Available online at www.sciencedirect.com
SCIENCE DIRECT
Geoderma 132 (2006) 116–130
GEODERMA
www.elsevier.com/locate/geoderma

The effect of environmental conditions on the decomposition rate of cellulose in mountain soils

Marek Drewnik*

Jagiellonian University, Department of Pedology and Soil Geography, Institute of Geography, 31-044 Kraków, ul. Grodzka 64, Poland

Received 8 May 2004; received in revised form 13 April 2005; accepted 29 April 2005
Available online 21 June 2005

Abstract

Ecological studies rarely deal with the altitudinal aspect of the variability of the decomposition rate of dead organic matter. This phenomenon is of great importance in the formation of soil properties as it determines the characteristics of humus horizons and determines nutrient transformations and availability in ecosystems. Moreover research on the decomposition of organic matter is very important because an increased rate of C mineralization is expected in response to the predicted temperature rise. There is still relatively little data to help quantify the reduction of organic matter decomposition under mountain conditions (altitude gradient). Previous papers show a clear decrease in decomposition as altitude increases (tropical Andes and Appalachian Mts.) and soil scientists explain the large thickness and specific composition of the humus compounds of mountain soils by the slower rate of organic matter decomposition due to harsh climatic conditions and due to the specific high mountain vegetation.

In recent years the issue has gained larger importance as several authors have connected the reduced rate of organic matter decomposition with the anthropogenous pollution of the soil environment by heavy metals and acid rain. Also particular investigations show a remarkable increase in heavy metal concentrations as altitudes rise (Alps and Tatra Mts.). The northern Carpathians, located in Central Europe, are distinctly exposed to pollution, although there are no significant signs of atmospheric pollution in this area. Therefore the aim of this paper is to determine the impact of environmental factors on the rate of cellulose decomposition in the mountain soils of the northern Carpathians. The main questions are: (1) Is it possible to distinguish the influence of climatic and edaphic factors in shaping the rate of cellulose decomposition? (2) There is a slower rate of cellulose decomposition due to harsh climatic conditions with altitude. Are there other factors which modify this simply-stated relationship?

The research was carried out in four mountain ranges representing physiographically different Carpathian regions. Soil properties were analyzed using common methods. The properties of humus substances were calculated after the extraction and fractionation. The measurements of cellulose decomposition rates were conducted using the cellulose filters method (periods: 10, 20 weeks, and year). Among the environmental factors, those that can considerably influence the processes of cellulose decomposition in soil were chosen for the purpose of analysis. To evaluate their impact on the rate of cellulose decomposition, it was necessary to identify components by principal component analysis. The analysis was carried out on two components (PC1 and PC2) accounting for almost 82% of the variability. The properties of humus in the soils indicate their

* Fax: +48 12 422 55 78.
E-mail address: m.drewnik@iphils.uj.edu.pl.

0016-7061/$ - see front matter
doi:10.1016/j.geoderma.2005.04.023

close relationship to environmental conditions as they change with altitude. This attempt to distinguish the influence of climatic and edaphic factors in shaping the rate of cellulose decomposition shows that the most important factor is the effect of altitude on overall environmental conditions (PC1). Separating the influence of particular conditions (i.e. climatic edaphic) is very difficult or impossible because they are closely connected. Their effect on specific humus horizons emphasizes the influence of harsh climatic conditions on the rate of cellulose decomposition. The relationship between a slower rate of cellulose decomposition and increasing altitude is not absolute. Within subalpine and alpine geoecological belts there is variation in the kind of feedback. Within the subalpine belt the feedback is negative. It is due to the fact that within that belt the ectohumus material originates from dwarf pine needles, which determines a relatively smaller rate of cellulose decomposition. Within the alpine belt the situation is opposite. Humus horizons here are determined by soft grass remnants and shape a relatively higher rate of cellulose decomposition (positive feedback). Both kinds of feedback occur under harsh climatic conditions.

Keywords: Cellulose; Decomposition; Soil organic matter; Soil genesis; Alpine environment

1. Introduction

Ecological studies rarely deal with the geographical–spatial aspect (including altitudinal gradient) of the variability of the decomposition rate of dead organic matter (Meentemeyer, 1978). This phenomenon is of great importance in the formation of soil properties as it determines the characteristics of humus horizons (thickness, morphology and chemical composition) and determines nutrient transformations and availability in ecosystems. Moreover research on the decomposition of organic matter is very important because an increased rate of C mineralization is expected in response to the predicted temperature rise (Coûteaux et al., 1995).

Several authors have estimated relative soil decomposition using the decomposition rate of cellulose. Mendelssohn et al. (1999) in northern Jutland find that soil fertility is the major environmental factor determining soil cellulose decomposition rates along a salinity gradient in soils. Haraguchi et al. (2003) in a minerotrophic mire found cellulose decomposition rates showed significant differences among community types and that this had a significant positive correlation with the oxygen consumption rate. There is still relatively little data to help quantify the reduction of organic matter decomposition with increasing altitude (altitude gradient). In mountain conditions it was measured in the tropical Andes by Coûteaux et al. (2002). Their results show a clear decrease in decomposition as altitude increases from 65 to 3068 m. Shanks and Olson (1961) described a similar dependence for the Appalachian Mts. They determined the decrease in the amount of organic matter decomposed in soil of 2.4% for each 100 ft of altitude.

Soil scientists explain the large thickness and specific composition of the humus compounds of mountain soils by the slower rate of organic matter decomposition due to harsh climatic conditions (Kubiena, 1953; Skiba, 1985). An additional factor favoring the accumulation of poorly decomposed organic matter at high mountain locations is the influence of specific high mountain vegetation (Kubiena, 1970; Bochter and Zech, 1985; Skiba, 1995).

In recent years the issue has gained a larger importance as several authors have connected the reduced rate of organic matter decomposition with the anthropogenous pollution of the soil environment by heavy metals and acid rain (Berg, 1986a; Bieńkowski, 1990; Fritze, 1991; Laskowski and Berg, 1993; Ohtonen et al., 1994). Also, particular investigations show a remarkable increase in heavy metal concentrations as altitudes rise (Pb, Cd, Zn, and S in the northern and eastern Alps—Zechmaister, 1995, Pb in the Tatra Mts.—Soltes, 1992) and that pollution by heavy metals is caused mainly by long-range transport (Zechmaister, 1995).

The northern Carpathians, located in Central Europe, are distinctly exposed to pollution (Grodzińska and Szarek-Łukaszewska, 1997), although there are no significant signs of damage by atmospheric pollution in this area (Wilczyńska-Michalik and Michalik, 1999). Therefore research into the natural factors shaping the decomposition processes in this area have great importance. These investigations help to establish the background for studies aimed at the