Available online at www.sciencedirect.com

SCIENCE DIRECT®

Geoderma 124 (2005) 215–222

GEODERMA

www.elsevier.com/locate/geoderma

Effects of land-use changes on humus forms on alpine pastureland (Central Alps, Tyrol)

Julia Seeber[a,*], G.U.H. Seeber[b]

[a]*Department of Terrestrial Ecology and Taxonomy, Institute of Zoology and Limnology, University of Innsbruck, Technikerstrasse 25, A-6020 Innsbruck, Austria*

[b]*Institute of Statistics, Universitätsstr. 15, A-6020 Innsbruck, Austria*

Received 15 July 2003; received in revised form 27 February 2004; accepted 7 May 2004
Available online 24 June 2004

Abstract

This study examines the effects of land-use changes on humus forms and soil properties (pH, C/N, SOM) on alpine pastureland. On 10 differently managed areas (alpine spruce forest, alpine tamarack forest, alpine meadow, alpine pasture, reforested area), humus forms were characterised morphologically, and soil properties were investigated in the laboratory and statistically analysed. Vermimull and Rhizomull were the humus forms found on intensively and lightly managed areas, while on abandoned sites and on forest floors more differentiated humus forms with varying thickness developed (Mullmoder, Leptomoder, Hemimor, Mormoder). Humus pH values ranged between 3.3 (abandoned pasture) and 5.5 (intensively managed meadow, abandoned meadow); soil pH values were generally lower and ranged between 3.0 (spruce forest) and 5.5 (intensively managed meadow). Both properties decreased from managed to abandoned areas. Humus C/N was lowest on the intensively managed meadow (21.1) and increased from managed to abandoned sites, with the highest value being 37.6 on the reforested area. Soil C/N ratios were narrow, ranging from 12.4 on the lightly managed pasture to 19.6 in the spruce forest. Soil C/N increased from managed to abandoned sites, while humus C/N showed no trend. Soil organic matter content (SOM) greatly increased from managed to abandoned areas, ranging from 12.9% (intensively managed meadow) to 41.3% (tamarack forest). In conclusion, reducing or abandoning management leads to the accumulation of litter material and the development of more differentiated humus forms. As a consequence of abandonment, the soil pH decreases, whereas humus and soil C/N and organic matter content increase from intensively managed to abandoned areas and to the forest.

Keywords: Humus forms; Soil properties; Land-use changes; Alpine pastureland

1. Introduction

Under alpine conditions, the development of humus forms (mull, moder and mor) depends upon parameters such as altitude, exposition, relief, micro-

* Corresponding author. Tel.: +43 512 507 6132; fax: +43 512 507 2930.
E-mail address: julia.seeber@uibk.ac.at (J. Seeber).

0016-7061/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.geoderma.2004.05.002

climate (temperature and humidity), vegetation type and land use practices. The humus form in turn influences the formation of major alpine soil types like brown earth and podzol (Neuwinger, 1980; Ozenda, 1988) and is therefore a more sensitive site indicator with a higher resolution than the soil type.

Soil properties such as pH, C/N ratio and organic matter content are closely connected to the decomposition of organic material. Low pH values result from the increased occurrence of humic and fulvic acids which eluviate from the humus layers (Gisi, 1997). This soil acidity reduces microbial and faunal activities (Schinner, 1978; Schaefer and Schauermann, 1990), which leads to an accumulation of organic material: the soil organic matter in the topsoil increases. C/N ratios control the available N, the total organic matter content and the rate of organic decay (Brady, 1990).

Abandonment of alpine meadows and pastures interferes with the ecological equilibrium which has developed between primary production and the harvest of plant material over centuries of cultivation (Cernusca, 1978; Cernusca et al., 1999). Immediate consequences of the disturbed system include snow gliding and enhanced soil erosion (Paldele, 1994; Körner, 1999; Coppus et al., 2003; Tasser et al., 2003).

This study was designed to provide basic information on humus dynamics and decomposition in alpine pastureland. Previous studies concentrated on characterizing alpine soils and their distribution against the background of afforestation practices and the effect of tourism (Neuwinger, 1965, 1980, 1987). Our lack of knowledge on humus forms requires descriptive studies to generate the necessary basic information.

The present study elucidates the effect of land-use changes on (1) the development of humus forms as a potential early indicator of a disturbed equilibrium and on (2) soil properties closely connected to the decomposition of organic material in alpine ecosystems.

2. Material and methods

2.1. Research site

The study was conducted on the Kaserstattalm above Neustift in the Stubai Valley, Austria (1800–2000 m a.s.l.). The research site is located on strongly inclined slopes with expositions to the south-east to east. The climate can be classified as temperate continental inner alpine (Fliri, 1975). The subsoil is formed by the Ötztaler rock, which consists of Mica schist, phyllite gneiss and sediment gneiss, and is favourable to the vegetation due to its high nutrient availability (Stern, 1991). Soil types reflect the different stages of soil development on silicate rock (Bitterlich and Cernusca, 1999): Dystric Leptosol-Cambisol and Podzol series (FAO-UNESCO, 1990).

2.2. Fieldwork

In July and August 1998, 10 differently managed and abandoned sites were sampled (alpine spruce forest, alpine tamarack forest, alpine meadow, alpine pasture, reforested area) (Table 1).

On each study site, seven sampling points were selected along a transect; all sampling points were similar in parent material, vegetation type and exposure. At each sampling point, the humus forms were characterized morphologically using the Canadian classification (Green et al., 1993), and samples from the humus material and the A_h-horizon were taken.

2.3. Lab work

Humus and soil material were air-dried and the soil material was sieved (mesh width 2 mm).

The pH of humus and soil material was measured using a 0.01 M $CaCl_2$-solution and a pH-meter (type pH-95, Weilheim/Germany). C- and N-content of soil and humus material were quantified with a CHNS-Analyser (LECO, St. Joseph/USA). Soil organic matter content of soil material was determined using a muffle-furnace. Oven-dried (105 °C) material was incinerated at 500 °C until a constant weight was obtained.

2.4. Statistical analysis

The experimental design suggests the use of mixed effects models assuming *sample point* to be a random effect. This allows possible dependencies for the seven measurements within a single study site to be taken into account. Estimates for the expected values (means) of response variables reported in Table 3 were obtained from a Gaussian linear model with *land use* as a fixed factor and *sampling points* as a random effect nested within *land use*. These models were