The Influence of Climate Change on the Function of the Qinghai-Tibet Plateau as an Eco-environmental Security Shelter

The Qinghai-Tibet Plateau (Tibetan Plateau) serves as an important shelter to safeguard China's environment and ecological system. Its vast area and lofty altitude have a strong bearing on the atmospheric circulation and climate pattern over the plateau and its surrounding regions. With numerous glaciers, large area of permafrost, a variety of lakes and a dozen of large rivers, it plays an important role in water source supply and conservation. Thanks to its vast grasslands and forests, the plateau constitutes a major carbon sink by absorbing a large amount of green-house gases.

A consultative team of the CAS Academic Divisions led by Prof. SUN Honglie and Prof. YAO Tandong, both CAS Members, has conducted research into the impact of climate change on Tibetan Plateau's function of environmental and ecological security barrier and the adaptive strategies. The following is major ideas of the research report presented by the team.

1. Development Trends of Its Ecological Security Shelter Function

(1) Changes in its surface heat source exert an influence on the spatial pattern of precipitation in east China

Due to the global warming, over the past 30 years (1982–2011), the annual mean temperature of the plateau's land between 4,000 to 5,000 meters above the sea level went up by 1.8°C, which is much higher than China's average, with marked changes of other meteorological elements such as the weakening of the wind speed and the surface sensible heating. From 1961 to 2008, the frequency of extreme high temperature events remarkably increased while that of extreme low temperature events is noticeably decreased. However, there have not been significant changes in precipitation in most areas of the plateau.

Extreme weather, climate events and corresponding changes in surface and atmospheric heat sources have had major impact on the climate and weather over the plateau and its neighboring regions. Over the past dozens of years, the weakening of surface sensible heat over the plateau in summer has led to the increase of precipitation in middle and lower reaches of the Yangtze River and the areas to its south, and the decrease of precipitation in north China. The snow in winter and spring over the plateau and the eastward movement of its low vortex cause weather and climate anomalies and disasters such as flooding and droughts in its lower reaches. For instance, it resulted in the flooding of the Yangtze River in 1998 and the frequent rain storms in the summer of 2003 in Yangtze-Huaihe river basin.

(2) Glacier retreat and permafrost degradation affect water source and conservation

Over the past 30 years, the total area of glaciers on the plateau and its vicinity has shrunk by 15% from 53,000 km^2 to 45,000 km^2, and that of its permafrost has shrunk by 16% from 150,000 km^2 to 126,000 km^2. With the rising of the ground temperature of the permafrost regions along the Qinghai-Tibet Highway, the number of its melting day increases, and the active layer of its permafrost has thickened. The overall trend of its total snow coverage is decreasing.

On the one hand, the changes in glaciers and permafrost have brought about significant impact on

the water circulation process and the temporal and spatial distribution of water resource on the plateau and its vicinity. One of its results is the increase of its surface water area. The area of its inland closed lakes has increased by 28% from 25,000 km^2 to 32, 000 km^2. In addition, with the release of its freezing water, the area of meadow wetlands has somewhat increased. Both of the factors might jointly contribute to the changes of precipitation over the plateau. Another result is the increase of its glacier runoff. Over the past 30 years, the annual mean glacier runoff has increased by 29% from 61.5 billion m^3 to 79.6 billion m^3. It not only replenishes surface water in the region, but also makes important impact on the rivers that replenished by melting glaciers in the vicinity. For instance, the mean runoff of the Tarim River, approximately 42% of whose total river flow comes from glacier runoff, has increased by 17.8% from 18.5 billion m^3 to 21.8 billion m^3 in this period. On the other hand, the rapid melting down of glaciers has increased the number of lakes and enlarged their areas, leading to increased frequency of glacier-lake outbursts and increasing the impact of permafrost degradation on its engineering constructions. For instance, over the past 10 years, the damage ratio of the Qinghai-Tibet Highway has kept at over 30%.

(3) Climate warming has enhanced the productivity of plant communities on the plateau, which is conducive to giving full play to its role as a carbon sink

Climate change was generally conducive to vegetation growth on the plateau over the past 30 years (1982–2011). Field surveys find that the density of the timberline vegetation on the Mt. Shergyla has remarkably increased during the period. A remote sensing image analysis indicates that the overall trend of its GSNDVI (growing season normalized difference vegetation index) is on the rise. The same is the NPP (net primary production), which is calculated using the CASA (Carnegie-Ames-Stanford Approach) model. As a result, the vegetation carbon storage has increased by 50 million tons, an increase of 16.7%. A model simulation of carbon budget shows that the annual net carbon sink of the vegetation over the Plateau is 23 million tons, accounting for about10% of the national total, showing the importance of the Plateau in net carbon sink.

Although its overall vegetation coverage and NPP are rising, there is significant regional unbalance. While the warming and wetting in the eastern part of the plateau have remarkably upgraded the vegetation productivity of its meadows and part grassland, the vegetation productivity has been decreasing as it becomes drier during the warming process in the western part of the plateau. Thanks to the vegetation restoration campaign, the degenerated vegetation in different climate conditions has been recovery in different degrees. In terms of recovery degree, degenerated alpine meadow steppe is the best, followed by degenerated alpine meadow, degenerated grassland, farmland (artificial grassland).

2. Recommendations to Maintain and Give Full Play to Tibetan Plateau's Role as an Ecological Security Shelter

In order to make accurate judgment of the impact of land surface processes of the Tibetan Plateau on the climatic pattern and the region and its vicinity, its water source and conservation, and the carbon sequestration capacity of its eco-system, and to make appropriate and optimum planning for its ecological engineering, it is advisable to introduce the following measures

(1) Further clarifying the correlation between land surface processes of the plateau with meteorological disasters in the east part of China, and make prepared plans accordingly

Changes in the land surface processes and atmospheric heat sources have an important impact on the weather and climate of its neighboring regions. At present, the overall analysis of the land surface cover of the plateau (such as its surface water and heat conditions, its snow ice distribution and vegetation growth) is mainly made through satellite remote sensing. Since the spatial range and underlying surface conditions to apply the findings of satellite remote sensing inversion are very limited, it is difficult to make clear the correlation between its land surface processes and the meteorological disasters in east China using this method. Therefore, it is urgent to conduct large numbers of long-term land surface observations so as to verify the findings of the satellite remote sensing inversion so as to enhance its correctness and precision. At the same time, it is important to form an appropriate structure of spatial network so as to make precise comparison between the changes of the land surface processes over the Plateau and the meteorological disasters in East China, and make timely emergency plans.

It is advisable to fully integrate field observation resources in the field of climate, environment and ecology housed by different departments and systems, and establish some new stations. They will carry out networking observations through stable support from the

national S&T infrastructure programs, so as to obtain long-term continuous data about the changes of ecology system and land surface process on the plateau, so as to provide scientific evidence for the prediction, early warning and reduction of meteorological disaster in East China.

(2) Conducting investigation into the disastrous impact of permafrost and glacier changes on large-scale engineering projects, and carry out prevention and control accordingly by adopting effective measures.

It is advisable, for instance, to minimize the loss caused by glacier-lake outbursts through such measures as monitoring, diversion and setback; to minimize the impact of temperature rise on permafrost and to safeguard engineering projects in permafrost region through strengthening the thickness of the stone filled layer of overlying earth and cooling embankment. Glacier retreat, which is caused by global warming, not only affects the water resources and water circulation on the plateau and its vicinity, but also gives rise to different kinds of disasters. In alpine gorge areas, the accelerated glacier melting has raised the number and scale of ice-lakes and increased the frequency of ice-lake outburst disasters. In alpine vide valley areas, glacier melting increases the amount of melt-water in lakes in a short period of time, submerging surrounding grassland in winter and spring. Permafrost degradation thickens its active layer, producing large-scale frost-heaving and thaw-settlement in permafrost region. This not only damages the existing Qinghai-Tibet Highway, but also affects its good preventive measures.

It is advisable to carry out a comprehensive monitoring survey of glacier retreat and the changes of lakes recharged by glacier melt-water, grading the possibilities of their outbursts, and reducing their disastrous losses by taking such measures as monitoring, diversion and setback. Residence should not be built nearby the lakes with rapid water level rise. Targeted Reparation should be performed for the Qinghai-Tibet Highway in line with the degradation degrees of permafrost and climate change trend.

(3) Advance the development of artificial grassland in winter and spring by taking advantage of enhanced productivity of grasslands brought about by climate warming, and lay a solid foundation of forage supply for the plateau's animal husbandry by strengthening national policy of ecological compensation

The objectives of ecological conservation engineering projects are to enhance their favorable impacts on the sheltering role on ecological security and reduce unfavorable results by changing surface vegetation. Policies such as restoring grazing to grassland, grassland reservation, and enrichment planting have played an important role in raising the productivity of the plateau's vegetation, stabilizing and lowering ground temperature rise and increasing water reservation capacity. However, the implementation of the policies concerns the protection and sustainable growth of grasslands in winter and spring, which has a major bearing on the development of the plateau's animal husbandry and the living standards of herdsmen.

It is advisable to promote the research and development of technologies on forage production, storage and transportation, take effective measures to mitigate the pressure of grazing on the winter and spring pasture, and promote the healthy development of the plateau's animal husbandry by further improving ecological compensation policies.

(4) Launch research programs to examine the processes and mechanism underlying climate change on the plateau, and provide scientific guarantee to the sustainability of the ecological conservation engineering projects on the plateau by strengthening the long-term monitoring of land surface system processes in the plateau

Such factors as land surface heat source changes, cryospheric processes and productivity of vegetation have enormous bearing on the ecological security shelter function of the plateau, such as climate regulation, water conservation and supply and carbon sink. At present, our understanding of the processes still remains at the level of phenomenon relationship. There is not only a lack of understanding of mechanisms; it is difficult to judge the extent to which they are related. At the same time, the understanding of the other functions of the ecological security shelter remains to be deepened.

It is advisable for the Ministry of Science and Technology to launch special S&T projects to study: (1) the functions of land surface cover on the Plateau and its ecological security shelter and relevant spatial differentiation; (2) the impact of plateau's land surface processes changes caused by climate change on its ecological security shelter function; and (3) spatial and temporal pattern of changes of the ecological shelter function in the plateau.