

Foreword to the special issue: looking into the impacts of global warming from the roof of the world

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To most people, the Qinghai–Tibetan Plateau is a place full of mystery. It is also mysterious to many ecologists. The vast central Asian plateau lies at an average elevation >4000 m and covers about 370 million km². Spanning the highest range of elevations of any ecosystem in the world makes the plateau unique even among alpine ecosystems due to the presence of extreme abiotic environments: the lowest atmospheric pressure and thus, the lowest partial pressures of CO₂ and O₂, low temperatures and high levels of radiation, including high ultraviolet radiation. Despite the stresses imposed by the environment, ecosystems on the plateau are well-developed and some of them are rich in biodiversity. Even at elevations ~5200 m, there are extensive and lush alpine meadows but such closed vegetations are rare at similar elevations around the world. Because of the long-term isolation we currently have little knowledge about alpine ecosystems on the plateau.

Modern scientific interests related to ecology in the Qinghai–Tibetan Plateau may date back to the 1800s. The British botanists Moorcroft, Hearsey and Trebeck provided the first scientific record of plants of the Tibetan Plateau in *Asiatic Researches*, despite the fact that, as early as China's Tang dynasty (ca. 753 AD), the ancient Tibetan medical literature had already recorded 209 species (though not in the modern sense of the word) of medicinal plants. From the 1800s to 1950s, more or less continuous exploration of the Tibetan region occurred, with botanists from around the world establishing a large collection of plant specimens. The whole plateau, however, remained unknown to the general public and to most ecologists. Revelation of the mysterious plateau had to wait until the 1950s, when Chinese scientists (mainly from the Chinese Academy of Sciences) conducted an extensive survey of the natural resources of the Qinghai–Tibetan Plateau. These integrated scientific surveys have contributed

a large body of detailed information on almost all aspects of the region's natural resources, including its vegetation and flora. The tremendous efforts have formed an important basis for our current and future ecological studies of the plateau.

The interest in ecological studies on the plateau has been rapidly increasing in the last two decades. One of the major areas of current interest concerns the carbon dynamics of the alpine ecosystems of the Qinghai–Tibetan Plateau. These studies were triggered by the recent surge of global warming research since the plateau is considered to be one of the world's most sensitive areas in terms of both the temperature and the response of these fragile alpine ecosystems. Most of these studies focused on the ecological process of carbon dynamics and the large-scale spatial pattern of carbon sequestration across the vast plateau. One example is an integrated study of the carbon cycles in the Haibei *Kobresia* alpine meadow ecosystem. Long-term observations of ecosystem CO₂ fluxes using the eddy covariance method in this meadow at an elevation of 3200 m revealed that the *Kobresia* meadow is currently a CO₂ sink, which suggests that the extensive alpine meadow on the plateau may play an important role in the regional carbon balance (e.g. Gu *et al.* 2003, Kato *et al.* 2004, Kato *et al.* 2006), though the grazing intensity may have had a large impact on carbon cycles in the meadow (Cao *et al.* 2004). Physiological and morphological observations have partly explained how some alpine plants contribute to the alpine ecosystem's carbon cycle (e.g. Cui *et al.* 2003, Shen *et al.* 2006). Beginning in 2001, a large-scale survey on soil carbon stocks was continuously conducted for 4 years to assess the soil carbon storage in all the alpine grasslands on the plateau (Yang *et al.* 2008, Yang *et al.* 2009). This large-scale survey, combined with remote-sensing data, also showed that the plateau's grassland ecosystem is likely to be a CO₂ sink.

This conclusion is basically consistent with the results of regional modeling (Piao *et al.* 2006, Tan *et al.* 2009). During the same period, some interesting findings on the ecological traits of alpine plants on the vast plateau have been reported by a research group from Peking University through their intensive and extensive surveys (He *et al.* 2006, He *et al.* 2009). Among the studies of carbon cycling on the plateau, field observations have also demonstrated that these alpine plants may contribute emissions of CH₄ (Cao *et al.* 2008, Hirota *et al.* 2004).

In contrast to the growing body of observational data, reports of plant ecology experiments on the plateau are very limited. Klein *et al.* (2004, 2005, 2007) have conducted a warming experiment with open-top chambers in combination with grazing treatments. In addition, a long-term grazing experiment demonstrating altered plant species composition in an alpine meadow community was recently reported (Zhou *et al.* 2006).

The contributions in this special issue, which will be published in two consecutive issue numbers due to the publication timetable, cover recent developments from the above-mentioned studies. The topics range from ecosystem energy flux to molecular ecology, but all focus on the issue of climate change on the Qinghai–Tibetan Plateau, which are mainly from a joint research project ‘Early detection and prediction of climate warming based on the long-term monitoring of alpine ecosystems on the Tibetan Plateau’ between Ministry of the Environment, Japan, and The Chinese Academy of Sciences, China. Hirota *et al.* and Yashiro *et al.*, using their portable NEP (net ecosystem production) measuring system’ specifically designed for the conditions in an alpine meadow, have attempted to clarify ecosystem CO₂ fluxes at different elevations along a vertical transect through an alpine meadow from 3600 to 4200 m in elevation. On the other hand, Zhang *et al.* focused on ecosystem CO₂ fluxes at similar elevations but at sites dominated by different *Kobresia* species under three contrasting soil water regimes. To scale-up local observations, Chen *et al.* tried to relate tower-based CO₂ flux observations to remote-sensing data through measurements of light utilization efficiency. In contrast to the ecosystem observations, Shen *et al.* provided the first reliable field measurements of leaf photosynthesis in a warming experiment and found that despite a slight acclimation of leaf photosynthesis of *Gentiana straminea* during an 11-year experimental warming period, the consequences of this physiological acclimation for leaf carbon budgets were significant.

In addition to these field observations and experiments, Lee *et al.* used soils from an alpine meadow on the plateau and from a lowland grassland in Japan to study the temperature sensitivity of soil respiration and test previous speculations that alpine ecosystems may be more sensitive to global warming. Shimono *et al.* assessed plant species diversity as a function of elevation to provide further insights into the potential elevational shift of plant species in response

to global warming. The only molecular ecological paper by Li *et al.* aimed to clarify the effects of past climate change and plant distribution on the plateau and increased our understanding of the phylogeography of *Potentilla fruticosa*, an alpine shrub on the Qinghai–Tibetan Plateau, by analyzing a new chloroplast DNA sequence. The molecular phylogeny and biogeography of alpine plants may provide insights into the evolutionary history and change in distribution of plant species as a function of climate in a unique ecosystem. These studies may also explain the high plant species diversity in some ecosystems on the plateau (Chen *et al.* 2008).

All these studies will add to our current knowledge on the unique alpine ecosystem, though most of these studies are preliminary. We hope that these studies can provide the impetus for further explorations that will increase our understanding of the roof of the world.

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