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REVIEW

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Trends and responses to global change of China's arid regions

Abstract I analyzed and elaborated the trends in and responses to global change in arid regions of China, from the perspective of nine variables, i.e., temperature, precipitation, river runoff, melting glaciers, water level of lakes, wind power and evaporation, vegetation, oases, and desertification. The climate and hydrology data I cited represent many years of observations. I conclude that, since the 1980s, the climate in arid regions of China has clearly changed with rising temperatures and precipitation in most areas. Wind power and the number of galestorm days have continuously decreased, which resulted in an improvement of humid conditions and increases in river discharge and water levels of lakes. Simultaneously, vegetation also has improved and the process of desertification has essentially been arrested. Although there are some unfavorable developments, such as decreased river flows or flow interruptions and downstream oases have suffered from degradation, these incidental cases should not distract our attention from the generally favorable trends during the middle and late 20th century. These discordant phenomena are not consequences of climate change but rather of unsuitable human activities. Despite a substantial increase in precipitation, the level of the original precipitation was so small that any increase in precipitation was still small. As a result, none of the fundamental conditions such as a scarcity of water resources and precipitation nor the landscape of drought-ridden deserts in the arid regions will change. The vulnerability of the eco-environmental system in the arid regions will not change fundamentally either in the near future.

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1 Introduction

With global warming, melting glaciers, rising sea levels, dryer climates, and reduced food yields, the scenario is scary and makes us feel afraid. Since the 1980s and 1990s, scientists have predicted changes in climate and the environment in arid regions using a number of models based on the effects of temperature rising in arid areas. It has been strongly suggested that evaporation would increase, climate would become drier, the vegetation would deteriorate, and desertification would worsen along with rising temperatures. However, the situation in the arid regions of China did not develop along the path of prediction of past decades, especially since the middle of the 1980s. Today, we see completely different scenes compared with previous ones, which still saddens us.

2 Trend and response of air temperature to global change

Rising temperatures are at the core of global change. It makes for strong responses to global change in the arid regions of China. The temperature tended to rise in most areas of China during past decades, except for some parts of southwestern China (Zhang et al., 2006). The average temperature in China rose by 1.1°C during the last 50 years, i.e., 0.22°C for every 10 years. The rate of rising air temperature in China was clearly higher than globally and in the northern hemisphere during the same period (Ding et al., 2006). The rate of rising temperature above of 35°N was obviously higher than that below 35°N (Zhang et al., 2006). The turning point of rising temperatures took place in the middle of the 1980s.

Given this background, the climate tended to become evidently warmer in the arid regions of China during the latter half of the 20th century, increasing by 0.19°C every decade in northwestern China (Zhang et al., 2006). The temperature rose higher in the Qaidam Basin and in northern Xinjiang. In the arid regions to the west of Lanzhou City, the temperature rose by 0.22°C every 10 years (Ren and Yang, 2007), which was 0.13°C lower than that of northeastern and northern China and 0.18°C higher than that in the middle of China and the southern regions (Zhang et al., 2006). For the entire country, the amplitude of rising temperatures in the arid regions seems to be at a medium or even a little higher level. Simultaneously, the climate change in the Qinghai-Tibetan Plateau was in line with that of the whole country, with a rise of 0.77°C during the last 50 years (Ding and Wang, 2001). The mean annual temperature over 10 years rose by 0.5–1.2°C in the agricultural-pastoral transition zones in northern China in the 1990s compared with the 1960s.

In theory, the result of rising temperatures will be increased evaporation, with subsequent loss of water from the soil and vegetation. In the end, given rain and water shortages, the environment in the arid regions will become drier and will worsen. On the one hand, a warmer climate will accelerate the melting process of the glaciers and mountain firn and lead to the degradation of the tundra in the Qinghai-Tibetan Plateau and will also result in environmental droughts near and below the lower limit of forest distribution in the arid regions. On the other hand, it will cause the tree line of mountain forests to move upwards, which will prolong the growing period of vegetation at higher latitudes and plateau regions and improve primary production. Therefore, rising temperatures will have huge impacts on the environment in the arid regions regardless whether in the short-term or long-term and whether positive or negative.

3 Trend of precipitation and response to global change

A shortage of water is an obvious natural feature as well as a basic condition for the formation and development of desertification. Hence, precipitation has a crucial effect on maintaining and keeping the ecosystem in arid regions. Although the national average precipitation has not obviously changed on the whole during the last 50 years, the annual precipitation, however, has clearly increased in most areas of western China and, to a certain extent, in northern China and some parts of Inner Mongolia, except for the Loess Plateau, the headwaters of Sanjiang (three rivers including the Yangtze River, the Yellow River, and the Lancang River), the Horqin Sandy Lands, and some other areas where precipitation has decreased somewhat. A slightly fluctuating change has taken place in agricultural-pastoral transition zones. Precipitation in arid regions to the west of the Helan Mountains, especially in some parts of Xinjiang and the Qinghai-Tibetan Plateau, appears to have clearly increased (Lu et al., 2006). The average precipitation in Xinjiang in the 1990s increased by 20–50% compared with that in the 1980s (Hu et al., 2002) and the same increasing trend continued at the start of the 21st century. According to the Daxigou Meteorological Observation Station located to the north of Tianshan Mountains at an elevation of 3650 m, the average annual precipitation during the period 1981–2001 increased by 12.7% compared with the period of 1958–1985 (Lan et al., 2007). The average annual precipitation in Urumqi City was minimal in the 1960s, increased gradually in the 1970s, obviously increased during the 1980s, and continued to rise in the 1990s (Liu et al., 2007). Precipitation in Bosten, Aydingkol, and Ebinur lakes during the 1990s increased by 5%–10% compared with the period between 1960 and 1990 and by 5%–20% during the summers. At Dashankou station located upstream of the Kaidu River, precipitation has increased by 23%. Most stations have recorded precipitation increases by 20%–50% compared with the 1980s (Hu et al., 2002).

The climate in the Qinghai-Tibetan Plateau in the last 30 years has undergone the following changes: temperature and precipitation have increased, potential evapotranspiration has reduced, and a dry trend ended and developed towards a damper climate in most areas (Ding et al., 2001; Wu et al., 2005). After experiencing drought years from 1963 to 1979, precipitation in the Qinghai-Tibetan Plateau has clearly increased since the 1980s, when the average annual precipitation rose by 5.9% over previous years, by 8.9% in the 1990s, and by 36.1% from 2001 to the end of 2003 (Lu et al., 2006). The Qinghai Plateau has developed from a warm-dry to a warm-wet climate zone since the middle and latter period of the 1980s. The average precipitation tended to rise on the whole during the 1960s–1990s period at five stations, i.e., Dari, Maduo, Wudaoliang, Yushu, and Qumalai, and increased by 28.7% in the 1970s, by 52.31% in the 1980s, and by 47.8% in the 1990s compared with the 1960s (Fan et al., 2005).

Precipitation in the northern desertification areas (including arid, semi-arid, and parts of the semi-humid areas) clearly reduced during the 1960s and 1970s, increased obviously by 21.5 mm in the 1980s, by 29.8 mm in the 1990s, and by 97.5 mm during period 2001–2003 compared with previous years (Lu et al., 2006).

Water is considered the blood of arid areas. Rising precipitation not only results in increased river flow rates, increased water volume of lakes, and improved oases but also physically compensate glaciers and mountain firns.

Despite the substantial increase in the rate of precipitation, the actual amount of precipitation is so small that the increased precipitation is still low. As a result, neither the fundamental state of a scarcity of water resource and precipitation nor the landscape of dry deserts in the arid regions will change; the vulnerability of the eco-environmental system will not fundamentally change in the arid regions.

4 Response of glaciers to global change

Rising temperatures have a significant impact on accelerating the melting of glaciers in arid regions. The runoff of melting glaciers is an important source of water flow for many rivers in the arid regions of northwestern China and plays an indispensable and important role in keeping the rivers flowing and maintaining the prosperity of downstream oases. But it also causes the glaciers and mountain firns to melt faster and leads to a reduction in water storage by the glaciers. Apart from a few glaciers, most glaciers in China are melting faster due to rising temperatures. The latest research (Shi et al., 2006) has shown that the area of glaciers has decreased by 5.5% and water storage of the glacier has been reduced by 7% during the last 40 years compared with the 1960s (The Fast Melting Glacier in China, People's Daily, April 9, 2003). Due to the rising temperature, the net loss in total water storage has been 5869×10^{8} m^{3} since the 1980s, equal to 10 times the annual runoff of the Yellow River (Lan et al., 2007).

The results judging from the observation data have shown that the annual net loss of water storage of glacier no. 1 located to the north of Tianshan Mountain with an area of less than 2 km^{2} in Urumqi was 9.3×10^{5} m^{3} during the 1964–1986 period, while during the 1986–2000 period, the loss of water storage increased 2.8 times over the 1959–1985 period, which clearly indicates that the melting speed of the glaciers has sharply accelerated since the middle of the 1980s. The area of the glacier in the headstream of the Kaidu River was reduced by 12.5% from 5479.0 km^{2} in 1963 to 4795.4 km^{2} in 2000, which largely occurred during the last 15 years of the 20th century (Lan et al., 2007). Moreover, the rising temperature caused the snow line on the mountains to move higher. Research conducted by the Meteorological Bureau of Gansu Province has shown that the snow line has annually moved higher by 2–6.5 m in parts of the Qilian mountains since the 1970s (The Shrinkage of Glaciers of the Qilian mountains has threatened the Hexi Corridor, People's Daily, May 11, 2006).

The reduction in the area of glaciers is expressed largely in the retreat of their leading edge, implying that rising temperatures have a more serious effect on smaller glaciers at low elevations, which are sensitive to warmer climates. We should emphasize more the effect of increasing precipitation in arid regions and in mountains due to the warming climate in addition to the effect on the increased rate of melting of glaciers. According to press reports, a French survey team found that the height of Mont Blanc in the Alps had increased. A possible reason was that the warming climate caused the snow to remain stuck at elevations above 4000 m and that the snow had not been blown away by gales, which accelerated the accumulation of snow. Perhaps the same phenomenon is occurring in the glaciers and in the perpetual snow regions of China and not limited to the Alps only. In other words, if precipitation increases, glaciers would develop from precipitation. There is ample evidence that the glaciers southeast of the Qinghai-Tibetan Plateau have been advancing during the last 30 years more than expected (Shi et al., 2006).

Some investigations have indicated that the area of glaciers has been reduced and that they have become thinner because of rising temperatures. This phenomenon has undoubtedly occurred for glaciers at relatively low elevations but not for the glaciers at high elevations where temperatures are always below the melting point. There are no accurate quantifiable assessments as yet available about the overall effect of accelerated melting glaciers and their reduced area on the climate in arid regions. From our estimates, the change in the extent of glaciers, especially of those glaciers at lower elevations, was so small compared to the total area of the arid regions that the increase in the number of melting glaciers has little effect on the climate in arid regions.

From a long-term point of view, the melting glaciers and increased snow line will have serious effects on the structures and stabilization of ecosystems and may even lead to the reduction of river flows relying on the water supply from melting glaciers. Seasonal flow interruptions and dried-up rivers would bring disaster to downstream oases. At present, the increase in the number of glaciers melting causes increases in river flows, which is beneficial for the development of oases in the middle and lower reaches of rivers, for vegetation restoration, and for a reversion in desertification in arid regions.

5 Response of river discharge to global change

River discharges depend on two factors. For rivers without a water supply from glaciers, precipitation is the major source of water. For rivers with their headstream from glaciers, both precipitation and glacial runoff are key factors. When not taking account of the melting factor, river discharges are the best indicators of the state of precipitation in the regions. Hence, the inland river discharge is the weatherglass of climate change in arid regions.

In reality, a precise measure of river discharges is disturbed by two factors: the first one is the dammed-up reservoir and the other one is the large amount of water withdrawn by industries and agriculture along its course, which leads to the reduction of the river discharge and even to flow interruptions downstream in the river. Therefore, we often make a wrong decision, misled by incorrect data, because the real conditions are hidden by the observation data of the river flow downstream of the river. In the arid regions of northwestern China, most rivers originate from high mountains, where there are few or no reservoirs in the upstream valleys. The dammed-up rivers are mainly in the plains. Hence, river flows in mountain areas reflect the real river discharges and climate changes in the regions.

Many river discharges have clearly increased in the arid regions of northwestern China, owing to increases in precipitation and melting glaciers since the middle 1980s. For instance, since 1996, the Kaidu River has had high flow periods; its highest annual flow was 50% higher than the average of previous values (Sun et al., 2006). Since 1987, the river discharge at Tomur Peak, south of Tianshan Mountain, has increased by 12% for the river depending mainly on melting glaciers only and by 33% for the river relying mainly on the precipitation (Shen et al., 2003).

A pending crisis occurred to us in the arid regions only since the middle and latter period of the 20th century. River discharges were reduced in some downstream inland rivers and some natural oases degenerated. For example, the annual river flow entering the main Tarim River has been reduced by 17.4% since the 1970s compared with the 1960s and the downstream flow has been reduced by 76.1%. But the average annual flow of the upper Tarim River in the mountain area has increased by 15.0% (Mansur and Liu, 2007). The average annual river flow to the downstream Heihe River was $1.05\times10^9\,m^3$ in the 1940s, $8.0\times10^8\,m^3$ in the 1950s, $4.0\times10^8\,m^3$ in the 1970s, and $2.5\times10^8\,m^3$ in the 1990s. A study on planning of ecological sustainable development in the Heihe River Basin (Zhangye of Gansu Province and Alxa of Inner Mongolia) during the 1995–2001 period (May 1997) was performed by the Research Institute of Environmental Sciences of Inner Mongolia, Chinese Research Academy of Environmental Sciences. The annual upstream flow of the Heihe River increased by 2% during the last 30 years since the 1970s (Liu and Zhang, 2007).

In short, the actual flow of many rivers has increased to a certain extent in the arid regions of China since the middle of the 1980s and reduced and even interrupted the flow in some parts of downstream rivers. The main reason is not climate change but the unwarranted overuse of water along the upper and middle parts of the rivers.

6 Trends and response of lakes to global change

The condition of lakes is the signal for climate change in arid regions. The surface areas and the water levels of lakes are highly sensitive to climate change in arid regions. Sediments at the bottom of lakes reflect the real mutation process of climate and the eco-environment and will become a valuable basis for studying historical climate changes.

I have come to the conclusion that the periodic variation of the water volume of lakes change along with climate changes in the arid regions in the history. Since the water resources of many lakes have been abused by human behavior during the last decades because of increased human management activities, this has led to the loss of their sensitivity to climate and the warning function of lakes.

Daihai Lake, located in Liangcheng County of Inner Mongolia, is a closed inland lake, which was in relatively stable condition with limited fluctuation before the 1960s, but its water level has been falling continuously from the middle of the 1970s to the middle of the 1990s. The water level declined by 3.85 m during the past 25 years. According to an analysis, anthropogenic factors (water used for agriculture) are responsible for 82% of this decline (Jia et al., 2006b). Ebinur Lake in northern Xinjiang has also seen a significant change: the surface area of the lake was $1200\,km^2$ at the beginning of the 1950s and was reduced to $520\,km^2$ because of large-scale use of water for agriculture. However, since 1987, the surface of the lake has again expanded up to $1000\,km^2$ due to a warm and wetter climate, but it fluctuates (Jia et al., 2006a). The water level in Qinghai Lake has fallen continuously in the past decades due to human activities. In recent years, the situation has improved, precipitation increased, and the water level in Qinghai Lake started rising again. The water level fluctuates owing to eco-environmental protection. Cleary, the water level of lakes responds largely to human disturbance and is no longer a reflection of real climate change in the regions.

Sayram Lake is a closed mountain lake at high elevation and almost without human disturbance. The hydrological data show that the total amount of water entering the lake increased by $2.64\times0^9\,m^3$ during the 1960–2000 period or $6.5\times10^7\,m^3$ annually (Gao and Jia, 2005). The surface of Bosten Lake, a lake with little human intervention, has fallen since the beginning of the 1950s, but since the middle of the 1980s, its water level has risen steadily because of increased precipitation and accelerated melting of glaciers and snow. Its water level was restored in 2000 to that at the beginning of the 1950s (Sun et al., 2006). It should be pointed out that the situation of these two lakes has reflected real climate change in the basin in recent decades.

In the past several years, degradation of the eco-environment in the green corridor downstream of the Tarim River has been reversed, the situation has improved, and a natural *Populus euphratica* forest has been revitalized. The corridor has benefited from increased precipitation and melting glaciers upstream of the Kaidu River. This has led to a rising water level in Bosten Lake, thus enabling water transportation of the Tarim River to its downstream areas.

It should also be noted that the surface area of some lakes in the Qinghai-Tibetan Plateau have shrunk or even disappeared without human disturbance; the reasons have not yet been identified. Such phenomena are possible through partial drought and the disappearance of small lakes can occur simply in the framework of a general trend in climate change on the wide expanse of the Qinghai-Tibetan Plateau. The bulk of observed climate data has shown that the climate in the Qinghai-Tibetan Plateau tends to change from dry to wetter seasons along with rising temperatures and precipitation (Wang et al., 2004; Wu et al., 2005; Lu et al., 2006).

7 Trend of wind power and evaporation capacity in response to global change

Evaporation and mean wind speed near the ground have shown clear decreases during the last 50 years in China (Ding et al., 2006). The mean wind speed has been reduced by 16% in China and 29% in the west of northwestern China (Wang et al., 2004). Except for the area in southwestern Xinjiang, the rate of variation in wind speed in most regions of Xinjiang, the Qinghai-Tibetan Plateau and in northern Gansu Province, is below-4 mm/year and-15 mm/year in eastern Xinjiang and in northern parts of Gansu Province (Chinese Research Academy of Environmental Sciences and Research Institute of Environmental Sciences of Inner Mongolia: "A study on planning ecological, sustainable development in the Heihe River Basin, Zhangye in Gansu and Alxa in Inner Mongolia, 1995–2001", 1997; Ren and Guo, 2006). The trend in the reduction of wind speed is obvious on the Qinghai-Tibetan Plateau, in the north of Gansu, and in the Xinjiang Autonomous Region. So far, a maximum reduction in mean wind speed of 0.3 m/s every 10 years, especially towards the east of the Tarim, Turpan, and Qaidam basins of Qinghai Province, has been recorded. The middle of the 1950s to the beginning of the 1980s and especially towards the end of the 1960s and 1970s was the period of the highest frequencies of gales in the arid regions of northern China; from the end of the 1980s, a period of fewer gales in this area seems to have started (Lu et al., 2006).

The number of days of fresh gales in the south and north of Xinjiang has been reduced by 3.03 days and that of more severe galestorms by 6.9 days for every 10 years in the last 44 years since 1961 (Xiang et al., 2007) and by 1.3 days in the Ningxia Hui Autonomous Region (Zhang et al., 2006).

The evaporation capacity seemed to have followed the same trend as the wind power in these arid regions in recent years. Evaporation had kept falling in the Ningxia Hui Autonomous Region, with reductions of 3.16% in the 1980s, 0.62% in the 1990s, and 1.05% during the 2000–2002 period compared with the mean values over the previous 43 years (Chen et al., 2005). The same trend has been noted in Inner Mongolia over the past 45 years. The maximum reduction has been observed in the desert grassland area (Zhang et al., 2007). The 1960–1980 period was a period of drought in the arid regions of northwestern China. Since then, dry and wet periods have alternated, but the area has become wet since 1987, and since 1997, humidity has clearly increased. The climate was comparatively dry from the end of the 1950s to the 1970s on the Qinghai-Tibetan Plateau but has become relatively wet since the 1980s (Wang et al., 2004; Lu et al., 2006).

The change in evaporation depends on the following three factors: temperature, humidity (precipitation), and wind power. Despite the obvious increase of temperature in arid regions, the integrated actions of rising precipitation and falling wind power has made necessarily a reduction in evaporation. Reduced wind power has tempered the sandstorm weather in the north of China since the late 1950s (Lu et al., 2006; Ding et al., 2006). The number of days with sandstorm weather in southern Xinjiang has been reduced by 2.69 days and by 0.74 days in northern Xinjiang for every 10 years in the past 45 years since 1960 (Xiang et al., 2007). This trend has also been noted in the Ningxia Hui Autonomous Region over the past 44 years since 1961, where the sandstorm weather and the dust weather has been decreased respectively by 1.1 days and 1.8 days in Ningxia every 10 years. The most obvious reductions took place since the beginning of the 1980s.

8 Vegetation trend and response to global change

The increase of precipitation favors natural restoration of vegetation, improvement of artificial treatment, and dissemination of positive results. According to the national records of monitoring desertification, the area of the restored desertified land with a vegetation coverage of 20%–50% has increased by 1240×10^4 hm^2 and restored desertified land with vegetation coverage over 50% has increased by 230 hm^2 (Zhu, 2006). The area with medium and higher coverage of vegetation has increased because of the shift from low vegetation coverage ($<20\%$) to higher coverage. Most desertified lands with low cover vegetation are located in arid regions.

Satellite monitoring data show results similar to the ones presented above. The productivity of primary vegetation in the arid regions of China appears to fluctuate, rising during the period from the beginning of the 1980s to the start of the 21st century. Since the middle of the 1980s, the primary vegetation productivity has shown a clear increase at the same time that precipitation also increased. In short, the increase in precipitation plays an important role in the improvement of vegetation in addition to appropriate protection policies and engineering measures applied in recent years.

Any climate change can have a significant effect and impact on biological and ecological features of entire biota, which have adapted to special environments and formed over long periods of time. For instance, *Saussurea involucrata* cannot survive easily if the snow line moves higher owing to rising temperatures. Plants with poor nutrient uptake and even poisonous plants will grow along with the degradation of arid grassland, which will quickly result in deteriorating quality and carrying capacity of the grass. Most investigators insist that the main reason for the degradation of grassland is human abuse and few quantitative reports attribute it to global climate change.

9 Trends and response of oases to global change

The oasis is an important component of the desert ecosystem and the location where the indigenous people survive and live in arid regions. The area of the oases in the arid regions in China covers about 8.64×10^4 km^2 (Shen et al., 2001; Tang, 2003), accounting for 4% of the total area of the arid regions, with over 90% of the population, 95% of social wealth, and 98% of the towns (Shen et al., 2001). The oases can be considered as the center and the heart of the desert ecosystem.

If the oasis is the heart of the arid region, the rivers connecting them are its main arteries. The oases are always located in their middle and lower reaches, where the reduction of river flow or flow interruption will become the most serious threat to oases. In our history, the disappearance of oases and their civilization is often related to the deflection of river courses or a discontinued water supply. In most cases, it occurs due to natural causes. But at present, the most serious threat to natural oases are human activities. On the one hand, the natural oases have been turned into pastoral areas (i.e., artificial oases). On the other hand, reclamation of the land outside the oases is for the creation of new artificial oases. Although the natural oases are not disturbed, the water sources surrounding it are depleted, which finally leads to degradation and even disappearance of natural oases. At present, degradation crises of oases in the arid regions is caused by the expansion of artificial oases and unsuitable use of water. The degradation of the oases of the Tarim and Heihe rivers is a typical case.

Accurate data on dynamic changes in the areas covered by oases in China are not available at present. Without doubt, the total area of the oases in the arid regions has definitely not been reduced. Indeed, it has increased continuously during recent decades. The problem is that natural oases are replaced by artificial oases in the form of farmland and the type, structure, and function of the oases are degenerating. Of course, some desert land has been developed into an oasis (Huang, 2003). For example, the area of the oases in Xinjiang in the middle of the 1980s has doubled compared with the conditions in 1949 when the People's Republic of China was founded (Han, 1990), and its irrigated area amounts to 587×10^4 hm^2 (He, 1990), of which the newly reclaimed land (after 1949) accounts for about 367×10^4 hm^2 (Han, 1990). The area of irrigated farmland (i.e., artificial oasis) increased by 30% in the last 20 years in the Shiyang River Basin, most of which are artificial oases transformed from natural ones. The agricultural area increased by 17.3% and garden plot by 45.2%, but grassland was reduced by 22.2% during the 8 years from 1996 to 2004 in Korla City (Zibibula Simayi et al., 2006), which shows the change of type and structure of the oases.

Theoretically, global change seems to have had its first impact on the oases in arid regions. However, the degradation of many oases in China is not caused by global change but rather by unsuitable use of water by humans, because, in the past decades, precipitation and total river flow have not decreased and the capacity for evaporation has not increased in the arid regions. Instead, the area of artificial oases has continuously increased and the natural oases are gradually degenerating. The degradation of the oases downstream of the Tarim and Heihe rivers is sufficient evidence for that claim. At least, we have no authentic evidence to prove that global change has caused the degeneration of our oases.

10 Trends in desertification and response to global climate change

Desertification is an integrated degradation of various ecological factors. The main climate factors have had a healthy change in the arid regions since the middle of the 1980s, which are helpful in the process of reversing desertification. During the last period of the 20th century, the area of desertification still expanded continuously in China. The area suffering from desertification increased by up to 1560 km^2 annually during the 1960s and 1970s. Then, during the 1980s, the desertification area increased by 2100 km^2 annually (Wang, 2003), by 2460 km^2 at the beginning of the 1990s, and by 3436 km^2 at the end of the 1990s (Zhu, 2006). By the end of the 20th century, the desertification situation started a healthy change, and since then, the trend in desertification expansion has been halted and the desertification area was actually reduced. The area of desertified land been has reduced annually by 1283 km^2 during the 1999–2004 period, of which the drifting sandyland and semi-fixation sandyland was reduced by 387.49×10^4 hm^2 and the sand-fixed land increased by 322.65×10^4 hm^2 (Zhu, 2006). At the same time, forest coverage increased considerably in the five provinces in northwestern China and in Inner Mongolia (Tian et al., 2006).

Increased precipitation represents an important factor in the healthy change in the reversal of desertification in addition to a number of policies on combating desertification, carried out by governments at various levels and national programs aimed at ecological improvement, including the program of converting farmland to forest and grassland, the program of water/soil conservation, and the program of grassland conservation. Therefore, the success of combating desertification in China can be summarized as follows: appropriate policies, human efforts, and favorable climate conditions together have been powerful driving forces in the reversion of desertification.

The form and development of desertification are constrained by natural factors and are also affected by human activities. Despite the fact that climate conditions have turned for the better in the arid regions since the middle of the 1980s, the trend in the expansion of areas of desertification continued and was only halted by the end of the 20th century. The main reason for the delay in control of desertification was the lack of care in eco-environmental protection policies under the pressure of a growing population and economic development. Hence, the positive results of combating desertification and favorable climate conditions are offset by unwise human activities.

11 Conclusions

The climate change is a normal, natural phenomenon, which never stopped since the origin of our planet. Given the background of global change, the main climate factors in the arid regions of China have obviously changed during the past several decades, especially since the 1980s: the temperature has risen, while precipitation has increased greatly in the arid regions especially to the west of Helan Mountain and in some parts of the Qinghai-Tibetan Plateau and wind power and evaporation have clearly declined. The climate in the arid regions has become warm and wet, the real flow of most rivers has increased, and the vegetation in turn has improved under the integrated impact of the above-mentioned climate factors (Shi et al., 2002; Jia et al., 2006a; Zhu, 2006); thus, the trend in the expansion of the area of desertification has been arrested within limits. These are, at present, the real responses of the arid regions in China to global climate change. However, we should be aware that none of the fundamental conditions of a scarcity of water resources, the lack of precipitation, and a landscape of drought-ridden deserts will change nor will the vulnerability of this eco-environmental system be fundamentally transformed in these arid regions in the near future.

Although the temperature in these arid regions has increased considerably since the middle of the 1980s, evaporation has not increased and the climate has changed to warm and wet from dry conditions. The climate in the arid regions is an organic system consisting of multiple and interdependent factors. Temperature is only one of these factors. Temperature has increased and so has precipitation, but wind power has been reduced precisely in the arid regions of China. Furthermore, the degree of fluctuating precipitation and the wind power are far greater than that of temperature, thus offsetting the negative effect brought about by rising temperatures. For example, in Xinjiang, the mean annual temperature increased by 0.3°C during the 1990s compared with that in the 1980s, but precipitation increased by 20%–50% (Ren and Yang, 2006). Similarly, the temperature increased by 0.77°C in the last 50 years in the Qinghai-Tibetan Plateau, but precipitation increased by 21% (Ding and Wang, 2001). In the south of Xinjiang, both temperature and precipitation increased over the past 45 years, but the amplitude of increased precipitation is 23 times greater than that of temperature (Qin et al., 2007). Maybe these results are beyond the ability of predictions made by people.

This discourse is an assessment of the general response to global change in the arid regions of China based on general trends in these regions over past decades. It does not exclude various trends in some regions and in certain years. But the basic situation in China as described here is a precise and relevant account given the background of global change. Judging from the general trend in the arid regions, Mr. Yafeng Shi, a well-known glacier scientist, called it "a climate change signal from a warm and dry climate to a warm and wet climate in northwestern China" (Shi et al., 2002).

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References

Chen X G, Su Z S, Zhen G F, Zhang Z, Chen X J, Chen N (2005). Analysis on climatic changes in Ningxia. J Arid Land Resour Environ, 19(6): 43–47 (in Chinese)

Ding Y H, Ren G Y, Shi G Y, Gong P, Zhen X H, Zhai P M, Zhang D E, Zhao Z C, Wang S W, Wang H J, Luo Y, Chen D L, Gao X J, Dai X S (2006). National assessment report of climate change (I): Climate change in China and its future trend. Adv Climat Chan Res, 2(1): 3–8 (in Chinese)

Ding Y H, Wang S R (2001). Introduction to Climate and Ecological Environment of West China. Beijing: China Meteorological Press (in Chinese)

Fan Q S, Sha Z J, Cao G C, Yang P, Cao S K (2005). Assessment of the influence of glacial resources on climatic changes in Qinghai Plateau. J Arid Land Resour Environ, 19(5): 56–60 (in Chinese)

Gao H J, Jia Y L (2005). The evolution characteristics of typical inland lakes in Northwest China during the past 40 years and their mechanism. J Arid Land Resour Environ, 19(5): 93–96 (in Chinese)

Han D L (1990). The strategy emphases and countermeasure against land desertification in Xinjiang. In: Association for Science and Technology, Industrial Dept.: Study on the Land Desertification in China. Beijing: China Science and Technology Press (in Chinese)

He T S (1990). The situation of degradation and control measures of the cultivable land resources in the reclamation area of Xinjiang Production and Construction Corps. In: Association for Science and Technology, Industrial Dept.: Study on the Land Desertification in China. Beijing: China Science and Technology Press (in Chinese)

Hu R J, Ma H, Fan Z L, Wu S F, He W Q (2002). The climate trend demonstrated by changes of the lakes in Xinjiang since recent year. J Arid Land Resour Environ, 16(1): 20–27 (in Chinese)

Huang S Z (2003). Study on the Oasis. Beijing: Science Press (in Chinese)

Jia C G, Wang X F, Jin H L, Yang L (2006a). Research on the dynamic changes of Ebinur Lake Area and the effects. J Arid Land Resour Environ, 20(4): 152–156 (in Chinese)

Jia Y F, Huang C C, Mao L J (2006b). Study on variation of sand-dust storms in northern China and its influence on soil formation of the Loess Plateau under the global warming. J Arid Land Resour Environ, 20(5): 78–83 (in Chinese)

Lan Y C, Shen Y P, Wu S F, Zhong Y J, Wen J, Ma X B, Hu Z Y (2007). Changes of the glaciers and the glacier water resources in the typical river basins on the north and south slopes of the Tianshan Mountains since 1960s. J Arid Land Resour Environ, 21(11): 1–8 (in Chinese)

Liu H Y, Wang X M, Xiao S J, Lu W H (2007). Study on the change of precipitation in Urumqi since recent 40 years. Arid Zone Res, 24(6): 785–789 (in Chinese)

Liu J F, Zhang B (2007). Impact of climate change on the alpine streamflow in the northwest inland arid region of China during the past 50a: Case study of Heihe River Valley. J Arid Land Resour Environ, 21(8): 58–63 (in Chinese)

Lu J T, Zhen X J, Li X L (2006). The analysis on the climate change of the desertification area in China since recent 50 years. In: ZHU L K: The Dynamic Study on the Desertification and Sandification in China. Beijing: China Agricultural Press (in Chinese)

Mansur S, Hu J L (2007). Influence of runoff variation on ecological environment in the Tarim River Basin. J Arid Land Resour Environ, 21(10): 83–87 (in Chinese)

Qing Y, Zhou Y Z, Shi Q D (2007). The analysis on South Xinjiang climate change based on temperature and precipitation changes. J Nat Resour, 21(8): 54–57 (in Chinese)

Ren C X, Yang D Y (2006). Study on the division and trends of temperature variation in northwest arid area of China in resent 50 years. J Arid Land Resour Environ, 20(1): 99–103 (in Chinese)

Ren C X, Yang D Y (2007). Impacts of climate change on agriculture in the arid region of northwest China in resent 50 years. J Arid Land Resour Environ, 21(8): 48–53 (in Chinese)

Ren G Y, Guo J (2006). Change in pan evaporation and the influential factors over China: 1956–2000. J Nat Resour, 21(1): 31–44 (in Chinese)

Shen Y C, Wu G H, Wang J W (2001). Oases in China. Beijing: Henan University Press (in Chinese)

Shen Y P, Liu S Y, Ding Y J, Wang S D (2003). Glacier mass balance change in Tainanhe River Watersheds on the south slope of the Tianshan Mountains and its impact on water resources. J Glaciol Geocryol, 25(2): 124–129 (in Chinese)

Shi Y F, Liu S Y, Shangguan D H, Li D L, Ye B S, Shebn Y P (2006). Two peculiar phenomena of climatic and glacial variations in the Tibetan Plateau. Adv Clim Chan Res, 2(4): 154–160 (in Chinese)

Shi Y F, Shen Y P, Hu N J (2002). Preliminary study on signal, impact and foreground of climatic shift from Warm-Dry to Warm-Humid in Northwest China. J Glaciol Geocryol, 24(3): 219–226 (in Chinese)

Sun Z D, Wang R, Huang Q (2006). Comparison of water level changes during the past 20 years between Daihai and Bositen lakes. J Arid Land Resour Environ, 20(5): 56–60 (in Chinese)

Tang Q C (2003). Introduction to the geography of oasis. In: Huang G Z, ed: Study on the Oasis. Beijing: Science Press (in Chinese)

Tian Z W, Liu J C, Li K C (2006). The relative policy of combating desertification and its performance assessment. In: Zhu L K, ed. The Dynamic Study on the Desertification and Sandification in China. Beijing: China Agricultural Press (in Chinese)

Wang T (2003). Desert and Stony Desertification in China. Shijiazhuang: Hebei Technology Press (in Chinese)

Wang Z Y, Ding Y H, He J H, Yu J (2004). An updating analysis of the climate change in China in recent 50 years. Acta Meteorol Sin, 62(2): 228–235 (in Chinese)

Wu S H, Yin Y H, Zhen D, Yang Q Y (2005). Climate changes in the Qinghai-Tibetan Plateau during the last three decades. J Geogr Sci, 60(1): 3–11 (in Chinese)

Xiang M Y, Fan L H, Haimit Y, He Q (2007). Study on the change of meteorological disasters and the prevention measures in Xinjiang since recent 45 years. Arid Zone Res, 24(5): 712–716 (in Chinese)

Zhang C H, Wu X H, Li Y L (2007). Characters of the climate change about evaporation in recent 45 years in Inner Mongolia. J Arid Land Resour Environ, 21(12): 93–98 (in Chinese)

Zhang J J, Chen S, Zhao X Y (2006). Spatial divergency of temperature change during 1951-2000 in China and its correlation with global climate change. J Arid Land Resour Environ, 20(4): 1–6 (in Chinese)

Zhang Z, Zhen G F, Lin L, Chen X J, Liang X (2006). Changes of gale days and its impacts on dust weathers in Ningxia. J Arid Land Resour Environ, 20(4): 30–34 (in Chinese)

Zhu L K (2006). The Dynamic Study on the Desertification and Sandification in China. Beijing: China Agricultural Press (in Chinese)

Zibibula S, Liu Z J (2006). Analysis of the time and spatial characteristics of land use change in Korla City. J Arid Land Resour Environ, 20(4): 83–87 (in Chinese)