Soil Microbiological Properties Of Reclamation Sites Compared To A Natural Succession

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Abstract For any re-establishment of vegetation it is essential that microbial activity is restored to ensure carbon and nutrient turnover. The mediator of this process is the microbial biomass (C_{micr}). Thus, if C_{micr} levels of a reclaimed site approach those of comparable ecosystems, one important part of the reclaimed system has been re-established successfully.

We compared the C_{micr} levels of two revegetation trials (established in 1982, elevation 2600—2800 m above sea level) with those of an adjacent natural succession. This succession is comprised of a series of recessional moraines of different ages. Before revegetation, the soils were bare and had very low C_{micr} levels (80 $\mu g \cdot g^{-1}$ soil). In 1986, the plots which had been amended with mineral fertiliser, Bactosol® or Biosol® (organic fertilisers) had reached biomass levels of 282, 603, and 584 $\mu g \cdot g^{-1}$, respectively. If the equation describing the development C_{micr} levels on the natural succession is taken as a calculation base, these figures correspond to 9, 37, and 34 years, respectively, of natural succession.

INTRODUCTION

Ecosystem functioning comprises two major processes, i.e., primary production and decomposition. For a successful reclamation it is equally important to restore both. The main target of any reclamation effort should be to accelerate this process. For the evaluation of the reclamation success, natural successions may serve as a yardstick. Therefore, it is necessary to select a parameter which is directly related to successional development.

Various soil microbial parameters have been used to study the time course of recovery of reclaimed land. Enzyme activities, ATP levels, and soil respiration have been used by Stroo and Jencks (1982), Schafer et al. (1979), and Visser et al. (1983), respectively, to describe the development of microbial activities in mine soils. Insam and Domsch (1988) emphasized the feasibility of soil microbial biomass (C_{micr}) as a parameter for reclamation studies. They found a close relationship between C_{micr} levels and the age of reclaimed agricultural and forest soils.

In this study, C_{micr} of a natural succession is compared to the C_{micr} levels of secondary successions of revegetation trials.

MATERIALS AND METHODS

Two reclamation sites at the Festkogel near Obergurgl (Austria) (2600 m and 2800 m sea level for site I and II, respectively) were established on July 15, 1982. The original vegetation as well as rocks had been removed and the remaining fine material and gravel levelled to make a ski-run. The parent material is silicious, and the organic matter content (attributable to parts of previous topsoil) was 2.9% on site I and 0.3% on site II. The pH of the bare soils before reclamation was 4.4 and 4.2 for site I and II, respectively. On both sites a mixture of grass and herb seeds, mainly *Phleum pratense* and *Festuca rubra*, as well as *Achillea* and *Trifolium* species, was sown. The sites were divided into plots (4 replicates) which were fertilised annually with inorganic fertiliser (30 $g.m^{-2}$; N:P:K:Mg = 12:12:17:2 + trace elements) or one of two different organic fertilisers, Bactosol® or Biosol®. These fertilisers consisted mainly of dried bacterial or fungal biomass, respectively. They were applied at a rate of 200 $g.m^{-2}$. Three replicate samples were taken from each plot, either shortly after spring thaw before the annual fertiliser application (21/7/83, 20/7/84, 18/7/85, 15/7/86) or at the very end of the vegetation period (18/9/82, 22/9/83, 20/9/84).

The natural succession is comprised of recessional moraines of the Rotmoos Glacier which descends from 3400 m to 2400 m at its toe. Mean annual temperature is about -0.5°C, with a mean of 6.1°C, with a mean of 6.1°C for June-September. Mean annual precipitation is about 1100 m. Petrographic series contributing to the till material are mica schists, phyllites, amphibolites, hornblende, and also some marble layers. From each of five sites, 8 samples were taken on 26 August 1985 and 10 July 1986. These sites, representing soils of different age, are described elsewhere (Jochimsen, 1970; Insam and Haselwandter, 1988).

All samples were sieved (2 mm), stored at 4°C and, prior to analysis, equilibrated to room temperature for at least two days. Microbial biomass (μg $C_{micr} \cdot g^{-1}$ soil dry mass) was determined by substrate-induced respiration (Anderson and Domsch, 1973) using an infra-red gas analyser (URAS1, Hartmann and Braun, Frankfurt, FRG). Organic carbon was assessed by dry combustion (Leco induction furnace) after expelling carbonate-C by addition of HCl (10%) and drying of the samples at 70°C.

RESULTS AND DISCUSSION

The plant succession of the Rotmoos Glacier as described by Jochimsen (1970) was accompanied by a change of microbial biomass levels. The development of C_{micr} on the Rotmoos Glacier may be described best by the exponential function

$$y = -290.1 + 293.2 \quad e^{0.03x}$$

where x is the ln of the site age and y is $\mu g\ C_{micr} \cdot g^{-1}$ soil.

As can be seen in Fig. 1, in the early stages of succession microbial biomass rose very fast, indicating that increasing amounts of carbon became available for microbial consumption with the initiation of higher plant's primary production. In the subsequent years, the increase of C_{micr} slowed down. It has to be mentioned that Site V could not be dated exactly; its age may be anywhere between 215 and some 1000 years. We based the calculation of the regression on an age of 999 years. However, any deviation of the actual age from this value would only change the slope of the curve but not its shape.

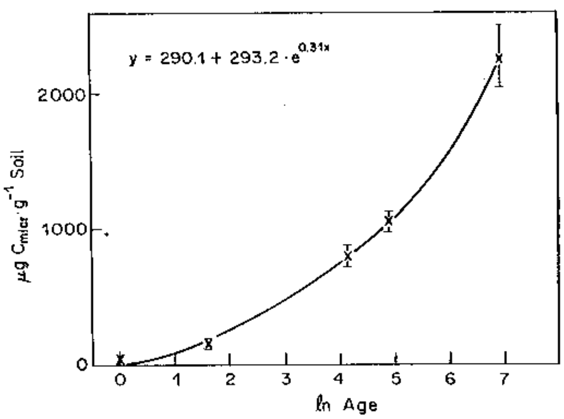

Fig. 1 *Development of miocrobial biomass (C_{micr}) levels on the Rotmoos sere with time. Bars indicate the standard error (n=16).*

As outlined in another paper (Insam and Haselwandter, in preparation), organic matter increased and the microbial respiration/biomass ratio declined with time. These parameters, too, indicate the maturation of the system.

On the reclamation site, the C_{micr} level before reclamation started was about 80 $\mu g\ C_{micr}/g^{-1}$ soil (Insam and Haselwandter, 1985). In contrast to the primary succession described above, where a plant cover only slowly established and thus primary production only slowly increased, the reclamation resulted in a high level of carbon input from the very beginning. This carbon input may be ascribed to the fertiliser and soil stabiliser amendments as well as to plant residue and root exudate inputs which commenced already in the first year after revegetation. As a result, the decomposer biomass (C_{micr}) rose sharply from the pre-vegetation level to 150 μg/g and 250 μg/g for the mineral and organic fertilised plots, respectively.

Subsequently, over the next 5 years, C_{micr} levels rose steadily, more rapidly on the organic than on the mineral fertilizer plots. If the data for both sites are computed together, the linear regressions

$$\text{(a) } y = 17.86 + 0.031x \quad r^2 = 0.14$$
$$\text{(b) } y = 20.99 + 0.115x \quad r^2 = 0.43$$
$$\text{(c) } y = 33.09 + 0.077x \quad r^2 = 0.18$$

describe the development of C_{micr} levels on the mineral fertiliser, Bactosol® and Biosol® plots, respectively (Fig. 2)[1].

With time, the difference between organic and mineral fertilisation became more and more pronounced. The same was observed for the state of the plant cover.

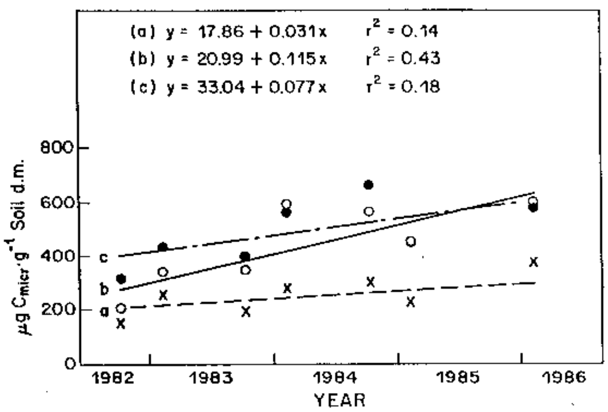

Fig. 2 *Microbial biomass levels on the Festkogel reclamation sites receiving mineral fertiliser (x), Bactosol® (o) or Biosol® (•). The data points represent the mean calculated from each of the two sites.*

If the mean C_{micr} figures (sites I and II) for 1986 and the regression line for C_{micr} on the natural succession are used as a calculation base, C_{micr} levels corresponding to 9, 37, and 34 years of natural succession have been achieved after only 5 years of reclamation, with mineral fertiliser, Bactosol® and Biosol®, respectively.

When the regression lines for the two sites were calculated separately, lower residuals were found. On site II, the initial values were higher, but the slope of the regression was steeper for site I than for site II. The regression lines found for the two sites and the three fertilisers were:

	SITE I	
Mineral Fertilizer	25.04 + 0.025x	$r^2 = 0.22$
Bactosol®	32.54 + 0.089x	$r^2 = 0.30$
Biosol®	52.49 + 0.043x	$r^2 = 0.24$
	SITE II	
Mineral Fertilizer	10.61 + 0.036x	$r^2 = 0.43$
Bactosol®	09.44 + 0.141x	$r^2 = 0.73$
Biosol®	13.69 + 0.111x	$r^2 = 0.49$

C_{micr} on Site II was lower than on Site I after the first growing season. This may be attributed to the more adverse climatic conditions and the lower organic matter content on Site II compared to Site I. However, the slope of the regression was steeper on Site II than on Site I.

The organic matter content of a soil is considered to be an important factor for its fertility and stability. Increases in organic matter content are often hard to detect directly. However, the amount of microbial biomass per unit soil organic matter may give an indication on whether a soil is losing or accumulating carbon (Insam and Domsch, 1988).

In 1986, high levels of C_{micr} within the organic matter (C_{org}) have been found on the reclamation sites, particularly on the organic amended plots. For these, 33.5 and 63.1 mg C_{micr}/C_{org} have been found on Site I and II, respectively. According to Insam and Domsch (1988) this indicates that C_{org} levels on these plots are rising. For the mineral fertiliser plots the amount of C_{micr}/C_{org} was found to be lower, 17.9 and 39.0 mg C_{micr}/C_{org} for Sites I and II, respectively. This indicates a slower accumulation of C_{org} on the mineral fertilised plots than on those amended with organic fertiliser.

These data seem to indicate a success of revegetation. However, it has to be considered that C_{micr} is only one of several parameters which are necessary for a functioning ecosystem. Additionally, one major question remains, namely, what will happen to the system once fertilisation is discontinued? Certainly, without invading autochthonous plant species, the system will not become self-sustainable.

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[1]Note that for the calculation of these regressions a vegetation period of 90 days was assumed, with spring samples taken 10 days after the beginning and fall samples taken 20 days before the end of the vegetation period. The x in the equations refers to the number of days during the vegetation period. y is the predicted C_{micr}

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