Geoderma 200–201 (2013) 114–119

Contents lists available at SciVerse ScienceDirect

Geoderma

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

Physical properties and organic matter of Fluvisols under forest, grassland, and 100 years of conventional tillage

B. Gajić *

Department of Soil and Melioration, Faculty of Agriculture, Belgrade University, Nemanjina 6, 11081 Belgrade, Serbia

ARTICLE INFO

Article history:
Received 30 August 2011
Received in revised form 10 January 2013
Accepted 12 January 2013
Available online 21 March 2013

Keywords:
Land use change
Fluvisols
Soil physical properties
Soil organic matter
Soil degradation
Continental lowland ecosystems

ABSTRACT

Although a large number of papers deal with effects of land-use change on soil properties, less attention is directed to the long-term effects of different land-use types on soil physical properties and organic matter in the lowland ecosystems.

The objective of this study is to assess the long-term cumulative effects of change in land-use type on some soil properties in the continental lowland ecosystems of Western Serbia. Three adjacent land-use types (deciduous forest, natural grassland and arable soils that have been converted from forests for more than 100 years) were chosen for the study. Disturbed and undisturbed soil samples were collected from nine sites at each of the three different land-use types from the depths of 0–10, 10–20 and 20–30 cm in noncarbonated Fluvisol. Conversion of forest to grassland and arable soil has led to significant decrease in total porosity (TP), infiltration rate (IR) and soil organic matter (SOM). The bulk density (BD) was lower in forest compared to the adjacent grassland and arable (ex-forest) soils. In addition, microaggregate stability, determined by the clay dispersion ratio (CDR) and aggregated silt and clay (ASC) indices, was significantly higher in forest than in grassland and arable soil. In conclusion, the results of this study indicate that removal of permanent vegetation in the conversion process from forest and grassland areas to cultivated land may lead to loss of soil productivity and serious soil degradation. Obviously, there is a need for greater attention to developing sustainable land use practices in management of these ecosystems to prevent further degradation of soils in the region.

1. Introduction

It is known that unsuitable change in land use due to human activities and agricultural management practices can affect soil properties (Haghighi et al., 2010; Li et al., 2007; Papini et al., 2011). However, the actual impact of change depends on several factors such as the type of forest ecosystem undergoing change (Rhoades et al., 2000), initial soil properties, the nature, duration and intensity of the subsequent land-use type and management practices (Rhoades et al., 2000; Zucca et al., 2010), long-term site-specific factors (e.g. climate, topography and parent material; Khormali et al., 2009; Ogle et al., 2005) and the soil type, mineralogy, texture, and soil depth (Bormann and Klaassen, 2008; Sparling et al., 2000).

The conversion of natural forests and grasslands to agricultural land may cause important changes in soil physical and chemical properties, especially reduce SOM and changes in distribution and stability of soil aggregates (Haghighi et al., 2010; Six et al., 2000), resulting in reduction of crop production capacity (Stevenson and Cole, 1999). A decrease in SOM leads to increased BD and decreased porosity, thus reducing soil infiltration (Li et al., 2007; Wall and Heiskanen, 2003).

Puget and Lal (2005) reported a lower BD in forest compared to cultivated plots and the pasture at 0–30 cm depth, on a Mollisol in Ohio.

In contrast to the conversion of forest and grassland to agricultural land, conversion from forest to grassland did not produce a clear trend in soil C change and soil physical properties. For example, the forest conversion to grassland can lower the content of SOM (Powers, 2004; Rasiah et al., 2004), leave SOM unchanged (Evrendilek et al., 2004; Geissen et al., 2009; Schwendenmann and Pendall, 2006) or increase SOM (De Moraes et al., 1996; Lemenih et al., 2005). The effects of the conversion of forest to grassland and management on BD and TP are also often mixed. Evrendilek et al. (2004) and Schwendenmann and Pendall (2006) found that the conversion of forest to grassland has no significant effect on BD and TP in a highland of Turkey and in Panama, in the topsoil, respectively. Conversely, Price et al. (2010) reported that conversion forest into grassland resulted in greater BD and lower porosity. Researchers have found that conversion of forest land to grassland affects soil properties, such as particle size distribution and distribution and stability of soil aggregates often vary for soil (Abbasi et al., 2007; Evrendilek et al., 2004; Price et al., 2010; Schwendenmann and Pendall, 2006; Spohn and Giani, 2010).

These contradictory findings warrant further research to clarify the effects of the conversion of forest land to non-forest soils. Most previous studies dealing with land use conversion effects on soil

* Tel.: +381 11 2615 315; fax: +381 11 2193 659.
E-mail address: bonna@agrif.bg.ac.rs.

0016-7061/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.geoderma.2013.01.018

physical properties and SOM content have focused on soil groups of semiarid, temperate humid, tropical, and subtropical dryland hilly or mountain ecosystems only (Bormann and Klaassen, 2008; Celik, 2005; Haghighi et al., 2010; Islam and Weil, 2000). More importantly, most of the research was carried out on a short term and medium term basis, using a time scale of 1–5 years and 6–20 years following land use conversion, respectively. Little research has been done so far on the land use conversion effects on soil properties in low-lying continental ecosystems.

According to Brejda et al. (2000), knowledge of the impact of land use on soil quality, through the quantification of relative changes in soil chemical and physical properties, is therefore essential in order to evaluate the sustainability of land management and to support government agencies in developing adequate agricultural policies aimed at protecting land from degradation.

In this context, the main purpose of our work was to evaluate the long-term (>100 years) effects of different land use types on soil quality by measuring the differences in the SOM and some physical properties, of noncarbonate Fluvisol in the sensitive continental lowland ecosystems of Western Serbia. The information obtained from the study would be important for appropriate and rational land use planning in accordance with the potential of each land-use type at the regional level.

2. Material and methods

2.1. Site description

This study was conducted in the Kolubara Valley (44°36′ N and 20°17′ E) located about 80 km southwest of Belgrade. The study area is about 92 m above the sea level. The area has continental climate, with a mean annual air temperature around 11 °C and mean annual precipitation of 730 mm. The soil of the study area was classified as noncarbonate Fluvisol (FAO, 2006), developed on a poorly carbonated alluvium of the Kolubara River. The area is geomorphologically plain and nearly flat.

Nine locations were selected in the Central Kolubara River Basin. At each location, sites of forest, grassland, and long-term conventionally tilled land were selected in close proximity (at a distance of ≈50–100 m) and of similar topography. The natural vegetation of the forest sites is characterized by a community of common oak and common ash (*As. Querceto-raxinetum serbicum*, Rud.). Grassland is dominated by grass species including black medick (*Medicago lupulina*) and sweet peas (*Lathyrus* sp.) and has been used over the last 100 years for hay production without tillage. The arable soils are under crop rotation using conventional plowing to a depth of 20–25 cm as a means of primary tillage and disking as a means of secondary tillage. Cropping systems include wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.). Crop residues are collected and used as animal feed or animal bedding. History show that the three types of land use (forest, grassland, and crop rotation) have not changed for the respective study sites for more than 100 years (farmers' statements). This allowed us to assess the influence of land use, particularly grassland and crop rotation, on some physical properties and SOM, compared to its natural condition over a period of 100 years or so.

2.2. Soil sampling design

Twenty seven sites were sampled, nine within each of the three adjacent land-use types of forest, grassland, and arable soil in late July 2008. For each land-use type and its nine sites, one monolithic (about 20 cm × 15 cm × 10 cm) soil sample of ≈4000 g was taken for each of the depth ranges of 0–10, 10–20, and 20–30 cm. This added up to 27 soil monoliths for each land use and 81 soil monoliths for all land uses investigated in the study.

In order to determine BD and TP, five soil cores from each depth were collected using a 100 cm^3 cylindrical steel sampler (inner diameter 5.0 cm, and height 5.1 cm). In total, 135 undisturbed soil samples (five soil cores at three depth levels and nine sites) were collected to represent each land-use study and 405 soil cores for all land-uses investigated in the study.

2.3. Soil physical and chemical analyses

In the laboratory, the monoliths were carefully broken up by hand along natural planes of weakness into aggregates of <25 mm. After visible plant materials were removed, all soil samples were air-dried and ground to pass 2 mm sieve for the following measurements.

Particle-size distribution of the soils was determined by combining sieving and the pipette methods (Rowell, 1997).

Bulk density was determined using the core procedure (Rowell, 1997).

Total porosity was calculated using the following equation:

$$TP = 1\text{–}BD/\rho_P \tag{1}$$

where ρ_P is particle density. Particle density was measured with a pycnometer (Rowell, 1997).

Infiltration rates were measured using a double-ring infiltrometer method (Rowell, 1997) with an inner diameter of 23 cm and an outer diameter of 49 cm (five replicates at each site), respectively. A constant head of 2 cm was maintained until steady state was achieved.

Stability of soil microaggregates to external forces was determined using clay dispersion ratio and aggregated silt and clay as described by Igwe et al. (1999).

Clay dispersion ratio was calculated as:

$$CDR = \frac{WDC\left(g\ \ kg^{-1}\right)}{TC(g\ \ kg^{-1})} \tag{2}$$

where WDC is water dispersible clay obtained in distilled water-dispersed samples and TC is total clay obtained in sodium hexametaphosphate dispersed samples.

Aggregated silt and clay was calculated as:

$$ASC = \left[\left(TC\left(g\,kg^{-1}\right) + TSi\left(g\,kg^{-1}\right)\right)\text{–}\left(WDC\left(g\,kg^{-1}\right) + WDSi\left(g\,kg^{-1}\right)\right)\right] \tag{3}$$

where WDSi is water dispersible silt obtained in distilled water-dispersed samples and TSi is total silt obtained in sodium hexametaphosphate dispersed samples.

WDC and silt were determined in the same way as particle size analysis, except that a chemical dispersant was not used.

Soils with higher CDR indicate lower aggregate stability, while the higher the value of ASC (%), the higher the aggregate stability at microaggregation level (Igwe et al., 1999).

Soil organic carbon concentration (SOC) was determined using the dichromate method (Rowell, 1997). The percent SOM was calculated by multiplying % SOC by a factor of 1.724.

2.4. Statistical analysis

All data in tables and figures are presented as means, with their standard deviations. In order to investigate the relationships between SOM content and soil properties, a correlation analysis was performed for the whole data set (all depths pooled). The correlations were expressed as Pearson's linear coefficients with the indication of statistical significance (* for $P \leq 0.05$, ** for $P \leq 0.01$ and *** for $P \leq 0.001$). All statistical analyses were performed using SPSS for Windows (SPSS, 1995).