Soil quality monitoring by farmers in the frame of a result-oriented scheme: the case of Swiss arable land

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Preserving soil quality
IPBES (2018) acknowledges that globally soil quality is severely depleted, particularly under intensive agriculture. The public awareness on the importance of soil functions has dramatically raised, and a large part of the Sustainable Development Goals rely on soil quality. Therefore, a growing pressure is applied on agriculture to preserve and restore soil quality.

The need for result oriented agricultural management schemes
Soil quality in arable land is addressed by different action-oriented policy tools. In high income countries, farmers can be subsided for the application of recommended techniques. A general finding is that the action-oriented schemes largely fail to reach their objectives (Burton & Schwarz, 2013). This is also observed in Switzerland, were the agro-environmental monitoring reports steady indicators of environmental impact along the past decade. In detailed studies comparing different soil management systems such as conservation agriculture and conventional tillage, a small or even non-significant difference of soil quality between these systems was found, together with a very large heterogeneity within each. This is why action-oriented schemes are questioned and result-oriented management schemes are called. The conditions and advantages of the latter are reviewed by (Burton & Schwarz, 2013). Result-oriented management schemes were not applied to the management of soil quality in arable land, so far, in particular because indicators fulfilling the conditions were not available.

Soil quality and visual assessment
Soil quality is the capacity of soils to function in an ecosystem with a given land management while guaranteeing agricultural production (Bünemann *et al.*, 2018). Since many soil functions depend on the soil's structural state, the structure becomes a guarantee of soil quality. The VESS spade test has been developed and tested in recent years (Ball *et al.*, 2017) i) delivers immediate and reliable results, ii) facilitates communication between farmers and scientists, and iii) provides an interpretable soil quality index. VESS is already used for soil quality monitoring (Mueller *et al.*, 2013). Soil structure may change rapidly with seasons and plant growth, upon trafficking or tillage. Therefore, VESS is a short term (season) indicator.

Soil quality and OM content
OM is the main indicator for overall soil quality because it determines most of the soil functions. However, the OM:clay ratio was shown to determine structure quality for different soils (Feller & Beare, 1997; Dexter *et al.*, 2008; Johannes *et al.*, 2017). In other words: more organic matter with increasing clay content is needed to reach a given structure quality level and OM:clay ratio is a driver of soil structure quality. Changes in OM content as a function of soil management are usually detectable after 5 to 10 years at field scale, therefore OM:clay ratio is a middle term (5-10 years) indicator. (Johannes *et al.*, 2017) showed that optimal structure quality (VESS score < 2) corresponds to an average OM:clay ratio of 24%, the limit

between acceptable and damaged structure corresponds to 17% OM:clay ratio, and degraded structures (VESS > 4) correspond to OM:clay ratio < 12%.

A farmer-based monitoring

Success of result-based schemes depends on i) the involvement of farmers by self-monitoring through visual assessment, ii) the combination with regular analytical control, and iii) the integration of a sampling protocol whose reliability has already been demonstrated. Self-monitoring by farmers increases their involvement and the social value of the result-based schemes (Burton & Schwarz, 2013).

VESS and OM:clay ratio, which is a relevant and more holistic assessment of soil quality, fulfill the conditions for a result-oriented management scheme of soil quality. This approach was discussed with the different actors involved in arable land management in Vaud canton, Switzerland. Farmers, advisers, cantonal authorities and scientists agreed on a monitoring based on these indicators and performed by farmers. A mobile phone app was designed to allow teaching VESS, help farmers in the monitoring, and store the results. The sampling requirements of the VESS spade test were established after a spatial variability analysis (Leopizzi *et al.*, 2018). In Switzerland, to receive subsidies, farmers must analyze their topsoil for OM content (2-20 cm) at least each 10 year at plot scale (Required Ecological Benefits: REB). The minimum detectable change (MDC) and the standard deviation of deviation to the true mean (representativeness) with REB sampling protocol were quantified and compare to most soil quality monitoring networks. Finally all agricultural plots are digitalized in a federal GIS.

Result oriented soil quality management scheme

The following scheme was adopted with the farmers: When OM:clay ratio is smaller than 12%, farmers can only receive subsides for personal training and advisers services. From 12 to 24%, the annual subside per ha is increasing, provided that the VESS score of the plot is not larger than 3 two consecutive years. At 24%, the maximum subside level is reached.

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