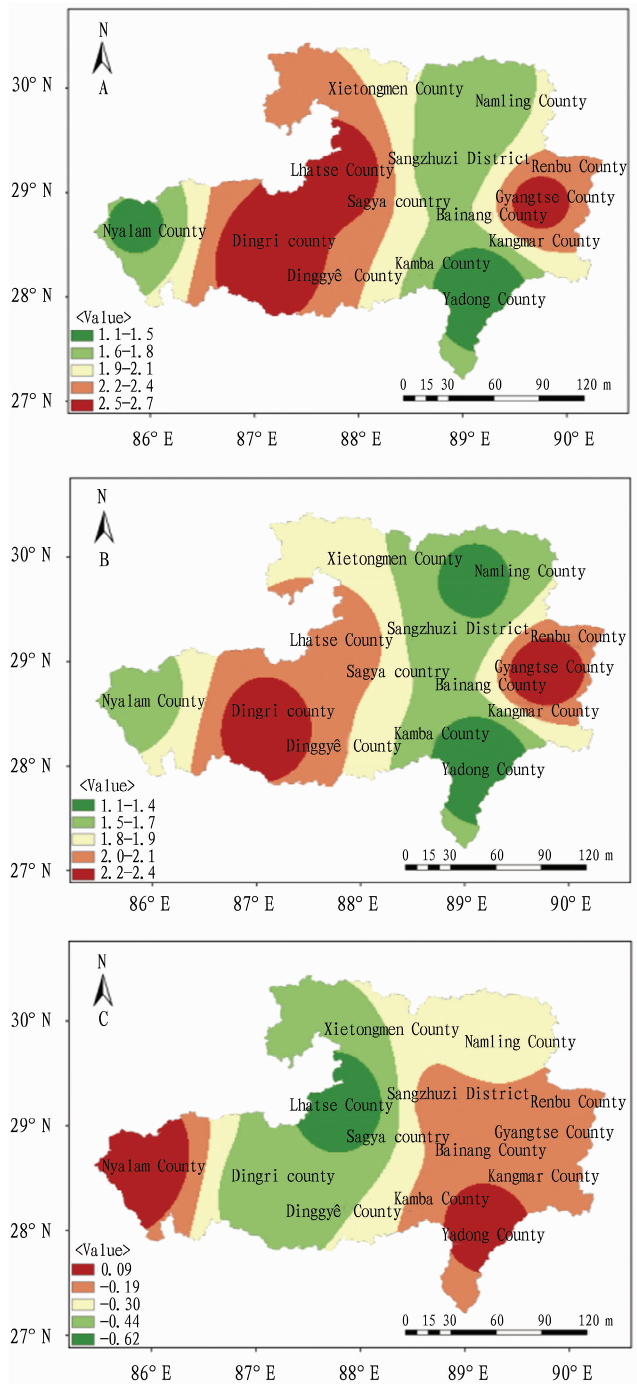
Fig. 6 Spatial distribution of linear variation trend in aridity index in the growing season of main grain producing areas in Tibet (1980 – 2021)

Variation characteristics of climate dry-wet pattern

According to the characteristics of abrupt change, 1994 was taken as the demarcation year, and before 1980 – 1994 was defined as before demarcation, and after 1994 – 2021 was defined as after demarcation. The analysis on the spatial distribution of aridity index before and after demarcation showed that the aridity index was 1.1 – 2.7 before the demarcation in Fig. 7a, and the value decreased (humidifying) to 1.1 – 2.4 after the demarcation in Fig. 7b, while the range was reduced, and the overall performance was characterized by " shrinking range of high-value areas (arid areas) and expanding range of low-value areas (humid areas)". The value in the high-value areas decreased (humidifying) from 2.2 – 2.7 before the demarcation to 2.0 – 2.4 after the demarcation, and the specific changes were reflected in the Dingri and Lhatse line in the west. Fig. 7c shows the variation ranges of aridity in different areas before and after the demarcation. After the demarcation, the aridity index was mostly decreasing (humidifying), and the largest decrease range was located in the area of Lhatse County, with a decrease reaching – 0.62 (humidifying). The second place was taken by the whole Dingri County, the western Dingjie County, the western Xietongmen and other areas, with a decrease of – 0.44 (humidifying). Moreover, the aridity index of Pagri zone in Nyalam and Yadong exhibited a slight increase (slight drying), with an amplitude of 0.09.

Main meteorological factors affecting aridity index

Pearson correlation coefficients of meteorological factors Analysis From Table 1, it could be seen that, on the whole, the aridity index *AI* had a extremely strong negative correlation with precipitation, a strong negative correlation with relative humidity and a strong positive correlation with sunshine hours, passing the significance test of the 0.01 level. The aridity index *AI* was also in a weak positive correlation with the highest temperature and wind speed, passing the significance test of the 0.05 level. However, the correlation with average temperature and the lowest temperature was very weak or they were uncorrelated. The results showed that AI was directly proportional to evapotranspiration and inversely proportional to precipitation, and the correlation coefficient with precipitation reached – 0.88, indicating that precipitation was the main factor affecting arid climate in the main grain producing areas of Tibet. Sunshine, relative humidity, the highest temperature and wind speed affected the changes in aridity and humidity by affecting evapotranspiration. Sunshine and relative humidity were main factors affecting evapotranspiration, while the highest temperature and wind speed were secondary factors. The change in the lowest temperature produced no obvious effect. Generally speaking, the correlation degrees were ranked as precipitation > sunshine hours >

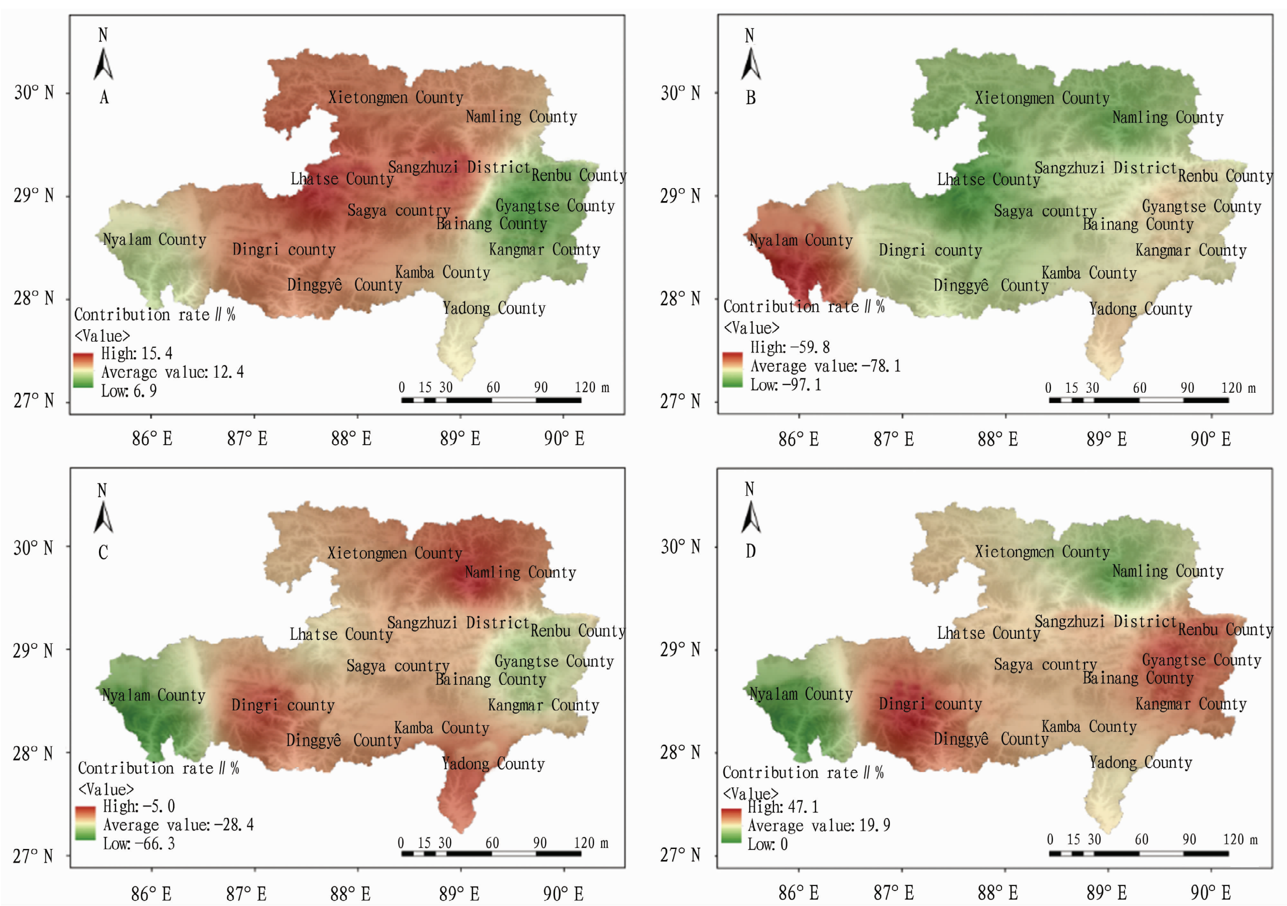


A. Before demarcation; B. After demarcation; C. Difference (after-before).

Fig. 7 Spatial distribution of aridity index (1980 – 2021)

relative humidity > highest temperature > wind speed > average temperature > lowest temperature. It was determined that the first four factors were main meteorological factors affecting the aridity index.

Analysis on contribution rates of meteorological factors According to the above correlation analysis, the highest temperature, precipitation, relative humidity and sunshine hours were the main meteorological factors affecting AI in the growing season of main grain producing areas in Tibet, so the contribution rates of these four meteorological factors to AI were quantitatively analyzed. From Fig. 8a, it can be seen that the contribution rates of the highest temperature were in the range of 6.9% - 15.4%, with an average of 12.4%. The main grain producing areas in Tibet were positive value areas overall, indicating that the increase of the highest temperature caused an increase in AI (drying) in this region, and the high value area was in the north-central part. From Figure 8b, it can be found that the contribution rates of precipitation were in the range of -97.1% - 0.3%, with an average of -78.1%. Except for Nyalam, most areas showed a negative value, indicating that the increase in precipitation caused a decrease in AI (humidifying) in this region. From Figure 8c, it can be found that the contribution rates of relative humidity ranged from -66.3% to -5.0%, with an average value of -28.4%. The values were overall negative, indicating that an increase in relative humidity caused a decrease in AI (humidifying), and the high-value areas were located in the north-central and south. From Fig. 8d, it can be found that the contribution rates of sunshine were in the range of 0% -47%, with an average of 19.9%. The values were positive on the whole, indicating that an increase of sunshine would cause an increase in AI (drying), and the high value areas were in Dingri, Gyangtse and other places. It could be seen that the contribution rates of various factors were different in different regions. The highest temperature contributed the most (15.4%) in the area from Lhatse to Sangzhuzi, while precipitation contributed the most (97%) in the area from Lhatse to Shigatse to Namling in the north-central part, and relative humidity was the one with the highest contribution (66%) in Nyalam, and sunshine hours contributed the most (47%) in Dingri and Gyangtse. Generally speaking, the average absolute values of the contribution rates, that is, the values of contribution degree, were ranked as precipitation (34.9%) > relative humidity (28.4%) > sunshine (19.9%) > highest temperature (12.4%).



A. Highest temperature; B. Precipitation; C. Relative humidity; D. Sunshine hours.

Fig. 8 Spatial distribution of contribution rates of main meteorological factors to the change in aridity index in main grain producing areas of Tibet (1980 - 2021)

Discussion on the potential impact of dry-wet climate change on plateau agriculture and its adaptation countermeasures

Discussion on potential impact The main grain producing areas in Tibet was located in the southwest of Qinghai – Tibet Plateau, with high seasonal crop water shortage, low available water capacity and low irrigation rate[4]. The degree of climate aridity and humidity in this area has a huge potential impact on agriculture. At present, the mainstream academic circles believe that the pattern of water and heat resources in the Qinghai – Tibet Plateau has changed under climate change, and that warming and wetting will expand the planting area of crops and be beneficial to crop yield (moderate confidence)[24]. Meanwhile, it is pointed out that precipitation is generally increasing, which is a favorable factor for prolonging the growth period of crops in Qinghai – Tibet Plateau[4]. Therefore, we believe that the overall dry and wet climate change trend in the main grain producing area of Tibet is conducive to crop growth.

Discussion on adaption strategy Through the analysis of the climatic aridity index, it is clear that the climate of major grain-producing counties in Tibet showed a slow humidifying trend from 1980 to 2021, with the characteristics of shrinking arid area and expanding humid area. However, some main producing areas, such as Dingri-Lhatse area in the west, were still in a situation of relatively arid climate, while Nyalam area showed a weak drying trend, so the spatial distribution of aridity index was extremely uneven. The results of many frontier studies, especially the prediction of future climate scenarios, relatively conformably show that the annual/seasonal precipitation in the Qinghai – Tibet Plateau will increase in the future, and the temporal and spatial distribution of the increasing trend of precipitation will be uneven, and the uncertainty of seasonal and regional droughts in the future is still great[4]. Therefore, it is necessary to strengthen drought monitoring, assessment and early warning based on complete irrigation facilities, supplemented by natural precipitation, and we also should make rational use of air water resources, carry out weather modification in a timely manner, and adjust regional planting structure and agricultural development model when necessary to better cope with climate change.

Conclusions

(1) Inter-annual variation characteristics: During the growing season in major grain producing areas of Tibet from 1980 to 2021, the dry-wet grades remained at semi-arid, which was consistent with the mainstream scientific cognition, and the overall change showed a decreasing (humidifying) trend with time, with the decreasing trend of 0.036/10 a, but it failed the significance test. Among these areas, Lhatse area was more obvious, with a decline rate of 0.17 – 0.26/10 a; and the AI abrupt change test did not break through the 0.05 significance test, and there was no obvious turning point change. There were two main periods in the series, and the first main period of aridity index was 24 years, and there was a periodic change of 16 – 18 years under the condition of 24-year time scale. The second main cycle of aridity index was 6 years, and there was a periodic change of 3 – 4 years under the condition of 6-year time scale. Judging from the overall fluctuation trend, in the long- and medium-term fluctuation where 2021 was located, the isoline of wavelet transform was not closed, and it is speculated that the aridity index will maintain a decreasing trend (humidifying trend) after 2021.

(2) Spatial pattern characteristics: The climate in the main grain producing areas of Tibet was unevenly distributed, and the low-aridity areas (humid areas) were located in Nyalam and Yadong in the western and southern marginal areas, Sangzhuzi in the north-central part, and southern Namling county, with aridity ranging from 0.5 to 1.5; and the high-value areas (arid areas) were located in most parts of Dingri and some counties such as Gyangtse and Renbu, and the aridity was 2.5 – 3.5. Meanwhile, taking 1994 as the demarcation year, the spatial distribution of aridity index before and after the demarcation was analyzed, and the variation range of aridity in different regions before and after the demarcation was clarified. After the demarcation, the maximum decrease of aridity index (humidifying) was located in the area of Lhatse County, with a decrease of 0.62 (humidifying); the second place was taken by the whole Dingri County, the western Dingjie County, the western Xietongmen and other areas, with a decrease of 0.44 (humidifying); and the decline in most other places was within 0.1. The degree of climate aridity and humidity was still semi-arid, and the range remained basically the same, but after the demarcation, the overall performance was characterized by "shrinking range of arid area and expanding range of humid area".

(3) Analysis on main influencing factors of dry and wet climate: Precipitation was the dominant factor affecting the arid climate in main grain producing areas of Tibet. The highest temperature, precipitation, relative humidity and sunshine hours were the four main meteorological factors that affected the growing season AI of main grain producing areas in Tibet, and their contribution rates were different in different regions. Generally speaking, the average absolute values of the contribution rates, that is, the values of contribution degree, were ranked as precipitation (34.9%) > relative humidity (28.4%) > sunshine (19.9%) > highest temperature (12.4%).

References

[1] LIU GN, LIANG YY, QIU Y, *et al.* Dynamic assessment of agricultural drought risk in Qinghai – Tibet Plateau from 2000 to 2018[J]. Pearl River, 2022, 43(4): 63 – 74. (in Chinese).

[2] ZHANG CJ, LIAO YM, DUAN JQ, *et al.* The progresses of dry-wet climate divisional research in China[J]. Advances in Climate Change Research, 2016, 12(4): 261 – 267. (in Chinese).

[3] SHI JQ, YANG FY, BIAN D, *et al.* Temporal and spatial patterns of barley in tibet major agricultural areas based on the comprehensive assessment index of drought disaster risk[J]. Chinese Agricultural Science Bulletin, 2021, 37(2): 80 – 87. (in Chinese).

[4] WANG JS, YAO YB, WANG Y, *et al.* Meteorological droughts in the Qinghai – Tibet Plateau: Research progress and prospects[J]. Advances in Earth Science, 2022, 37(5): 441 – 461. (in Chinese).

[5] ERKEJAN HOYHAZI, APAR RUZI, WANG XJ. Variation of dry-wet condition of the main crop growth season in Changji City during 1961 to 2009[J]. Journal of Agricultural Catastrophology, 2019, 9(3): 36 – 39. (in Chinese).

[6] HU ZY, HU RJ, ZHOU QM, *et al.* Spatiotemporal variation of wetting or drying in the arid regions in central Asia[J]. Arid Zone Research, 2018, 35(2): 160 – 168. (in Chinese).

(Continued on page 63)

[12] Jiangsu New Medical College. Great dictionary of Chinese materia medica[M]. Shanghai: Shanghai Scientific and Technical Publishers, 1979. (in Chinese).
[13] Editorial Board of Chinese Materia Medica, State Administration of Traditional Chinese Medicine. Chinese materia medica[M]. Guiyang: Guizhou Science and Technology Publishing House, 2005. (in Chinese).
[14] Editorial Board of Flora of China, Chinese Academy of Sciences. Flora of China[M]. Beijing: Science Press, 1994. (in Chinese).
[15] SU J. Newly revised materia medica[M]. Hefei: Anhui Science & Technology Press, 1981. (in Chinese).
[16] RIHUAZI. Rihuazi materia medica[M]. Hefei: Anhui Science & Technology Press, 2005. (in Chinese).
[17] LEI X. Leigong Paozhi Lun[M]. Hefei: Anhui Science & Technology Press, 1991. (in Chinese).
[18] LIU M. Determination of matrine content in Qingre Tonglin Tablets by HPLC[J]. Chinese Medicine Modern Distance Education of China, 2010, 8(2):159. (in Chinese).
[19] LI SS. Application and observation of Compound Huangbai Kushen Lotion in the treatment of vaginitis[J]. Clinical Research, 2019, 27(7): 130-131. (in Chinese).
[20] WU L, DAI GL, WANG Q, *et al.* Pharmacokinetic pharmacodynamic correlation study of oxymatrine in Qingre Yangxin Granules in mice with viral myocarditis[J]. Pharmaceutical and Clinical Research, 2017, 25(5): 377-381. (in Chinese).
[21] XIAJIN YUANZHI. Tujie Bencai[M]. Kyoto: Tianzhong Libing Wei, 1685. (in Japanese).
[22] SONGGANGXUANDA. Yongyao Xuzhi[M]. Osaka: Hanfang Wenxian Kanxinghui, 1972. (in Japanese).
[23] LIN ZL. *Bencao Bianming*[M]. Osaka: Jiwenziwu Shibingshu,1772. (in Japanese).
[24] SONGGANG DIAN. *Qianjin Yaofang Zhu*[M]. Heiankyo: Yetian Tengba,1778. (in Japanese).
[25] TANG SW. Classified materia medica[M]. Beijing: Huaxia Publishing House, 1993. (in Chinese).
[26] SIDAO LIANGAN. *Wohan Sancai Tuhui*[M]. Osaka: Qiutianwu Taiyou Yamen, 1824. (in Japanese).
[27] NEITENG SHANGXIAN. Gufang Yaopin Kao[M]. Tokyo: National Congress Library, Japan, 1843. (in Japanese).
[28] Committee of The Japanese Pharmacopoeia. The Japanese pharmacopoeia[S]. Tokyo: The Ministry of Health, Labor, and Welfare, 2016: 1782. (in Japanese).
[29] CHAITIAN ZHENGJIAN. Riyong Yaopin Kao[M]. Owari: Yonglewu Dongsilang, 1811. (in Japanese).
[30] MANASE DOSAN. Yunzhen Yehua[M]. Tokyo: National Congress Library, Japan 1843. (in Japanese).
[31] DAOSHENG XUANYI. Paozhi Quanshu[M]. Heiankyo: Dahewu Zuoyamen, 1702. (in Japanese).

Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU

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[7] ZHANG CJ, REN YY, CAO LJ, *et al.* characteristics of dry-wet climate change in china during the past 60 years and its trends projection[J]. Climate Change Research Letters, 2021, 10(6): 728-741. (in Chinese).
[8] ZHANG YZ, ZHANG B, LIU YY, *et al.* Spatiotemporal variation of dry-wet climate from 1961 to 2013 in Loess Plateau Region[J]. Journal of China Agricultural Resources and Regional Planning, 2019, 40(6): 2-7. (in Chinese).
[9] CAO LJ, SUN HL, LAN XL, *et al.* Temporal and spatial evolution characteristics of extreme drought/wet events in Tianshan Mountains, Xinjiang[J]. Arid Zone Research, 2021, 38(1): 188-197. (in Chinese).
[10] ZHENG R, LI DL. Decadal changes of the wet and dry climate zone boundaries in the Qinghai-Tibet Plateau during 1971-2011[J]. Journal of Desert Research, 2016, 36(4): 1107-1115. (in Chinese).
[11] DU J, BIAN D, HU J, *et al.* Responses of climatic change on surface humid index in Northern Tibet during the period of 1961-2006[J]. Acta Ecologica Sinica, 2009, 29(5): 2438-2444. (in Chinese).
[12] DU J, HU J, CHEN H, *et al.* Trend of surface humid index in the middle reaches of the Yarlung Zangbo River over Tibet in recent 40 years[J]. Journal of Natural Resources, 2006(2): 196-203. (in Chinese).
[13] SHI JQ, DOU YL, YANG FY, *et al.* Temporal and spatial pattern characteristics of potential evapotranspiration in Tibet and its influencing factors[J]. Arid Zone Research, 2015, 38(3): 724-732. (in Chinese).
[14] DUAN YN, JI X, GUO RY. Analysis on the sensitivity and dominant meteorological factors identification of potential evapotranspiration variation in Yarlung Zangbo River Basin[J]. Research of Soil and Water Conservation, 2020, 27(2): 261-268. (in Chinese).
[15] QIAO L, WANG WK, MA ZT. Sensitivity of meteorological factors to potential evapotranspiration in Lhasa River Basin[J]. South-to-North Water Transfers and Water Science & Technology), 2020, 18(4): 97-103. (in Chinese).
[16] YANG SK, LIU J, ZHANG T. Characteristics of spatio-temporal variations of surface aridity index and its response to meteorological factors in the upper reaches of the Yangtze River[J]. Journal of Water Resources and Water Engineering, 2021, 32(4): 101-108. (in Chinese).
[17] ZHANG CJ, ZHANG JQ, HU ZH, *et al.* Study on drought monitoring, early warning and disaster risk assessment technology[M]. Beijing: China Meteorological Press, 2020: 205-209. (in Chinese).
[18] ZHANG B, CAO H, WU ZP, *et al.* Analysis on the status of dry-wet climate and the influence factors in Guizhou[J]. Meteorological and Environmental Sciences, 2021, 44(3): 39-46. (in Chinese).
[19] LIU J, CHEN TT, CHI DC. Rainfall trend analysis of the northwest liaoning province based on Daniel and Mann-Kendall Test[J]. Journal of Shenyang Aricultural University, 2014, 45(5): 599-603. (in Chinese).
[20] CHEN HS. Analysis and prediction of precipitation characteristics in Anhui Province based on wavelet analysis[D]. Hefei: HeFei University of Technology, 2019. (in Chinese).
[21] LI HY, XUE Y, CAO D, *et al.* Temporal and spatial variation characteristics of water profit and loss in Wulanchabu City in recent 50 years[J]. Journal of Arid Land Resources and Environment, 2019, 33(12): 145-155. (in Chinese).
[22] SHABITI, MAIMAITI, HUANKEXI, *et al.* Climate feature and dry-wet area change in Urumqi Region of Xinjiang during 1961-2014[J]. Arid Meteorology, 2016, 34(3): 448-455. (in Chinese).
[23] ZHAO XM, LI DL. Assessing meteorological conditions concerning icing in Southwest China based on GIS[J]. Journal of Glaciology and Geocryology, 2012, 34(3): 547-554. (in Chinese).
[24] QIN DH, ZHAI PM. Evolution of climate and ecological environment in China: 2021 (volume II, regional impact, vulnerability and adaptation)[M]. Beijing: Science Press, 2021. (in Chinese).

Editor: Yingzhi GUANG Proofreader: Xinxiu ZHU