THE APPLICATION OF SOIL BIOLOGICAL INDICATORS TO SUPPORT SOIL CONSERVATION PRACTICES AND LANDSCAPE QUALITY IN VITICULTURE

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Key words: soil management, soil biology, soil conservation, terroir, landscape

Abstract
The aim of our work was to investigate the influence of different soil management systems in viticulture on soil biological parameters as indicators for soil conservation and soil quality. Soil conservation is indispensable for a sustainable viticulture and the protection of the terroir.
Our results showed, that soil organic matter and soil microbial biomass are good indicators for the efficacy of soil conservation techniques. Soil biological activity can by supported by green cover or application of organic material. Also post-emergence herbicides, used in a reasonable way, can be employed for the goals of soil conservation. Efficient soil management systems and high soil quality are a prerequisite for the protection of the landscape and the environment. Landscape quality deals with the visual appearance of the environment. A high quality of the landscape should become more important as a component of the terroir.

Résume
Le but de notre travail a été d'étudier l'influence de différents systèmes de la gestion du sol en viticulture sur des paramètres biologiques de sol comme indicateurs de la protection et de la qualité du sol. La conservation de sol est indispensable pour une viticulture durable et la protection du terroir.
Nos résultats ont montré, que la matière organique et la biomasse microbienne du sol sont des indicateurs pour l'efficacité des techniques de conservation du sol. L'activité biologique du sol peut être soutenu par l'enherbement ou l'amendement des résidus organique. Même des herbicides de post-levée, utilisés dans une manière raisonnable, peuvent être utilisés pour les buts de la conservation du sol. Des systèmes efficaces de la gestion du sol et une qualité du sol élevée sont un préalable à la protection du paysage et l'environnement. La qualité de paysage traite l'aspect visuel de l'environnement. Les aspects de la qualité du paysage devraient devenir plus importants comme composant du terroir.

Introduction

In the context of terroir the soil can be regarded as a connecting link between plant and geology. A lot of environmental functions are related to the soil (e.g. water infiltration and supply, organic matter and nutrient cycling, habitat for flora and fauna) determining the vigour of the vines and the oenological potential of the grapes. The capacity of a soil to fulfil its functions in the environment is described as soil quality. This capacity is based on biotic and abiotic soil properties, local climatic factors, and is further related to agriculture and land use practices.
Soil living organisms influence many soil properties and the biological activity is a key factor for nutrient turnover and humus formation. The later influences in its turn soil physical and chemical properties like water holding or ion exchange capacity. In particular soil micro-organisms are a sink and source of mineral nutrients and organic compounds. They are strongly regulated by living plants (e.g. exudates) and died off plant residues. In a vineyard, the feeding of the soil micro-organisms is mainly depending on green cover (permanent or temporary), amendment of organic matter (straw, compost, manure etc.) and weed control system (chemical or mechanical). For chemical weed control two methods with different mode of action of the herbicide molecules are performed: 1. pre-emergence herbicides preventing the germination of weeds and resulting in an uncovered bare soil and 2. post-emergence herbicides killing off the established weeds and resulting in a soil covered by died

off plants. With mechanical weed control, there is an incorporation of organic matter in the soil -the controlled weeds- but the soil structure is disturbed by the mechanical impact and the aeration of the soil is increased, favouring the degradation of soil organic matter (Reicosky 2001).
In the frame of environmental friendly viticulture, herbicides are banished from vineyards because of environmental arguments. Further, the visible effect of the herbicide use (bare soil or damaged and dried-out weeds) is a reason for negative image formation in the public. On the other hand, landscape quality might be endangered if economical and technical efficient systems like post-emergence herbicide application are refused: e.g. giving up of vineyards at terraces or steep slopes because of high production costs and difficulties to get to with machines for soil cultivation. Increasing parts of fallow or derelict land within typical viticultural landscapes can be the consequence and have a high potential to damage the originality and consequently the quality of a landscape.
At landscape level, the soil has a fundamental regulatory function and a lot of functions of a landscape are closely related with the functions of the soil (e.g. water regime, nutrient cycling, buffering and degradation of xenobiotics). Therefore, the conservation of soil is a basic tool for landscape quality. Erosion for example affects not only the vineyard by destroying the nutritive upper soil layer, but it also damages the landscape.
From the point of view of soil conservation, soil organic carbon and soil microbial biomass are useful indicators for soil quality in viticulture (Chaussod *et al*. 2000) and a sustainable and terroir respecting land use in viticulture should imply the impact of soil management on biological soil functions. The aim of our studies was to get a better understanding of the interactions between soil management and soil biological properties including soil organic matter formation. Therefore, soil samples were taken from vineyard soils of different sites and with different soil management. The samples were analysed for soil microbial biomass and soil organic carbon.

Materials and Methods
In our working group, projects about the influence of soil management in viticulture on the fate of soil biology and soil organic matter are of particular interest. Different soil management systems were investigated like compost application, the use of post-emergence herbicides, permanent green cover, and open soil (mechanical cultivation). For our investigations, vineyards from the Rhineland-Palatinate (Germany) were selected according to typical soil conditions and management systems. The soil sampling was performed separately for the lane between the vines and for the line of vines.
Soil samples were taken during the whole year with the exception of periods of dryness or frost. The sampling was performed with an auger from the topsoil to a depth of 15 cm. At each vineyard site 16 samples were taken per soil management and were mixed to achieve one representative sample. After sewing (< 2 mm) the soil samples were adjusted to a water content of 60 % of maximum water holding capacity, equilibrated at room temperature for at least one week and stored at 4°C prior to further analysis. The organic carbon content of the soil samples (C_{org}: parameter for soil organic matter content) was analysed by dry combustion in a Carlo Erba CNS-Analyzer ANA 1500. The amount of inorganic carbon of the soil sample was taken into consideration. The soil microbial carbon (C_{mic}: parameter for soil microbial biomass) was determined by the Fumigation-Extraction-Method after Vance *et al*. (1987).

Results and Discussion
In the following, results from different vineyard sites and different sampling periods will be summarized to give an overview of the soil biological properties of vineyard soils in relation to different soil management systems. These results will be further discussed in the context of soil conservation and landscape quality.
The positive effect of green cover, manuring and compost application on soil microbial biomass and soil organic matter could have been demonstrated at different vineyard sites. The values for both parameters were clearly lower in the lane with mechanical cultivation compared to the lane with permanent green cover or application of organic material (Reuter & Kubiak 2001, Reuter 2003, Reuter 2004, and figure 1). In contrast, if there was a conversion of green cover in open soil and vice versa every 2nd year, like it was performed in two vineyards which are managed according to the organically viticulture (Reuter 2004), the differences between the lanes disappeared. This temporal alternation of green cover and open soil provided a sufficient source of easily degradable organic material as

nutritional source for soil organisms. Organic material (e.g. plant residues, organic fertilizer) and soil organic matter are important for the growth of soil micro-organisms. The absence of a weed cover results in an impoverishment in organic matter. As a consequence of this alimentary deficiency the soil microbial biomass will be reduced. Additionally, soil tillage favours the degradation and mineralization of organic matter because of an enhanced soil aeration (Reicosky 2001). Therefore, in particular the mechanically cultivated soils showed a reduction in organic matter and microbial biomass compared to the soil with permanent green cover.

The application of farmyard manure additionally increased the amount of soil organic matter (Reuter, 2004). But, compared to the other vineyard sites, the soil microbial biomass was not increased in a comparable way. Farmyard manure has a high proportion of stabilised organic matter, that serves less as nutritional source but more as source for humus formation, like it was also observed with compost used in viticulture (Reuter & Kubiak 2001). Compost application one year before soil sampling had a strong effect, whereas this effect was not observed, or not any longer observable with the compost applied already two years before soil sampling. The comparison of the C_{mic}/C_{org} ratio shows, that the quality of organic carbon as nutritional source for the micro-organisms is poor in the older compost variant, and that this ratio is best under green cover. By analysing different C-fractions, Arshad *et al*. (1990) demonstrated, that a no-till system improves the quality of soil organic matter enabling enhanced biochemical activities in the soil. A high proportion of micro-organisms in the organic fraction is important to stabilise the organic matter. In viticulture, there is only a low input of crop residues. Therefore, green cover or organic manuring can serve as an important source of organic matter for the soil. Beside the function as nutrient source for soil organisms the soil organic matter improves the structure of the soil and favours water infiltration. This is important to reduce surface run-off in particular at steep sites (Meyer & Martínez-Casasnovas 1999).

The use of post-emergence herbicides transforms the developed weed coverage in a mulch layer of died off plant residues, which protect the soil surface and serve as an easily degradable carbon sources. The effect of post-emergence herbicide application on soil microbial biomass depends mainly on the density of weeds before the treatment. This was investigated in 5 vineyards with the application of these herbicides in the line of vines (Reuter 2004). In 2 vineyards no negative effect compared to permanent green cover was observable. In 3 vineyards the soil microbial biomass was reduced, but the reducing effects were not stronger than comparable effects with mechanical cultivation.

The alteration of soil properties by soil management was most obvious in a vineyard with absence of any mechanical soil cultivation for more than 10 years (permanent green cover in the lane between the vines and post-emergence herbicide application in the line of vines). To investigate this long term effect the vineyard was compared with an adjacent vineyard being mechanically and chemically treated several times per year to keep the ground free of weeds. With post-emergence herbicides microbial biomass increased for 72% and with permanent green cover for 150% compared to the open soil (figure 1). The results for organic matter had the same trend.

The presented results showed, that soil microbial biomass increased with duration of green cover and that the relation of microbial biomass to organic matter decreased. Therefore, it can be assumed that microbiological conditions in soils with green cover are more stable. But also the use of post-emergence herbicides, applied in a growth stage where weeds cover the whole ground, favour the supply of the soil biota with easily degradable plant residues. Further, the died off weeds keep the soil covered and protect it against drying out or erosion.

Soil microbial biomass and soil organic matter content are recommended as indicators for soil quality in viticulture (Chaussod *et al*. 2000). They are important e.g. for a better soil structure favouring water infiltration and hence reducing the risk for erosion. The documentation of erosion phenomena after a strong rainfall of about 50 mm during one hour demonstrated the differences in the susceptibility of a soil surface to erosion in relation to the soil management. An example from a vineyard with a silty sand soil type at a moderate slope is shown in figure 2. The soil with permanent green cover (lane between the vines) was not affected by erosion. The lane with open soil showed strong erosion phenomena, visible as accumulated soil material (alluvial soil) at the end of the lane. The soil treated with post-emergence herbicides (line of vines) also showed a high stability against erosion. The more plant residues remained on the soil surface after treatment with post-emergence herbicides, the better was the protection against erosion, resulting in very low to no soil movement. Even if the residues on the soil surface were washed away, the remaining bare soil showed considerably lower erosion than

the mechanically cultivated soil. These observations demonstrate, that a soil structure, built up by plant roots and soil biota and not disturbed by mechanical cultivation, is more stable against erosion. Further, the residues of the treated weeds protect the soil surface.

Conclusions

Our results showed that soil biological parameters are a good indicator for soil conservation and that it is important to support soil biological activity by green cover or application of organic material. Further, post-emergence herbicides, used in a reasonable way, should not lead to negative impacts on soil biology but might help to maintain soil organic matter and soil microbial biomass.

To protect the soil and the edaphon, an operational concept a priori cannot be given. The effects caused by different concepts might be regarded differently from the point of view of biology, economy, quality of the harvest, or pictorial qualities.

Landscape quality deals with the visual appearance of the environment. In the context of viticultural zoning, a landscape represents a typical region and is a carrier of emotions and culture. Functions like image formation or esthetical aspects therefore have to be attributed too.

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List of tables and figures

Figure 1: Soil microbial biomass (C_{mic}) and soil organic carbon (C_{org}) from the topsoil of a vineyard with different soil management in the lane between the vines and in the line of vines.

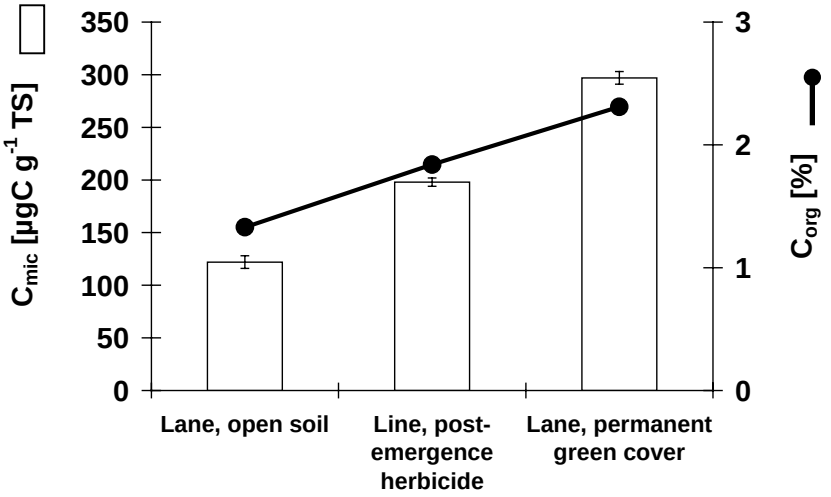

Figure 2: The visible effect of soil management on soil erosion