Soil acidification with various planting patterns in Lhasa, Tibet, China

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Abstract
The spread of vegetable production around Lhasa, Tibet, China, with high nitrogen fertiliser use may cause accelerated acidification which has consequences for soil productivity. In order to understand the different patterns of soil acidity in Lhasa, Tibet, China three patterns of land use were studied namely: grain, open-field vegetable, and greenhouse vegetable. Fertilizer application was higher in vegetable cultivation and greenhouse vegetable cultivation among the three patterns of land use. Soil pH for greenhouse vegetable production was lowest, while soil pH for grain production was the highest. Higher fertilization and the higher evaporation coupled with very low leaching in vegetable greenhouse caused a dramatic change of soil quality. We should improve management to increase nitrogen uptake efficiency and to reduce nitrogen application.

Key Words
Soil pH, N and P over accumulation, soil quality, vegetable land, semiarid area, Tibet Plateau.

Introduction
Several studies have found that the additions of nitrogen fertilizers can result in an acceleration of soil acidification compared with no fertilization in arid climates with naturally alkaline soils (Bowman and Halvorson 1998; Xu *et al.* 2002). Soil pH was lower in cropped and fertilized treatments compared to the fallow treatment in China's Loess Plateau (Wei *et al.* 2006). Soil pH is decreasing in many soils in the semiarid Great Plains of the United States (Tarkalson *et al.* 2006).Nitrogen fertilization significantly reduce soil pH by 0.3 and 0.5 units for low and high rates respectively (Rodriguez *et al.* 2008). The soil ecosystems are fragile and sensitive in the semi-arid middle Tibet Plateau. Some papers had reported on biological fertility and its dynamics in degraded soil of this area (Qian *et al.* 2006).Changes of cropland soil pH have occurred in the semiarid middle Tibet Plateau since the Second National Soil Survey in 1980s, with average pH values decreasing from 7.70 in the 1980s to 7.22 in 2008(Zhou *et al.* 2009). Although the Tibetan Plateau may have been little affected by industrial activities, land use change is occurring, with an increasing trend towards vegetable land. There is an increasing trend of land use change from grain to vegetables, with or without plastic film covering, since the early days of the 1990s in Lhasa, Tibet, China. There were only 493 ha of vegetable lands in Lhasa in 1990, but 3953 ha in 2006. This land use change was driven by a dramatic increase in demand for vegetables due to both improved living standards and increased urban populations. There was, however, scarce information on the soil acidity changes in vegetable land. Hence there was a need to understand differences in soil acidity between the three patterns of land use namely: grain, open-field vegetable, and greenhouse vegetable.

Methods
Study area
This study was conducted in Lhasa (29º14´-31º04´N, 89º45´-92º37´E, 3600-4100m), Tibet autonomous region, China. This region is dominated by a continental temperate climate with annual mean of 1.5-7.8ºC. Annual precipitation is 340-600 mm, with 75% concentrated during June-August. The mean annual sunshine duration is 2400-3150 h. According to the genetic soil classification of China, alluvial soil (Inceptisols, Soil Taxonomy) in the study area are sandy loam or loam in texture. These are the major vegetable production soils in the area. The common grain tillage system of the study area is winter wheat or Tibet barley continuous farming, with nearly 11 months growing period from mid or later October for sowing to early next September for harvest. The growing period of open-field vegetable cultivation covers 7 months from April to October. But the growing period of greenhouse vegetables occurs all the year.

Soil sampling and analysis
In 2008, 53 representative sites were selected and geographic coordinates recorded using a hand-held global

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

positioning system (GPS). At each site, 5-7 topsoil sub-samples were gathered in a 0.1 ha area at a depth of 0-20 cm and then pooled and mixed. Soil samples were air-dried and ground to pass through a 2-mm sieve before analysis. Soil analysis for pH (1:2.5 soil: water), total N (Kjeldahl digestion), total P (molybdenum method), total K (flame photometer method)-according to the methods described by Liu (1996).

Statistical analysis

All statistical analysis procedures were conducted using SPSS 11.0. Duncan's multiple range tests was used to test for differences of soil groups. Significance was determined at the 0.05 probability level.

Results

Soil pH

Compared with the Second National Soil Survey in the 1980s, average soil pH of 53 soil samples value declined 0.30 units ($P < 0.05$). Average soil pH value for grain, open-field vegetable, and greenhouse vegetable land use were 7.56 ±0.61, 6.92 ±1.16, 6.07 ±0.99, respectively. Soil pH was significantly different between grain or open-field vegetable and greenhouse vegetable.

Soil nitrate and phosphorus accumulation

Noticeably, soil total N and P content in greenhouse vegetable soils was higher ($P < 0.05$) than for other soils (Table 1). Soil N has accumulated in greenhouse vegetable land. Soil total N was significantly different between grain and greenhouse vegetable soils. Soil total P was significantly different between the three types of cultivations. Soil total K was significantly different between grain and open-field vegetable.

Table 1. Effect of land use on total N, total P and total K in soil (0-20 cm depth).

Land use	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)
Grain	1.33 ± 0.32^{b}	0.76 ± 0.14^{c}	24.2 ± 2.46^{a}
Open-field vegetables	1.57 ± 0.33^{ab}	1.09 ± 0.31^{b}	21.8 ± 1.99^{b}
Greenhouse vegetables	1.87 ± 0.63^{a}	1.51 ± 0.58^{a}	22.6 ± 2.18^{ab}

Means ±1 SD. Significant differences among land uses are denoted by different lowercase letters.

Soil acidification

Soil pH depends on the intrinsic factor like soil parent material and exogenous factors such as acid deposition and farming practices. In the semi-arid middle Tibet Plateau, each factor played a difference role in soil pH changes. Firstly, the soils experienced weak pedological development, resulting in a high level of free base cations and a weak cations exchange capacity; so nutrient loss was prone to occur. The study soils were sensitive to acidification (Pan 1990). Secondly, addition of ammonium N fertilizer accelerates nitrification. Annual N application of Lhasa City has overloaded the national threshold of 150 kg N/ha (Zhou *et al.* 2009) and total soil N has accumulated. High Nitrogen caused losses of up to 70 % of exchangeable base cations (Högberg *et al.* 2006). Annual N and P application of greenhouse vegetable was the maximum in three patterns of land use. Among three patterns of land use, soil pH of greenhouse vegetable was the lowest, but soils used for grain production was the highest. A significant increase of fertilizer input, particularly ammonium N fertilizer, most likely caused the severe acidification in greenhouse vegetable land. Higher fertilization and the higher evaporation coupled with very low leaching in vegetable greenhouse caused dramatic change of soil quality.

Conclusion

Soil pH value of greenhouse vegetable areas was the lowest among the three patterns of land use. Soil pH was significantly different between grain or open-field vegetable and greenhouse vegetable. These results suggest that surface soils under greenhouse vegetable production are acidifying under current management practices. Although soil pH in this region was neutral in 2008, if this trend continues, it will adversely affect soil properties such as heavy metal bioavailability, fertility, and microbiology; and plant growth will be threatened. Improved management to increase N uptake efficiency from applied fertilizer would help reduce the rate of acidification. We should fertilize evenly, improve utilization efficiency of the fertilizer, and avoid using ammonium N fertilizers.

Acknowledgment
This research was support by the project on classification and gradation of soil erosion in the Lhasa city of the Tibet plateau. The authors are grateful for Mr. Xiancai Hu, Mr. Jidong Sun and Mr. Feng Rong, for soil sampling. We are grateful for the comments of the referees.

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