Catena 115 (2014) 1–10

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Research on the relationship between vegetation and soil resource patterns on lands abandoned at different times

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A R T I C L E I N F O

Article history:
Received 19 June 2013
Received in revised form 4 November 2013
Accepted 12 November 2013

Keywords:
Vegetation
Soil resource
Resource islands
Resource pattern
Geo-statics analysis
Point pattern analysis

A B S T R A C T

Many studies on the effect of vegetation on soil resources have compared the patterns of soil resources in different land environments. Few studies have compared the spatial pattern of soil resources in different secondary succession stages. Although various studies have evaluated the heterogeneous soil resources patterns caused by vegetation, few have provided high-resolution analyses of heterogeneous soil resource patterns on a fine scale, with the exception of trees and shrubs. This study has been performed on four abandoned farms (abandoned for 4, 12, 22, and 50 years) to evaluate the dynamic effect of vegetation on soil resource patterns at the scale of herbaceous plants. It was found that dominant species in a vegetation family at a given succession stage will play a primary role in the formation of resource islands. Resource islands developed during vegetative succession and subsequently change the patterns of soil resources. There are different soil resource patch sizes and soil parameter patterns on farms abandoned for different periods. A method was developed for this study called the Integration of Geostatistics, Point pattern analysis and Spatial comparison to provide an effective method to research the effect of vegetation on soil resource patterns at a fine scale.

1. Introduction

Recently, there has been a great deal of research concerning the heterogeneous soil resource patterns that occur following the formation of "resource islands" that often appear in arid and semi-arid ecosystems around the world (Puigdefabregas, 2005; Segoli et al., 2008). Resource islands are defined as vegetation patches that accumulate nutrients and water from the environment and thus become increasingly nutrient rich, while the space between resource islands become increasingly nutrient poor (Reynolds et al., 1999).

There are several significant aspects to this research topic. First, the short- and long-term feedback relationship between vegetation and soil resources in arid and semi-arid ecosystems requires further investigation. This area of investigation couples plant ecology and soil science (Sauer et al., 2006). It is also important to understand the formation of resource islands and to identify their ecological function at the population, community, and ecosystem levels (Robertson et al., 1993). Second, a research on this topic can provide useful information to land managers about the scale of soil nutrient patterns. This information is useful for managers to clearly understand ground conditions and effectively manage their land. Third, a proper understanding of this topic is necessary to avoid the spatial autocorrelation of soil elements when performing field experiments (Rodríguez et al., 2009b).

The factors and processes that determine soil resource patterns in arid or semi-arid ecosystems have been discussed in research reports over the past two decades (Guo et al., 2002; Okin et al., 2008; Robertson et al., 1997). Soil resources are primarily controlled by pedogenic factors, such as climate, topography and vegetation (Oueslati et al., 2013). The effects of climate on soil resources emerge at local or larger scales. Soil resources are affected by topography primarily through the influence of micro-topography on water movement (Oueslati et al., 2013; Yoo et al., 2006.). In addition, soil texture, i.e., the organic, moisture and cation exchange composition, also influences soil resources (Rodríguez et al., 2009b).

Vegetation plays an important role in the regulation of soil resource patterns and availability (Augusto et al., 2002; Gross et al., 1995; Okin et al., 2008). Plants alter the physical, chemical, and biological properties of soil beneath the canopy (Gallardo et al., 2000; Jackson and Caldwell, 1993; Rodríguez et al., 2009a). Many papers have reported that in arid and semi-arid regions, plants enhance soil resource variability by generating and containing soil moisture and nutrients within vegetation patches (Yavitt et al., 2009). In addition, this capability of plants may also affect seedling establishment (Diekmann et al., 2007; Huante et al., 1995; Lawrence, 2003). Simultaneously, the altered spatial pattern of soil resources may in turn influence the functioning and performance of individual plants and microorganisms and, ultimately, ecosystem-level processes and community structure (Li et al., 2010; Schlesinger et al., 1996). There is a clear bidirectional spatial relationship between plants and soil (Covelo et al., 2008; Ettema and Wardle, 2002; Rodríguez et al., 2009b; Zhou et al., 2008).

Despite a substantial research concerning the heterogeneous nature of soil resources caused by vegetation, there are poorly understood issues in this area of research. First, many studies have been

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http://dx.doi.org/10.1016/j.catena.2013.11.009

performed comparing soil patterns in different environments. Few studies have compared the spatial pattern of soil resources in different secondary succession stages (Diekmann et al., 2007). Second, although studies of heterogeneous soil resource patterns caused by vegetation are fairly common, only trees and shrubs have typically been considered. Few studies have provided high-resolution analyses of soil resources pattern caused by herbaceous plants. Third, research scales are often related to the scale of trees or shrubs (one meter or larger). A further research is necessary to investigate the formation of the spatial pattern of soil resources at a scale more relevant to herbaceous plants (no greater than one meter). Finally, many studies have compared the scales of soil resources and vegetation patches to understand the relationship between the pattern of soil resources and vegetation patches and to identify whether the soil resource patterns were affected by vegetation. These studies have assumed that similar scales share a strong relationship. Though this method is easy to understand, it is not accurate, and some details governing the relationship between soil resources and vegetation are not easy to determine.

In this paper, we have studied four areas with abandonment times of 4, 12, 22, and 50 years. The purpose of this paper was to study the dynamic effect of vegetated patches on soil resources patterns at a scale related to herbaceous plants. The objectives of this study were to (i) investigate the pattern of soil resources by geo-statistics analysis of different abandoned areas; (ii) use a point pattern analysis to research the relationship between soil resources patterns and vegetation after different periods of abandonment; (iii) compare these two works to reveal the relationship between soil resources and vegetation and the formation of resource islands. After that, a universal method was devised to investigate this relationship.

2. Materials and methods

2.1. Study area

This study was performed in the Yangjuangou catchment (36°42′N, 109°31′E) in the Loess Plateau, Shaanxi Province, China (Fig. 1). This catchment has a semi-arid continental climate, mean annual precipitation of 531 mm and mean air temperature of 9.85 °C from 1952 to 2010, according to data from the meteorological station in Yanan city (Fig. 2). The elevation of the catchment ranges from 1050 to 1298 m (Liu et al., 2012). Rainfall in the catchment is concentrated between June and September. Soil in the study area was derived from loess parent material. The soil type is Calcaric Regosol which is characterized by a uniform texture. It is an infant soil, without distinct development of genetic horizons and zonal characteristics of profile (Huang, 1987). A soil organic layer (10–30 cm) emerges under vegetation coverage. The color of this layer is gray-brown or dark gray-brown. Parent material is under the organic layer. It is an illuvial horizon with little calcium carbonate (Huang, 1987). The composition of the loess in the Yangjuangou catchment is typically more than 50% silt (0.002–0.05 mm) and less than 20% clay (<0.002 mm), and the porosity of the soil is almost 50% (Liu et al., 2012). The experimental plots were located in abandoned croplands. Due to the sparse population and a grazing ban, there has been little human impact on vegetation in the secondary succession after these croplands were abandoned. Among the native species, *Stipa grandis* and *Carex korshinskii* et al. are largely distributed on the sunny slopes, and, *Artemisia sacrorum* and *Artemisia giraldii* et al. often have been found on the shady slopes in the Yangjuangou catchment. In this research, different vegetation communities have been found on different test areas, and they were shown in Table 1.

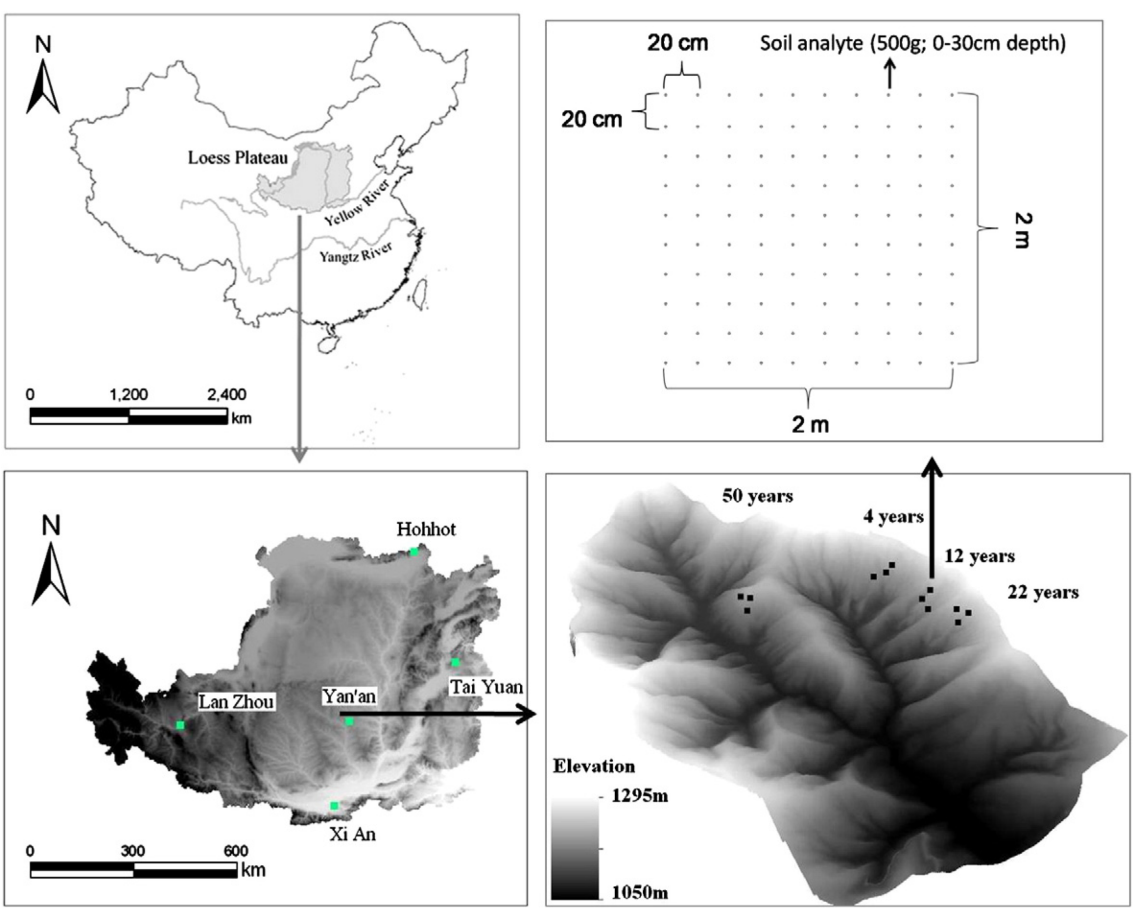

Fig. 1. Locations and design of experimental plots.