Catena 127 (2015) 340–348

Contents lists available at ScienceDirect

Catena

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

Climate and relief influence on particle size distribution and chemical properties of Pseudogley soils in Croatia

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ARTICLE INFO

Article history:
Received 23 April 2014
Received in revised form 9 December 2014
Accepted 15 December 2014
Available online 21 January 2015

Keywords:
Stagnosols
Loess parent materials
Precipitation gradient
Repeated measures statistical method

ABSTRACT

Pseudogley is a soil characterized by vertical texture contrast and periodic stagnation of precipitation water. Its profile is often designated as A-Eg-Btg-Cg. It is the second most frequent soil type in Croatia, found almost exclusively on non-calcareous loess sediments in the Pannonian region of the country. The aim of this research was to determine if differences in particle size distribution and basic chemical properties exist among Pseudogleys formed along the 600–1100 mm mean annual precipitation (MAP) gradient on two different relief positions (plateau and slope) across the Pannonian region of Croatia. A total of 33 soil pits were dug in natural forests. The trends observed with soil depth for particle size distribution, organic C content, pH, Ca^{2+}/Mg^{2+} ratio, and base saturation point to the predominance of top-down formation of the investigated soil profiles. Both relief and climate influenced the distribution of Pseudogleys across the Pannonian region of Croatia. The incomplete homogeneity of loess parent materials across the study region governs the variations in clay content, silt content, and cation exchange capacity among the investigated Pseudogleys. Conversely, the increase in MAP along the investigated transect caused a decrease in soil pH, base saturation, and Ca^{2+}/Mg^{2+} ratio, and the increase in organic C content along the investigated profiles. Therefore, future studies of climate impact on loess-derived soils in this region should take into account only soil chemical properties that are not directly dependent on particle size distribution. The relief position on which soil pits were situated had no effect on soil characteristics. Hence, it seems that Pseudogleys should not be systemized according to their position on plateau or on slope, as it is the case in some classification systems.

1. Introduction

Pseudogleys are soils that largely correlate with Stagnosols (IUSS Working Group WRB, 2006). Due to periodic stagnation of precipitation water on/in the poorly permeable subsurface horizon, redoximorphic features (RMF) develop in such soils. RMF comprise redox depletions (Fe-depleted and/or clay-depleted soil matrix), redox concentrations (soft Fe–Mn masses and coatings; cemented Fe–Mn concretions and nodules), and reduced matrix (soil matrix with Fe^{2+}-containing minerals) (see Schoeneberger et al., 2002).

Pseudogley is the second most widespread soil type in Croatia, almost exclusively found in its Pannonian region (Bogunović et al., 1998) (Fig. 1, see also Appendix A). As the climax soil in most of the Pannonian region of Croatia, Pseudogley is also the most widespread soil type in this region (Bogunović et al., 1998). It is largely found in environments that are favorable for agriculture (loamy loess sediments, moderate climate, and gentle relief) (Škorić, 1986). Thereby, 55% of Croatian Pseudogleys comprise agricultural land or agro-ecosystems (Husnjak et al., 2011).

Although soils with vertical texture contrasts are very often polygenetic (e.g., Phillips, 2004), Pseudogleys in Croatia and the wider southwestern Pannonian Basin were traditionally considered to form either by the erosional–sedimentational pedogenesis (primary Pseudogleys) or by the normal top-down pedogenesis (secondary Pseudogleys) (e.g., Ćirić, 1984; Škorić, 1986). Janeković (1960) even suggested that the upper two (coarser-textured) horizons originate from the non-calcareous Holocene loess that was deposited over the finer-textured Pleistocene loess.

Nevertheless, micromorphology, particle size distribution, bulk/clay mineralogy, and geochemical properties of three Pseudogleys studied by Rubinić et al. (2014) in Croatia (soil profiles 1, 13, and 25 in this study—see Appendix B) point to top-down pedogenesis from initially vertically homogeneous loess deposits. Rubinić et al. (2015), who studied morphology, particle size distribution, chemical properties, and modal compositions of heavy/light mineral associations of three Pseudogleys (soil profiles 7, 19, and 28 in this study—see Appendix B), confirm that most Croatian Pseudogleys formed primarily by top-down pedogenesis. Therefore, natural Pseudogley profiles in Croatia can be generally designated O-A-Eg-Btg-Cg.

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http://dx.doi.org/10.1016/j.catena.2014.12.024
0341-8162/

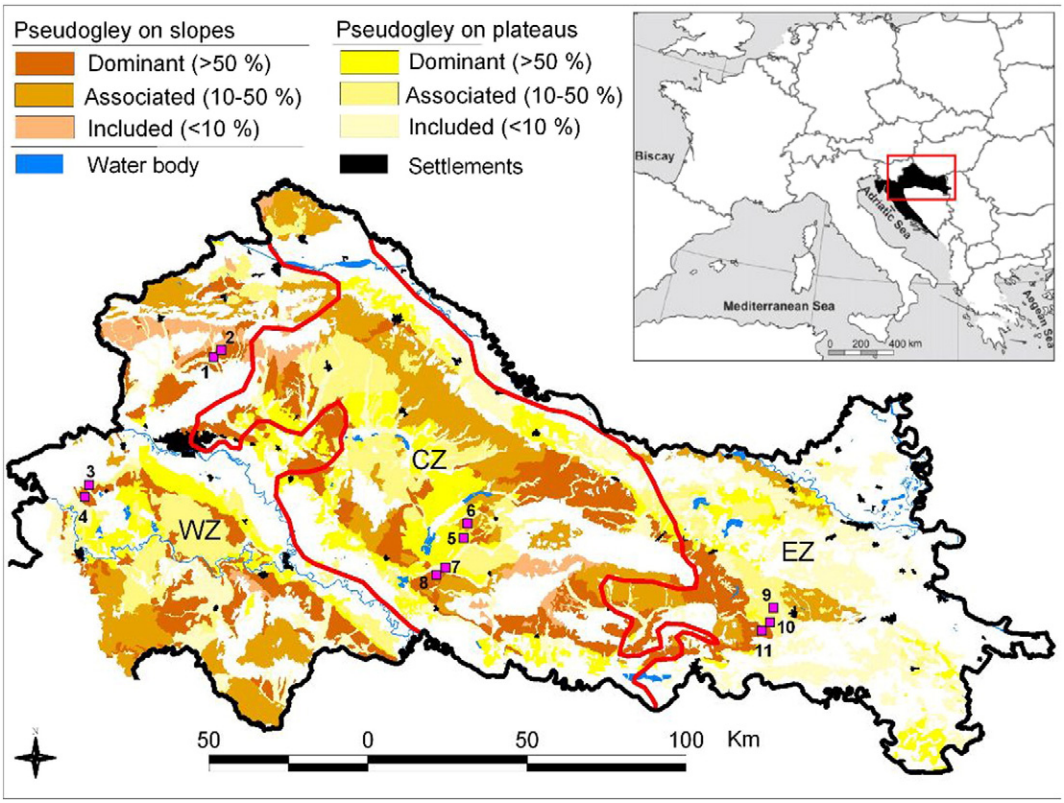

Fig. 1. Map of Pseudogley distribution in the Pannonian region of Croatia (determined according to Bogunović et al., 1998). The 11 points on the map indicate the approximate positions of the investigated locations. At each location three replicate soil pits were investigated. WZ, CZ, and EZ are mean annual precipitation zones (western zone with 900–1100 mm, central zone with 800–900 mm, and eastern zone with 600–800 mm of precipitation, respectively; simplified according to Perčec Tadić, 2008). The red line on the west represents the 900 mm isohyet, and the red line on the east represents the 800 mm isohyet. In the upper right corner of the Figure, the map with the marked position of Croatia in Europe is presented (the red rectangle roughly marks the Pannonian region of Croatia).

Numerous researchers recognized various effects of relief (e.g., Alaoui et al., 2011; Daniels et al., 1971; Griffiths et al., 2009; Venkatesh et al., 2011; Yang et al., 2012) and climate (e.g., Alexandrovskiy, 2007; Alvarez and Lavado, 1998; Dahlgren et al., 1997; Wanhong and Yao, 2006) on both formation and characteristics of soils. The aim of our study was to determine if distinct differences in particle size distribution and basic chemical properties exist among 33 Pseudogleys found on two different relief positions (plateau and slope) along the 600–1100 mm mean annual precipitation (MAP) gradient in the Pannonian region of Croatia. Therefore, spatial distribution of Pseudogleys in respect to relief and MAP was determined across the study region, and representative Pseudogley profiles in climax forests and on loess parent materials were selected for the study.

Given that the increase in water balance surplus along the MAP gradient in the Pannonian region of Croatia distinctly influences soil formation (Bašić, 2013), we wanted to test the effects of MAP on Pseudogleys in this region. Furthermore, because studies of climate effects on soils are increasingly used for predicting the biogeochemical responses to the global climate change (e.g., Egli et al., 2008; Griffiths et al., 2009; Wanhong and Yao, 2006), we wanted to highlight the data relevant for this issue.

Additionally, we aimed to test if Pseudogleys in Croatia (and several other countries of the region) are rightfully systemized into lower soil units (e.g., subtypes) in respect to their position in the relief (plateau or slope) (e.g., Bašić, 2013; Resulović et al., 2008; Škorić et al., 1985). Namely, within the leading soil classification systems of the World (e.g., IUSS Working Group WRB, 2006), relief and other soil-forming factors are avoided as systematization criteria, and only clearly observable and/or measurable soil properties are considered.

2. Materials and methods

2.1. Study area—Pannonian region of Croatia

2.1.1. Basic geomorphic characteristics

Pannonian region of Croatia (Fig. 1) covers 46% of the country (Bašić, 2013) and represents the southwestern edge of the Pannonian Basin. The dominant geomorphic units of this region are the Holocene terraces and the Pleistocene terraces (Bašić, 2013). The Holocene terraces make the lowest part of the study area (80–120 m asl) and comprise valleys formed by Sava, Drava, and Danube rivers (and their tributaries). The Pleistocene terraces are found roughly between 100 and 200 m asl. At the east of the region, the Pleistocene terraces are flat, spacious, and elevated several meters above the Holocene terraces. Towards the west, they mostly cover the bases of hills/mountains made from the Tertiary deposits (Bašić, 2013). Consequently, from the east to the west of the Pannonian region of Croatia, the Pleistocene terraces get progressively ragged and interspersed by drainage ditches and streams.

The Pleistocene terraces in the Pannonian region of Croatia largely comprise loess derivates, with brown loess and typical loess found only in the most eastern part (see Haase et al., 2007). Due to their modification by syngenetic and/or postgenetic processes, both loess derivates and brown loess are considered as non-calcareous polygenetic sediments with increased clay content compared to the typical loess (Haase et al., 2007). Brown loess developed after the deposition of aeolian material in a humid environment, which is why it is less affected by pedogenesis compared with loess derivates (Haase et al., 2007).

The increased clay content in brown loess deposited in eastern Croatia is explained by Mutić (1990). Namely, the uplift of the Đakovo loess-plateau in Croatia occurred only after the beginning of the Holocene. Accordingly, this plateau was submerged under the shallow