European Journal of Soil Biology 61 (2014) 49–57

Contents lists available at ScienceDirect

European Journal of Soil Biology

journal homepage: http://www.elsevier.com/locate/ejsobi

Original article

Effect of vegetation types on chemical and biological properties of soils of karst ecosystems

Xiaoqiang Lu [a,*], Hiroto Toda [b], Fangjun Ding [c], Shengzuo Fang [d], Wanxia Yang [d], Haigen Xu [a]

[a] *Nanjing Institute of Environmental Sciences, Ministry of Environmental Protection of China, Nanjing, China*
[b] *Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu, Tokyo, Japan*
[c] *Karst Forest Ecosystem Research Center, Guizhou Academy of Forestry Sciences, Guiyang, China*
[d] *College of Forest Resources and Environment, Nanjing Forestry University, Nanjing, China*

ARTICLE INFO

Article history:
Received 20 January 2013
Received in revised form
17 December 2013
Accepted 23 December 2013
Available online 7 January 2014
Handling editor: Yakov Kuzyakov

Keywords:
Karst
Afforestation
Chemical and biological properties
Carbon and nitrogen mineralization
Soil quality index

ABSTRACT

Inappropriate human activities have caused widespread reductions of forests and have produced degradation in karst regions of China. In the past two decades, numerous attempts have been made to promote recovery of the degraded soil using afforestation and natural regeneration approaches. A better understanding of the effects of vegetation types on the chemical and biological properties of the soil is very important for both reforestation approaches. Five vegetation types, namely, natural old-growth forest (>80 years old), grassland (15–25 years old), natural regeneration (20–25 years old), bamboo plantation (23 years old) and pine plantation (22 years old), were investigated in the Maolan karst area of Guizhou Province. The soil quality index (SQI) was evaluated with a cluster analysis and a principal components analysis to compare soil quality classes among the vegetation types. The results indicated that soil organic matter, the MBC/TOC ratio and soil basal respiration were the most important factors reflecting the general chemical and biological properties of the soil. Based on the SQI values, the soil quality under the selected vegetation types could be divided into three groups: low soil quality (pine plantation with SQI = 0.26 and grassland with SQI = 0.29), intermediate soil quality (bamboo plantation with SQI = 0.41 and natural regeneration forest with SQI = 0.46) and high soil quality (natural old −growth forest with SQI = 0.63). The results of this study suggested that the pure plantation of *Pinus massoniana* had a negative impact on soil quality and that natural restoration may represent a more effective approach to the improvement of soil quality in degraded karst areas. These results also showed a strong interaction between soil quality, nutrient dynamics and vegetation types.

1. Introduction

Karst is a distinctive topography developed as a result of the dissolving action of water on soluble rocks. A karst landscape is characterised by fluted and pitted rock surfaces, vertical shafts, sinkholes, sinking streams, springs, subsurface drainage systems and caves [7]. Karst terrain represents approximately 12% of the earth's land area and is distributed primarily in the Mediterranean Sea area, Eastern Europe, the Middle East, Southeast Asia, Southeast America and the Caribbean region [27]. Because of the low soil-forming capability of soluble bedrock and the highly weathered, leached and impoverished condition of soil nutrients, soil is usually thin and scattered in karst regions [26]. The forest ecosystems developed in karst regions have been shown to be relatively fragile as a result of inappropriate human activity such as cultivation, deforestation, grazing and burning [23]. One of the most critical problems in the karst area of southwestern (SW) China is "rock desertification", i.e., the transformation of a karst area formerly covered by soil and vegetation into a rocky landscape or lithologic desert almost entirely lacking soil and vegetation [27]. Consequently, significant losses of economic resources and human lives have been caused by frequent floods, droughts, landslides, debris flow and other destructive events [26].

In the past 20 years, an increasing area of agricultural land (much of which was formerly covered by forests) has been abandoned and supports various forms of secondary forests. Vegetation recovery in degraded karst areas can be achieved through a variety of recovery pathways, including ecological restoration,

* Corresponding author. Tel.: +86 25 85287252.
E-mail addresses: luxiaoqiang2010@gmail.com, lxq@nies.org (X. Lu).

1164-5563/$ – see front matter © 2013 Elsevier Masson SAS. All rights reserved.
http://dx.doi.org/10.1016/j.ejsobi.2013.12.007

afforestation and natural regeneration on abandoned or marginal agricultural land. Many studies have addressed the effects of natural vegetation succession on the improvement of soil quality in this region [11]. However, these studies have generally focused on the effect of a particular vegetation recovery pathway on soil properties rather than providing information on the regeneration of soil properties under vegetation recovery pathways that may occur within a landscape. Moreover, there is a lack of information on types of restoration suitable for promoting the chemical and/or biological properties of the soil during the reforestation process in degraded karst areas. It still remains unclear whether forest ecosystems can be successfully restored solely by afforestation and/or natural processes. There has been increasing concern in recent years about the consequences of vegetation recovery pathways and the resulting effects on soil quality [14]. Vegetation restoration not only alters above-ground vegetation but also produces significant changes in the chemical characteristics and biochemical cycles of soil ecosystems [16]. However, soil restoration focuses more specifically on the chemical and microbial characteristics of soil, i.e., the maintenance of soil organisms and their proper functioning as regulators of nutrient cycling and thereby of soil fertility [11]. Additionally, the loss of soil nutrients is the most marked feature of degraded karst regions. For this reason, it is important to know how particular vegetation recovery pathways affect the properties of developing soils in degraded karst areas. The aims of this study are to evaluate the effect of vegetation types on the chemical and biological properties of karst soil and to determine which vegetation recovery pathway is the most effective for improving soil quality in karst areas. The results of these investigations would provide representative reference data for protecting and restoring this fragile karst forest ecosystem. Moreover, our results can also provide a reference for protecting and restoring degrading forest ecosystems in other regions with similar special geographic contexts and environments.

2. Materials and methods

2.1. Site description

The study was conducted at the Karst Forest Ecosystem Research Center of the Guizhou Academy of Forestry, situated in the Maolan National Nature Reserve in southeast Guizhou Province (25°09′20″–25°20′50″N, 107°52′10″–108°05′40″E). Guizhou Province, located in the upper Yangtze River region of SW China, is particularly rich in carbonate bedrock (approximately 74%). A subtropical mountainous monsoon climate dominates the study area at elevations between 400 and 1000 m. This climate is characterised by a mean annual temperature of 14.3 °C and 83% relative humidity. The region experiences annual precipitation of 1672 mm, with 60% of the rainfall occurring in summer (June–August) [29]. The parent rock in the study area is dolomitic limestone of Middle and Lower Carboniferous origin. The soils belong to Mollic Inceptisols (USDA Soil Taxonomy) with a sharp lithic contact, primarily within a profile depth of 20–30 cm.

In the mid-late 19th century, the subtropical primary forest cover was largely destroyed by human activities such as firewood harvesting and clearing of land for agriculture and animal grazing [29]. As a result, naturally regenerated forest and then grassland appeared in certain areas. Through conservation activities, pine and bamboo plantations have been artificially established in the degraded area. A small land area is covered by natural old-growth forest, which occurs in small, highly fragmented patches [29]. The selected five vegetation types represent the principal vegetation types in the region of the study area. The stand age was determined from interviews with local residents. Table 1 summarises the properties and management histories of the five vegetation types.

2.2. Soil collection and pretreatment

Five types of vegetation were selected, including natural old-growth forest, grassland, bamboo (*Dendrocalamus tsiangii*) plantation, pure pine (*Pinus massoniana*) plantation and one type of natural regeneration. To ensure comparability, only two replicate plots were selected for each vegetation type in the study area. The size of each plot was 600 m^2 (20 m × 30 m). All plots were located at elevations between 650 and 750 m, and the soils were developed from limestone. For this reason, we made the assumption that the differences in soil properties could be attributed to the type of vegetation. The litter layer was removed, and mineral soil samples at the 0–5 cm, 5–10 cm and 10–20 cm layers were randomly collected from three sub-plots in each plot in August 2009. Samples in the same soil layer from the three sub-plots were combined and placed in prepared plastic bags, and the bags were then sealed. The samples were transported at a cold temperature to the laboratory of TUAT in Japan.

2.3. Soil chemical and microbial properties

Prior to analysis, coarse debris and stones were removed, and the soils were sieved through a 2 mm sieve. Each sample was then divided into two portions. One part was air-dried and used for chemical analyses, and the other was stored at 4 °C and used for biological analyses.

Table 1
Vegetation properties and management histories of vegetation types in the study.

Vegetation types	Years	Coverage	Main vegetation	Management
Natural forest	>80	>95%	*Platycarya strobilacea*, *Carpinus pubescens*, *Michelia martini*, *Symplocos sumuntia*, *Cyclobalanopsis glauca*, *Acer wangchii*, *Symplocos adenopus*	It grew under natural conditions, without disturbance.
Natural regeneration	20–25	75–85%	*Carpinus pubescens*, *Coriaria sinica*, *Broussonetia papyrifera*, *Platycarya fortuneana*, *Rose cymosa*, *Itea ilicifolia*, and *Rubus* sp.	It recovered naturally without disturbance.
Bamboo plantation	23	85–90%	*Dendrocalamus tsiangii*	It was periodically cleared the grass and shrubs in order to establish the pure forest per 1 year. The last tending was about in 2000.
Pine plantation	22	70–80%	*Pinus massoniana*	It was periodically cleared the grass and shrubs in order to establish the pure forest per 3–4 years. The last tending was about in 2005.
Grassland	15–25	>95%	*Miscanthus floridulus*, *Heteropogon contortus*, *Cynodon dactylon*, *Rubus palmatus*, *Rosa laevigata*, *Cyperus* sp.	It is periodically tended per 1–2 years. The way to tending is to clear the shrubs in order to establish the pure grassland. The last tending was about in 2004.