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Effects of vegetation restoration on soil quality in degraded karst landscapes of southwest China

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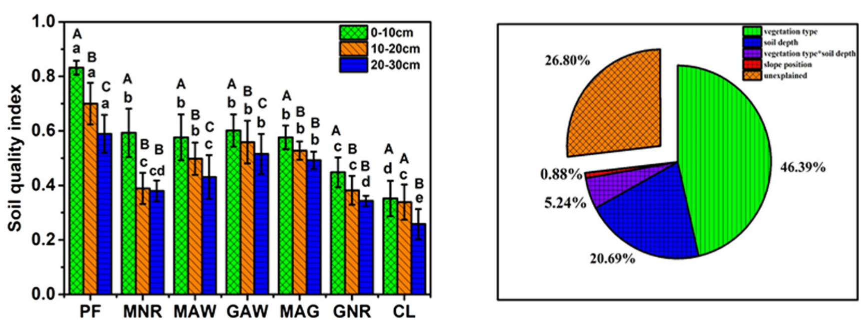
HIGHLIGHTS

- TN, TP, TK, AP, and clay content were representative indicators for soil quality index (SQI).
- SQI of any vegetation restoration type was significantly greater than that of cropland.
- Vegetation type is the dominant factor influencing SQI.

GRAPHICAL ABSTRACT



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ABSTRACT

Vegetation restoration was implemented to control soil erosion in the karst regions of southwest China. It is essential to assess the soil function and quality scientifically during this process and to adopt suitable management practices for this area. However, few studies have been conducted to comprehensively evaluate the effect of vegetation restoration on soil quality in this severely eroded karst area. By taking 302 soil samples from 11 vegetation types, this study investigated the influence of different types of vegetation restoration on soil quality using an integrated soil quality index (SQI) and a generalized linear model (GLM). Vegetation types had significant effects on soil properties and thus on soil quality. SQI was developed by using TN, TP, TK, AP, and clay content; TN had highest weighting values (0.58), which indicated that it contributed the most to final SQI. The highest and lowest SQI values were observed for primary forest and cropland, respectively. Overall, vegetation restoration (e.g., natural restoration, artificial forests and artificial grassland) improved soil quality significantly. A GLM model explained 73.20% of the total variation in SQI, and vegetation type explained the largest proportion (46.39%) of the variation, which implies that the vegetation restoration practices can greatly enhance the soil quality in karst landscapes of southwest China. The results of this study may be used to improve implication of ecological restoration and management in degraded regions.

1. Introduction

Soil quality is defined as the capacity of soil to function within ecosystem boundaries, sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran et al., 1994; Karlen et al., 2003). Soil quality has suffered a remarkable decline

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worldwide as a consequence of soil degradation causing by anthropogenic and natural factors (Marzaioli et al., 2010; Peng et al., 2013). The karst landscape of southwest China is particularly susceptible to severe soil degradation due to its special geological conditions and fragile ecosystems (Cai, 1996; Li et al., 2017; Peng et al., 2013). To improve soil condition and to restore ecosystems, the "Grain for Green" program was carried out by the Chinese government in this area (Yang et al., 2017) and, therefore, the soil function and quality may improve during the restoration of vegetation (Raiesi, 2017).

Many studies have examined the performance of this program (Fu et al., 2010; Zhang et al., 2011). However, most of these studies focused primary on the influence of vegetation types on individual soil parameters or only a very few limited soil parameters, such as soil organic carbon stock (Deng et al., 2015; Zhang et al., 2010), soil physical properties (Wang et al., 2008; Yao et al., 2009), and soil nutrients (Emadi et al., 2009; Raiesi and Beheshti, 2014). Nevertheless, soil quality cannot be evaluated by individual soil properties, because many of these properties are interdependent, and their responses to environmental change are difficult to interpret (Griffiths et al., 2010). Thus, to comprehensively assess soil quality, a soil quality index (SQI) that integrated soil properties into an overall index was established and has been used widely (Andrews et al., 2002a). Most studies that assessed soil quality concentrated on the influence of land use (Rahmanipour et al., 2014; Yu et al., 2018), soil management (Andrews et al., 2002b), tillage practices (Obade and Lal, 2014; Qi et al., 2009) and tree species (Ngo-Mbogba et al., 2015; Zhang et al., 2015). Although the effect of vegetation restoration on soil quality has been studied in some regions, such as the Loess Plateau (Guo et al., 2018; Zhang et al., 2011), few studies were conducted to evaluate the influence of vegetation restoration on soil quality in a karst landscape.

The objectives of this study were (1) to examine how vegetation types affect soil physical and chemical properties of soil, (2) to establish a soil quality index based on a Minimum Data Set (MDS) to evaluate the effect of vegetation types on soil quality, and (3) to identify the factors that influenced soil quality.

2. Materials and methods

2.1. Study area

The study was conducted in three typical peak–cluster depressions, Mulian (24°44′N, 107°51′E), Guzhou (24°54′N, 107°57′E), and Mulun National Nature Reserve (25°07′–25°12′N; 107°54′E–108°05′E,). All three areas are associated with the Huanjiang Observation and Research Station for Karst Ecosystems of the Chinese Academy of Sciences (CAS), located in northwest Guangxi Province, southwest China (Fig. 1).

This area is characterized by a subtropical monsoon climate with average annual temperature of 18.5 °C and mean annual rainfall of 1389 mm. The rainy season occurs during April–August, and the dry season occurs during October–March. The topography of Mulian and Guzhou are similar, high on all sides and low in the center. In the Mulun reserve, topography is low in the southeast and high in the northwest. The soils of Mulian and Guzhou are calcareous and developed from a dolostone base and a limestone base, respectively, but in the Mulun reserve, soils were developed predominantly from soluble and porous limestone (Drew, 2011; Nie et al., 2011). Natural vegetation in Mulian and Guzhou mainly included shrubs and grass, and artificial forest and grass were planted gradually after restoration began in 2003. The Mulun nature reserve was established in 1991 and approved as the National Nature Reserve in 1998 (Yang et al., 2017). Farming, grazing, and fire occurred at the edge of the reserve until its establishment. The primary forest reserve is dominated by subtropical species and it is classified as a subtropical, mixed evergreen-deciduous, broadleaf forest. With a forest coverage of 94.8%, the biological resources of this region are abundant, and biodiversity quality is high (Du et al., 2017).

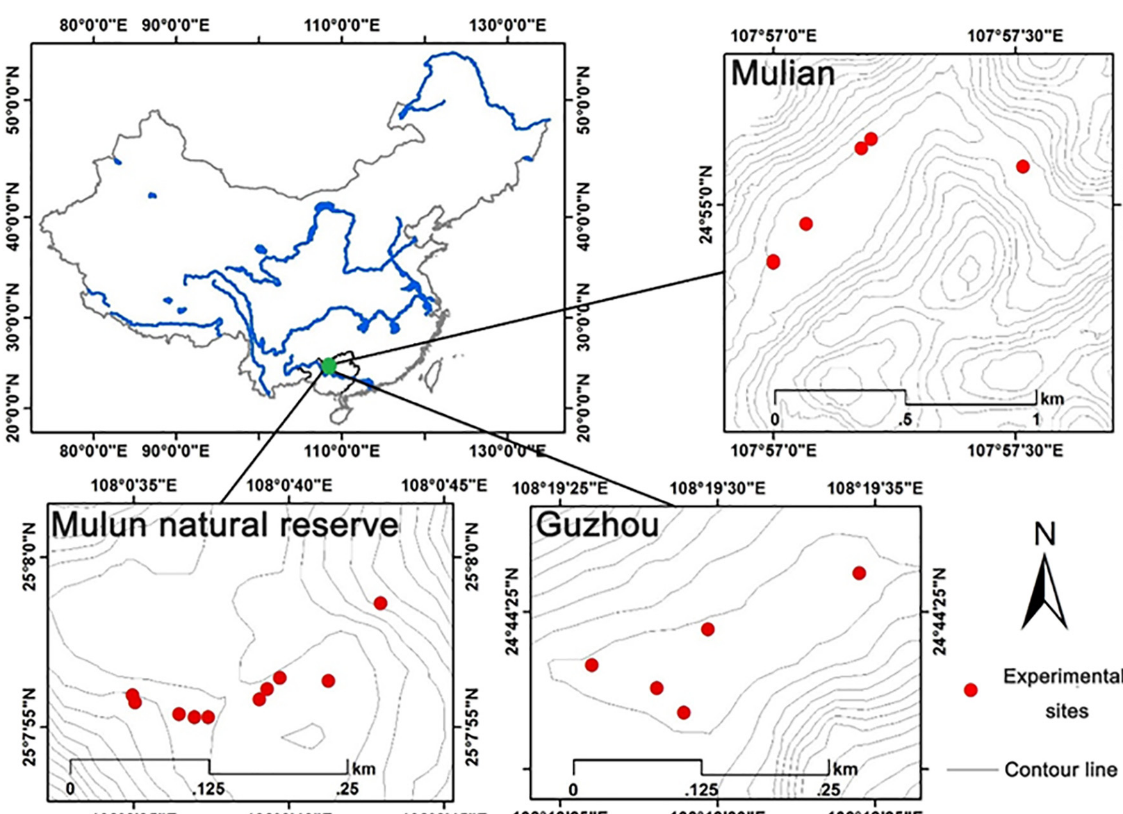

Fig. 1. Location of study area at the Huanjiang Observation and Research Station for Karst Ecosystems of the Chinese Academy of Sciences (CAS), Guangxi province, Southwest China.