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# Conversion of Tibetan grasslands to croplands decreases accumulation of microbially synthesized compounds in soil

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ABSTRACT

Conversion of grassland to cropland affects microbial transformation of plant derived organic substances and the accumulation of microbially synthesized products in soil. We investigated long-term effects of agricultural use [more than 50 years' rotation with barley (*Hordeum vulgare*) and rapeseed (*Brassica rapa*)] after conversion from grasslands (grazed in the winter season) on the contents and composition of non-cellulose sugars and amino sugars in a broad range of soils on the Tibetan Plateau. Soils from two types of croplands (barley or rapeseed) were compared to a reference grassland soil by detailed analysis of plant vs. microbial and bacterial vs. fungal biomarkers. Long-term cultivation decreased total soil organic matter (SOM), light SOM and total non-cellulose sugar contents in the 0–20 cm soil by 27%, 47–72% and 57%, respectively, reflecting decreased root biomass compared to grassland. The ratios of (galactose + mannose)/(arabinose + xylose) and (rhamnose + fucose)/(arabinose + xylose) were both 26% smaller in cropland than in grassland soils, while the ratios of hemicelluloses in shoots or roots were similar between native and cultivated plants. Consequently, net transformation of plant substances to microbially synthesized polysaccharides decreased in cultivated soils. The total amino sugars (muramic acid, glucosamine, mannosamine, galactosamine) in cropland soils decreased by 42% as did their contribution to the SOM pool by 22%, compared to grassland soils, but the ratio of glucosamine/muramic acid in cropland soils doubled when compared to the grassland soil. This shows a strong decrease in microbial residue under cultivation, with the magnitude of the decrease greater in the bacterial than in the fungal components. All the above results from the intensively sampled site were confirmed in seven other sites featuring lower sampling intensity. We concluded that the conversion of grassland to cropland strongly decreases microbial transformation of plant residues and accumulation of the resulting microbial compounds – necromass – in soil (i.e., reduction of microbial input to stable SOM). The conversion also leads to a shift in the composition of microbial compounds towards a decreasing contribution of bacterial compared to fungal necromass.

## 1. Introduction

Conversion of native vegetation to croplands usually decreases soil organic matter (SOM) storage. This decrease in the SOM pool during cultivation is ascribed to accelerated mineralization (Huggins et al., 1998; Six et al., 1998; Lobe et al., 2001; Lal, 2002; Zingore et al., 2005) and lower plant residue input. Tillage disturbances destroy the physical protection of SOM (through adsorption on mineral surfaces and occlusion in aggregates), leading to better SOM accessibility to microorganisms. This mechanistic explanation is mainly deduced from reduced preservation of plant residue dominated particulate or/and light fraction SOM during decomposition compared to soils under native vegetation (Besnard et al., 1996; Lobe et al., 2002; Zingore et al., 2005; Lützow et al., 2006). Numerous studies, however, have demonstrated by physical fractionation (e.g., Lobe et al., 2001; Li et al., 2007; Shi et al., 2010) that, besides the depletion of plant-dominated SOM fractions by cultivation, mineral-associated SOM is also decreased when compared to native soils. This implies that the portion of litter that is incorporated into the stable SOM pool also decreases along with the stimulated decomposition under cultivation. The mineral-associated SOM pool that accounts for most SOM (Lützow et al., 2007) contains more microbially recycled components than the light SOM fractions (Lützow et al., 2006; Clemente et al., 2011). Therefore, conversion of native vegetation to cropland may affect microbial transformation of plant substances and accumulation of microbially synthesized products in soil.

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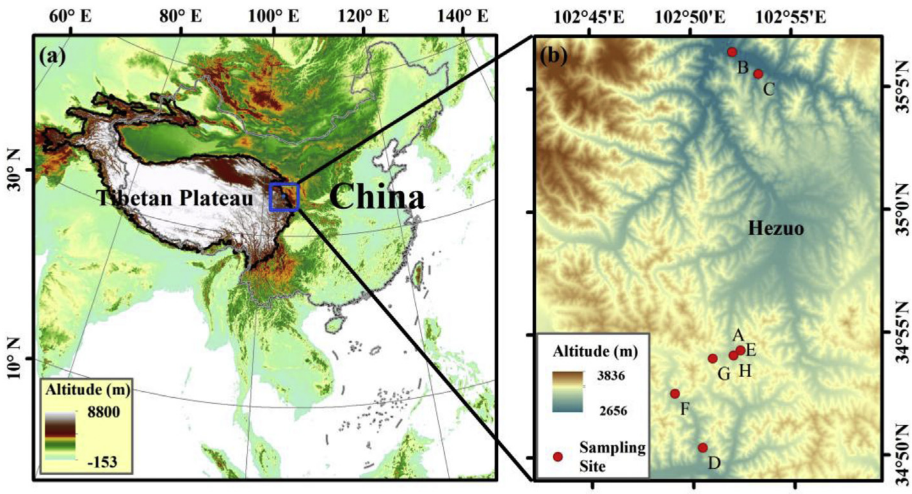


**Fig. 1.** The investigated area (a) and sampling locations (b) on the Tibetan Plateau.

The current mechanistic explanation for the decreased SOM storage after conversion of native vegetation is incomplete. SOM content is not always related to soil organic carbon (SOC) input quantity or the degree of soil disturbance (Cotrufo et al., 2013; Kallenbach et al., 2015; Cyle et al., 2016). Microbial biomass and moribund necromass significantly contribute to SOM (Liang and Balser, 2011; Miltner et al., 2012; Malik et al., 2013; Ludwig et al., 2015). Microorganisms synthesize many structural and storage compounds, including polysaccharides, peptidoglucans, proteins, lipids, melanins, chitin and teichoic acids (Kögel-Knabner, 2002). Recent advances emphasize that SOM formation and stabilization are associated with accumulation of those microbially synthesized compounds in soil (Kindler et al., 2006; Miltner et al., 2012; Cotrufo et al., 2013; Kallenbach et al., 2015; Liang et al., 2017). Conversion from native vegetation to arable lands, besides involving tillage disturbance, also significantly changes root properties and quality as well as total C input (DuPont et al., 2014). These biotic and abiotic factors influence microbial C use efficiency (C used for biomass growth per unit of C uptake) and turnover rate of microbial debris and consequently may affect SOM formation (Cotrufo et al., 2013; Kallenbach et al., 2015; Shao et al., 2017). Thus, investigation of microbial transformation of plant residues and accumulation of microbial compounds in soil is necessary to clarify mechanisms of the decreased SOM storage after conversion of native vegetation to cropland.

Soil microorganisms rarely synthesize pentoses (Oades, 1984; Prietzel et al., 2013; Schmidt et al., 2015) and plants do not synthesize amino sugars (Amelung et al., 1999; Amelung, 2003). Consequently, the composition of non-cellulosic polysaccharides (ratios between hexoses and pentoses) is a powerful tool to show the net transformation efficiency of plant materials to microbial derived polysaccharides (Oades, 1984; Kögel-Knabner, 2002) and the content of amino sugars can be used to indicate the abundance of microbial residue in soil (Joergensen and Wichern, 2008; Gunina and Kuzyakov, 2015). In addition, particular amino sugars (that is, muramic acid and glucosamine) can indicate the relative contributions of bacterial and fungal origins to microbially derived residues in soil (Turrión et al., 2002; Joergensen and Wichern, 2008; Liang et al., 2009). Conversion of native vegetation to cropland results in systematic changes in soil hydrothermal conditions, composition and quantity of organic input to soil and intensity of soil disturbances in management (Lal, 2002). All these alterations may in turn induce variations in physiology and composition of microbial communities and thus affect C use efficiency and accumulation of microbially synthesized compounds (Murphy et al., 2008; van Eekeren et al., 2008; Bissett et al., 2011; Constancias et al., 2014; Baer et al., 2015; Finn et al., 2017; French et al., 2017). Microbially synthesized compounds during decomposition of plant materials are the main precursors of stable SOM (Turrión et al., 2002; Kiem and Kögel-Knabner, 2003; Mambelli et al., 2011; Schmidt et al., 2011; Cotrufo et al., 2013; Cyle et al., 2016).

Despite being the largest livestock farming area in the world, the Tibetan Plateau has a long agricultural history (Chen et al., 2015). Cultivating on the "roof of the world" to elevations above 4000 m a.s.l. began 3600 years ago and facilitated permanent human occupation of the plateau (Chen et al., 2015). The proportion of the plateau under cultivation is small, but arable lands (converted from grasslands) used for planting grain crops such as wheat (*Triticum aestivum*), naked barley (*Hordeum vulgare*) and rapeseed (*Brassica rapa*) and other forage crops such as oat (*Avena fatua*) and common vetch (*Vicia sativa*) are more frequent in northeastern and eastern areas and river valleys. Previous studies (Li et al., 2007; Shi et al., 2010) have reported that conversion of grasslands to arable lands strongly decreased SOM storage on the Tibetan Plateau. Nonetheless, it remains uncertain whether and how agricultural use of grasslands affects microbial transformation of plant inputs and accumulation of resulting microbial products – the necromass – in soil. We compared contents and compositions of non-cellulosic polysaccharides and amino sugars between grazed grassland and arable soils across eight sites located at altitudes between 2745 and 3120 m e.s.l. We hypothesized that conversion of grasslands to croplands would induce decreases in the ratios between hexoses and pentoses in non-cellulosic polysaccharides and accumulation of microbial necromass in soil. The objective was to elucidate the effects of conversion of grassland to cropland on microbial input to SOM in alpine regions.

## 2. Materials and methods

### 2.1. Site description and sampling

Soil sampling was conducted in early August 2015 at eight sites (named with letters from A to H, respectively) with an altitude range of 2745–3118 m, in Gannan Tibetan Autonomous Prefecture, Gansu Province, on the eastern edge of the Tibetan Plateau (Fig. 1a and b; Table 1). Annual mean air temperature and precipitation are 1.7 °C and 545 mm, respectively, recorded at a weather station (Hezuo) nearest to site A. The native vegetation, alpine meadows, was dominated by *Kobresia humilis*, *K. capillifolia*, *K. kansuensis*, *Elymus nutans*, *Poa annua* and shrub *Potentilla fruticosa*. Soils at all sites are classified as alpine meadow soils according to the Chinese soil classification system, developed from alluvial materials. At the sites B, C and D (altitudes 2745–2986 m), soils contained some carbonates, indicated by production of $CO_2$ bubbles after adding hydrochloric acid.