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Soil seed bank and its relation with above-ground vegetation along the degraded gradients of alpine meadow

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ABSTRACT

Degradation of alpine meadow may change the composition and size of the soil seed bank, which will impact on the seed bank's capacity for restoration. Four plots were selected to represent the degradation gradients of alpine meadow on Tibetan plateau, namely normal meadow, lightly-degraded meadow, moderately-degraded meadow, and severely-degraded meadow. Soil cores were collected in two seasons, November of 2004 (after seed dispersal) and April of 2005 (before seedling emergence). Soil seed banks were examined by a seedling emergence method. Totals of 56 and 57 species were identified from soil seed bank of four plots in November and April, respectively. The mean size of the soil seed bank on the four plots varied between 2662 and 8026 seeds m^{-2} in November, and between 3744 and 9773 seeds m^{-2} in April. The difference in soil seed bank size between the two sampling times (November and April) was not significant within plots. Soil seed banks and above-ground vegetation presented the same trend with vegetation succession across the differently degraded meadows. In all plots, hemicryptophytes accounted for the majority of species and produced the largest number of seeds, of which the majority was weeds. In degraded meadows, the significant increase in weeds (species richness, plant density) changed species composition of soil seed bank and above-ground vegetation along degrading trend. The soil seed bank has important implications for vegetation succession and the restoration of species-diverse alpine meadow on the Tibetan plateau.

1. Introduction

The total area of alpine meadow is about 58.2 million ha, which is 46.1% of the total rangeland area of the Tibetan plateau (Xie et al., 2003). The alpine meadows are distributed mainly in the eastern and southern parts of Tibetan plateau, which has greater rainfall than other rangeland types (alpine steppe, alpine deserts) on Tibetan plateau, then it has higher vegetation biomass (Long et al., 2009). The dominant plant species is sedge species and some grasses, such as *Kobresia*, *pygmaea*, *K. microglochina*, *K. kumilis*, *Elymus nutans*, and so on (Zhou, 2001). The Tibetan alpine meadows support 92% of all the world's yak population, which is the main livelihood resource of Tibetan people (Lu, 2007). The alpine meadows of Tibetan plateau have a huge capacity for carbon storage (162.51×10^8 t C), accounting for about 48.5% of all rangeland carbon storage (335.26×10^8 t C) of Tibetan plateau (Wang et al., 2002). In addition, they contain specific species and high biodiversity, so the maintenance of their ecosystem is important for sustainable development in the Tibetan plateau (Xu et al., 2004). However, due to overgrazing and irreversible cultivation of grassland during the last 50 years, especially before the 1980s, much of the natural grassland in China has become degraded (Shang and Long, 2007; Li et al., 2013b). About 90% of all alpine meadow had been degraded in recent years, even to the extent of becoming bare land, with little of any utilization value and ecological function (Zhou et al., 2005; Li et al., 2013a). Thus, restoring degraded alpine meadow is an enormously important concern for the Tibetan plateau, requiring scientific research.

Soil seed banks act as an important resource in ecosystems underpinning restoration management (Lang and Halpern, 2007; Kalamees et al., 2012). Persistent seeds in the soil (seed banks) may be regarded as 'a reserve of genetic potential' (Bertiller and Ares, 2011), and are important sources for the regeneration of plant communities (Fenner and Thompson, 2005). Reports have often

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indicated the lack of beneficial seeds as the major limiting factor when attempting to restore degraded vegetation back to its original state within diverse plant communities (Peterson and Baldwin, 2004a,b; Luzuriaga et al., 2005; Jacquemyn et al., 2011). If land managers wish to promote the recruitment of desirable species from existing seed banks, the first crucial step is to determine the composition of the soil seed banks (Tracy and Sanderson, 2000).

Grasslands have different species composition and size of soil seed bank depending upon the extent of degradation, which have different functions in restoration activity (Kassahun et al., 2009). Knowledge of the soil seed bank is very important for restoring degraded alpine meadow. However, such information on the soil seed bank of degraded alpine on Tibetan plateau has been absent. Therefore, we selected pastures representative of normal alpine meadow and meadows having undergone degradation to differing extents, in order to investigate (1) the size and species composition of the seed bank, (2) the relationship between the above-ground vegetation and the soil seed bank, and (3) the potential implication of the soil seed bank for restoring degraded alpine meadows.

2. Materials and methods

2.1. Study sites

The study site was located in the centre of the Tibetan Plateau within the administrative purview of Guoluo ('Golog' in Tibetan) Prefecture, Qinghai province (Fig. 1). The longitude and latitude of the site are 34°27′–34°31′ N and 100°02′–100°13′ E, and the altitude range is from 3700 m to 4000 m above sea level. The climate is alpine semi-humid. According to local weather station records (Maqin station), the basic weather condition from 2001 to 2005 was as following descriptions. Whilst the annual average temperature is −0.6 °C, the extreme minimum temperature is −34.9 °C. The annual accumulated daily temperature ≥0 °C and ≥5 °C are 1203 °C and 865 °C, respectively. The average annual precipitation is 513 mm, with most precipitation occurring from May to September. The major soil types are alpine meadow soils. The vegetation type is alpine meadow (Shang et al., 2008).

According to the description of soil and vegetation conditions of different degraded alpine meadows by Ma et al. (1999, 2002) and Li (2002), we selected four types of meadow as our study areas (1 ha each), typical of different stages of degradation in alpine meadows. They were normal meadow (NM), lightly-degraded (LD), moderately-degraded (MD) and severely-degraded (SD) meadows. Basic vegetation, soil and soil microorganism content were reported by Shang et al. (2007, 2008) and Sun et al. (2010) which confirmed that the four plots were typical of a degradation gradient from un-degraded, through to severely degraded alpine meadow. The soil within four plots was basically the same alpine soil type, but with variation in mineral status, especially within the top soil horizon of SD where there had been some surface erosion (Shang et al., 2013a,b). According to Shang et al. (2013a,b, 2015), the soil characteristics had been measured and list in Table 2.

The normal meadow (NM) was located at 3972 m a.s.l., N34°31.673′; E100°02.064′ and had a vegetation canopy cover of 95–100%. The normal meadow was dominated by *Kobresia* and *Gramineae* plants, with little weed incursion and no bare soil. The normal meadow was the un-degraded alpine meadow chosen as our control plot. The lightly-degraded meadow (LD) was located at 3732 m a.s.l., N34°28.921′; E100°13.067′, with vegetation canopy cover of 70-80%, dominated by *Gramineae* plants. The coverage of *Kobresia* plants was less than that of *Gramineae*. The plot had bare soil covering about 20–30% of the surface area. The moderately-degraded meadow (MD) was located at 3728 m a.s.l., N34°28.748′, E100°13.159, with vegetation canopy cover of 40–60%. This plot had more bare soil, covering about 40–60% of the surface. The community was dominated by *Gramineae* with few *Kobresia* plants, but there were many weeds. The severely-degraded meadow (SD) was

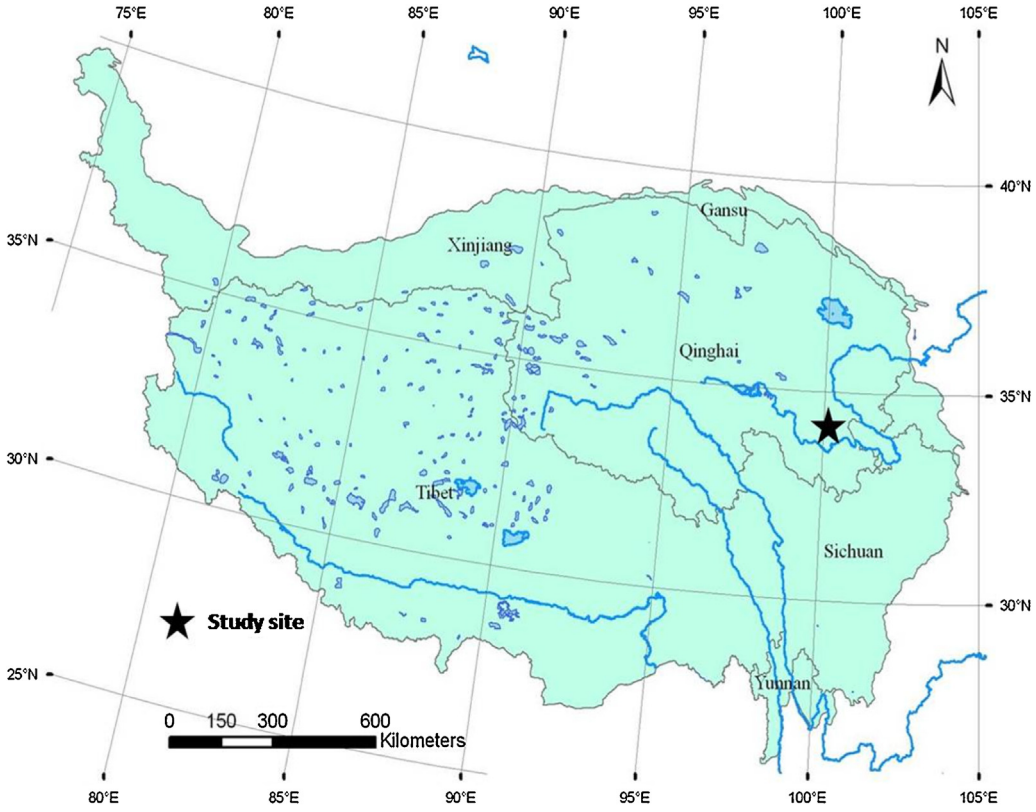

Fig. 1. Study site on Tibetan plateau.