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EVALUATING THE STRENGTHS AND WEAKNESS OF CONVENTIONAL, NO-TILL AND ORGANIC CROPPING SYSTEMS: AN ASSESSMENT OF YIELD, SOIL PROTECTION AND ENVIRONMENTAL PERFORMANCE

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Abstract: In a comprehensive study on 60 observed fields in organic, conventional and no-till cropping, a coherent set of different indicators for cropping management, crop performance and soil physical, chemical and biological properties has been developed to describe and assess these systems. The high yield level in conventional, the soil surface protection and diversity of crops in no-till, and the higher soil organic carbon content and the complexity of root-associated microbial networks in organic systems underline the areas for improvement to be considered for the further development of sustainable cropping systems.

Introduction: Different cropping systems coexist in the European agricultural landscape with their own characteristics, notably in terms of soil protection. Traditional mixed cropping systems benefit from diversified crop rotations with temporary meadows and from organic fertilisers. These systems have relative balanced nutrients fluxes and carbon inputs. No-till systems have been mainly developed in stockless farms to counteract soil protection risks; no-till systems have demonstrated the combination of minimum soil disturbance, maximal soil cover and diversified crop rotation enhances soil surface protection. Organic agriculture uses different agronomic tools to produce without mineral fertilizers and synthetic pesticides; it includes a strategy for maintaining soil fertility by the use of organic fertilizers and a balanced rotation between demanding and regenerative crops regarding soil protection. However, these systems also show specific limitations in their capacity to promote fertile and living soils or to achieve high yields. Consequently a characterisation of their specificities should allow to understand their strengths and weaknesses and to further develop systems that are even more sustainable regarding the use of soil as a resource. The questions are 1) to what extent do these systems modify soil properties, 2) which properties are modified and what are the responsible factors/mechanisms for this modification, 3) can we identify appropriate indicators for soil quality and associated cropping practices. To answer these questions, a coherent set of indicators has been developed and implemented in a network of fields conducted under different cropping systems.

Material and methods: A network of 60 fields under conventional, no-till and organic cropping systems on the Swiss plateau has been set up to allow the assessment of 63 different parameters describing soil and crop management, crop performance and soil quality. The organic fields were managed according to Bio Suisse's regulations, while the other two systems met the Swiss cross-compliance requirements. The management systems had been applied for a minimum of 5 years. Farmers known for their good management practices were chosen.

Crop and soil parameters were assessed during one year of winter wheat cultivation and farmers were interviewed about their management. Farm structure, crop diversification, soil disturbance, organic and mineral fertilisation, crop protection, and yield were assessed with an initial set of 37 indicators (Büchi et al., 2019). Biological, physical and chemical parameters were used to characterize soil quality. Physical soil properties were assessed on 30 plots of the network (Colombi et al., 2019). Investigation on the impact of different cropping systems on soil life focused on wheat root fungal communities using next generation sequencing on collected samples (Banerjee et al., 2019).

Results: A set of complementary indicators has been identified to obtain a broad picture of cropping practices and to help the interpretation of measures of soil and crop (Büchi et al., 2019). The indicators highlighted differences but also similarities between the three systems. For some indicators there was high within-system variability, suggesting that there is a need to use quantitative indicators to help the evaluation across the systems. However, trends could be identified for the systems, generally related to their specificities. Conventional system was characterised by higher yields, more frequent pesticides applications (particularly with fungicides), higher nitrogen fertilization, and more machinery passes. The no-till system showed intermediate yield level, a higher soil coverage, more cover crops and legumes, a higher crop diversity and more herbicide applications. The organic system was characterised by lower yields, more leys, more weeds (in wheat), a higher organic nitrogen fertilization, a higher soil perturbation intensity (weed control and soil tillage).

With regard to physical properties relationships between gas transport properties and organic carbon content in the topsoil and subsoil were studied (Colombi et al., 2019). Considerable variation was observed within the management systems. Tillage increased soil gas transport capability in the topsoil, while organic cropping resulted in higher soil organic carbon content. Higher soil gas transport capability was associated with higher soil organic carbon content, both in the topsoil (12.5cm) and subsoil (37.5cm) ($0.53 < R^2 < 0.71$). Organic carbon inputs (crop residues, amendments) were not related to soil organic carbon content. The results of higher soil gas transport was conjectured with improved conditions for root growth and eventually corresponding increased input of soil organic carbon. This may be relevant in the evaluation of carbon sequestration strategies in cropping systems.

The cropping systems showed differences in the structure and complexity of root-associated microbes (Banerjee et al., 2019). Organic systems showed a much more complex fungal network including higher abundance of keystone taxa than both other systems. The majority of key stone taxa belong to mycorrhizal fungi, which were also more abundant in roots and soils under organic cropping. A strong negative association ($R^2 = 0.37$; $P < 0.0001$) was identified between root fungal network connectivity and an index of agricultural intensification. This index, (calculated based on the use of fertilizer (available N), pesticide and fuel for machinery) ranked the systems in the following decreasing order: conventional > no-till > organic.

Discussion: The improvement of agricultural production needs to evaluate practices for their effectiveness to promote yield, soil quality and other ecosystem services. The different coexisting systems show specific favourable characteristics that should be integrated. The critical trade-off between yield in conventional system, high soil surface protection in no-till and high soil biological quality in organic system show the challenge to be faced for the further development of sustainable systems. In organic system, a more systematic cultivation of cover crops and legumes, as well as a reduced soil perturbation by tillage and better weeding control measures need to be practiced to improve soil conservation. In addition, the availability of quantitative and complementary indicators should help to manage these improvements provided that there are understood in practice.

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