A Conceptual Framework for Soil management and its effect on Soil Biodiversity in Organic and Low Input Farming

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Key words: Soil biology, soil management, biodiversity, sustainability, soil model

Abstract

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems. We designed a conceptual framework linking soil management practices to important soil-life groups and soil fertility services like nutrient cycling, soil structure and disease suppression. We selected a necessary parameter set to gain insight between management, soil life and soil support services. The findings help to develop management practices that optimise yields, soil fertility and biodiversity in organic farming.

Introduction

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems. Organic farming aims at optimising production while maintaining a rich biological diversity of the soil (Davis and Abbott, 2006).

Farmers have an ongoing economic interest in soil ecosystem services like nutrient cycling and soil aggregate formation. Little knowledge exists however, about the relationship between specific soil management practices influencing soil biodiversity and these services. It may be true that environmental variables like soil type and climate determine to a large extent the soil community (Davis and Abbott, 2006). However, individual practitioners have many opportunities to influence this community in regard to optimising biological fertility at their individual farms.

In this paper we present a the conceptual framework linking soil services, soil management and its effects on soil biodiversity. The study focuses on the question: if we want to achieve certain soil ecosystem services, which soil life is then important and with which soil management practices can we obtain the desired soil life? The conceptual framework is a mind map that enables the evaluation of the effects of farming practices on soil biodiversity parameters. This study contributes to national research programs concerning the Biological indicator-system for soil quality (BiSQ) (Rutgers et al., 2005).

Materials and methods

The study included the elaboration of two typologies of both soil (ecosystem) services as well as (organic) soil management practices. With the typology as a starting point, interactions were explored, based on literature (e.g. Bloem et al., 2005) between

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important soil services and soil management practices like nutrient cycling, soil structure formation and disease suppression. Soil biodiversity is involved in these interactions. Parameters of soil biodiversity (based on BiSQ) were selected, that are supposed to be essential for linking management to soil services. The result was a conceptual framework based on experimental data, literature and expert judgement, that links soil management practices, soil life groups and soil services like soil fertility. Subsequently the framework was used to evaluate and understand the impact of type of manure on soil biodiversity and soil services, as an example of one of the most important soil management practices

Results and Discussion

Figure 1 presents the link between the services an agricultural soil can perform, the most important soil management practices by farmers and effects of these practices on soil biodiversity and productivity. The soil practices in our study focus primarily on the soil fertility service and all services linked to soil fertility like nutrient cycling, soil structure and disease suppression.

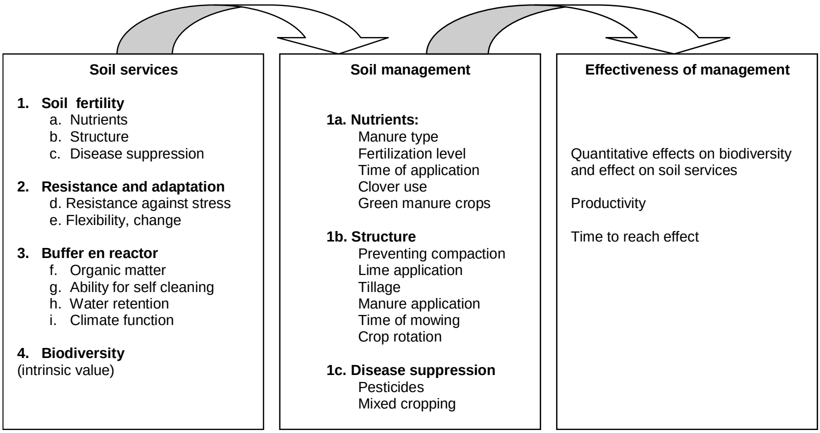

Figure 1 relates soil services to certain soil management practices and the effect of the soil management on soil biodiversity.

Linking soil management practices and services can be considered as a new management tool. The choice of services reflects the local use of the soil by farmers (Rutgers et al., 2005).

In the conceptual framework of figure 2 the central question is: how to obtain a particular soil service? The framework clarifies the most important relations to soil life and requirements in terms of soil management practices. Therefore the framework consists of three important squares which are related to each other: soil management (including tillage), soil life and soil ecological services.

Additional to the three squares, the circle includes the management effects that are mediated by crop development i.e. the root system. As indicated by many authors soil management can impact soil life directly or through plant growth and especially root production.

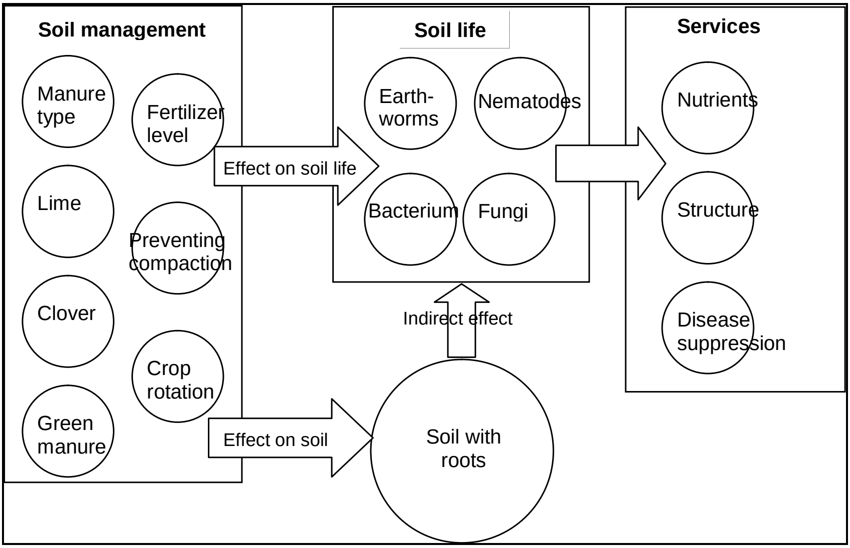

Figure 2: A simple conceptual framework for soil management and its effect on soil biodiversity and soil services.

The value of the elaborated approach is primarily the link between soil management practices and soil (ecosystems) services that represent the farmers profit and external demands (e.g. clean drinking water). Second: a conceptual framework can help the practitioner to better understand the soil-life black box. In this respect decision support is important because in practice different soil management practices are always taken simultaneously. The framework can show whether soil practices synchronise in their effect on soil life or work in the opposite direction. The framework is able to give an estimate of the impact of different management practices.

The soil food web structure and the life support services of soil organisms can be indicated by a selection of parameters (table 1). With this standardised parameter set based on the BiSQ (Rutgers et al., 2005) it is possible to determine the effects of management on these biodiversity parameters which should be measured.

An example of the application of the framework is presented by Zanen et al. (this issue). That study shows that soil management practices like organic amendments allowed in organic agriculture, alter soil life (i.e. nematode population) and change soil indicated by organic N mineralization potential. Other studies (Koopmans et al., 2006) suggest that changes in the response of crop roots due to different organic inputs altering the composition of the soil community over time.

Conclusions

This study shows that important soil services, soil management practices and soil biodiversity indicators can be linked in a framework to develop sustainable agricultural systems that manage beneficial soil biological processes. This may be a key step towards understanding the biological mechanisms behind soil biodiversity. The findings could be useful to support management practices that optimise yields, soil fertility and biodiversity in organic farming.

Tab. 1: Parameters of the dataset of the soil biodiversity framework.

Area	Parameter	Unit
Biological	Bacterial biomass	μg C/g soil
	Thymidine incorporation	pmol/g soil/hr
	Leucine incorporation	pmol/g soil/hr
	Fungal biomass	μg C/g soil
	Active Hyphae	%
	Pot. N mineralization	mg N/kg/week
	Pot. C mineralization	mg C/kg/week
	Bacterial feeding nematodes	n/100 g soil
	Fungal feeding nematodes	n/100 g soil
	Plant feeding nematodes	n/100 g soil
	Nematodes predators	n/100 g soil
	Earthworm biomass	g/m^2
	Lumbricus rubellus	n/m^2
	Aporrectodea calliginosa	n/m^2
	Lumbricus terrestris & Aporrestodea longa	n/m^2
Physical	Structure crumb	% in 0-10 cm
	Structure round	% in 0-10 cm
	Structure angular	% in 0-10 cm
	Plant roots 10 cm	$n/400\ cm^2$
	Plant roots 20 cm	$n/400\ cm^2$
Chemical	Organic matter, clay, pH, Ct, Nt, Pt, Pw, P-Al, K2O	divers

References

Bloem, J., Schouten, A.J., Sørensen, S.J., Rutgers, M., Van der Werf, A., Breure, A.M. (2005). Monitoring and evaluating soil quality. In: J. Bloem, A. Benedetti, D.W. Hopkins (eds.). Microbiological Methods for Assessing Soil Quality. CABI, Wallingford, UK, pp. 23-49.

Davis, J., Abbott, L. (2006). Soil fertility in organic farming systems. In Kristiansen, P., Taji, A., Reganold, J. (eds.): Organic agriculture. A global perspective. CABI Publishing, Wallingford, p. 25-51.

Koopmans, C.J., Smeding, F.W., Rutgers, M., Bloem, J., Van Eekeren, N. (2006). Biodiversiteit en bodembeheer in de landbouw. Louis Bolk instituut, RIVM, WUR-Alterra, Driebergen, 69 p.

Rutgers, M., Mulder, Ch., Schouten, A.J., Bogte, J.J., Breure, A.M., Bloem, J., Jagers op Akkerhuis, G.A.J.M., Faber, J.H.,Van Eekeren, N., Smeding, F.W., Keidel, H., De Goede, R.G.M., Brussaard, L. (2005). Soil ecosystem profiles – sustainable land-use with references for a healthy soil. Report 607604007, RIVM, Bilthoven. (In Dutch, with English summary)