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Multi-criteria indexes to evaluate the effects of repeated organic amendment applications on soil quality

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Objectives
The soil application of organic waste products (OWP) favours the recycling of nutrients, the crop production, the increase of soil biological activity and biodiversity. It may also lead to soil contamination. All these effects occurred simultaneously and must be considered in the evaluation of the practice. This study aims at deciphering the long-term impact of repeated applications and the short-term effect of an additional application on soil quality using 5 different Soil Quality Indices (SQI)[a]: fertility, microbial activity, biodiversity, physical properties and productivity and one pollution index by heavy metals.

Methodology
A long term field experiment was used (QualiAgro, Ile de France) where repeated applications of 4 amendments (a municipal solid waste compost, MSW; a biowaste compost, BIO; a co-compost of sewage sludge and green waste, GWS and a farmyard manure, FYM) have differentiated soil characteristics and crop production compared to a control treatments without organic residue and receiving mineral fertilizer or not (CONT+N and CONT). The OWP are applied every 2 years, in September, at doses equivalent to 4 t C/ha (4 replicates) on a maize-wheat succession. We used 2 sampling dates: 3 weeks before application (cumulative residual effect of 7 applications) and 3 weeks just after the 8th application (short-term additional effect of a recent application), in 2011. More than 30 different variables were used: chemical (pH, Polsen...), physical (bulk density, plasticity...) and biological (microbial biomass, enzymatic activity...) soil indicators. All of these were classified in 6 classes: fertility, microbial activity, biodiversity, physical properties, productivity and pollution. Five SQI and one pollution index by heavy metals were estimated using a weighted additive index calculation method described by Velasquez et al. (2007)[a]. Only parameters with statistically significant differences ($p<0.05$) were taken into account, the maximum value of data set permits to normalized the data set, a principal component analysis was used for each data in order to explain the variability and at the end, the combination of all indicators selected and weighted by anterior steps defined SQI.

Results
The repeated applications of organic amendments increased soil fertility and microbial activity compared to control treatments as revealed by the corresponding indices. The largest improvements were observed in treatments that increased more the soil organic matter content (GWS, FYM and BIO) compared to MSW. The regular application of OWP did not significantly modify the SQI dedicated to biodiversity. A recent additional application did not lead to significant supplementary effect on the SQI. Physical properties, productivity and pollution index need more time to be explained.

Conclusion
The use of SQI allows the aggregation of different indicators to evaluate specific ecosystem services (soil fertility, soil biodiversity, vegetal productivity...) and disservices (heavy metal contamination) of the introduction of OWP in soil. Separate indices made possible to assess different aspects of soil quality separately. Other field results on the effect of OWP application would make possible to relate more precisely the observed effects to the SQIs.

References
[a] Velasquez, Elena, Patrick Lavelle, et Mercedes Andrade. « GISQ, a Multifunctional Indicator of Soil Quality ». Soil Biology & Biochemistry 39, no 12 (décembre 2007): 3066 80. doi:10.1016/j.soilbio.2007.06.013.