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Short Communication

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What do humus balances really tell about soil organic matter?

Christopher Brock[1*], Meike Oltmanns[2], Günter Leithold[1]

[1] *Justus Liebig University, Giessen, Germany*

[2] *Forschungsring e.V., Darmstadt, Germany*

Humus balance methods (HBM) are applied as tools for decision support and environmental impact assessment in arable farming. For reasons of applicability in practice, several HBM avoid a demand for comprehensive site data and are only sensitive to management. As a consequence, these methods, from a methodological point of view, cannot quantify SOM changes. Still, we show that such HBM can be used to assess the relative impact of different management scenarios at a defined site. To do so, we calculated humus balances for treatments in two long-term field experiments according to the well-recognized VDLUFA (2014) method, and compared the variation of treatments in humus balances to the variation in SOM level changes by applying analysis of correlation. In fact, the variables were positively correlated, even though the absolute deviation between balances and SOM changes was considerable. The application of another HBM that considers management impact on SOM as a site-dependent process (HU-MOD-2) showed that the ability to predict absolute SOM changes actually is dependent on sensitivity to environmental drivers of OM turnover in soils.

Keywords: humus balance, decision support, environmental impact assessment, methodology

1 Introduction

Humus balance methods (HBM) have been developed as tools to analyze the impact of arable farming on organic matter (OM) in soils. Today, several approaches to humus balancing are available. From a conceptional point of view, they can be categorized into 'ecological' and 'agronomical' methods (Brock et al. 2013). 'Ecological' methods try to quantify soil organic matter (SOM) changes based on a parametrization of ecological drivers of OM turnover in soils. The backdraw of such methods is the comparably high data demand and the sensitivity to flawed parameterization. The big advantage of most agronomic methods is that they omid the demand for comprehensive site data, and soil data in particular. Therefore, the most recognized HBM in practice in Central Europe today is the VDLUFA method (VDLUFA 2014), which applies a typical 'agronomical' approach. The major backdraw of 'agronomical' HBM is that balances cannot quantify SOM changes, unless they provide sensitivity for environmental drivers of SOM turnover, and soil, climate.As environmental drivers of OM turnover are not considered in the VDLUFA method, the tool is not sensitive to changes in these factors, and therefore cannot be used to quantify SOM changes at a site from a methodological point of view. As a consequence, the assessment scheme for balance results in the VDLUFA method does not refer to SOM changes, but to the risk of decreasing soil productivity (at insufficient organic matter supply) and increasing N loss potential (at excessive balances), accordingly. Even though this is a valuable approach, the common application of HBM both in management decision support and in environmental impact assessment requires that they effectively provide information about soil organic matter. Therefore, we are going to analyse the link between the VDLUFA method and SOM changes in this article to support the proper application of this 'agronomical' HBM. Further, we compare the performance of the VDLUFA method with the one of an environmental impact-sensitive humus balance model (HU-MOD-2, Brock et al. 2015).

* **Correspondence:** Christopher Brock, Justus Liebig University, Organic Farming, Karl-Glöckner-Strasse 21c, 35394 Giessen, Germany. E-mail: christopher.j.brock@agrar.uni-giessen.de

2 Material and Methods

Humus balances according to VDLUFA (2014) and HU-MOD-2 (Brock et al. 2015) have been calculated for treatments in two long-term field experiments, and the results are compared to SOM dynamics (indicated by annual data on carbon in topsoils). The Organic Arable Farming Experiment Gladbacherhof OAFEG (Schulz et al. 2014) compares three different 'farm types' (differing in crop rotation and fertilization) and four different 'tillage intensity' treatments in an orthogonal design. All treatments comprise 6y crop rotation cycles, and the survey period in this study covers the first two complete cycles (1998-2009). The second experiment was the Darmstadt fertilization long-term field experiment that is outlined in Raupp et al. (2006). The experiment was started in 1980 and compares mineral fertilization with composted farmyard manure application and farmyard manure application plus biodynamic preparations in a 4y crop rotation that is constant over all treatments. Annual data were available for the survey period 1980-2009. As the effect of biodynamic preparations on SOM change has not been analyzed sufficiently for a parametrization in HBM until now, we left out these treatments in our survey. Briefly, balance calculation according to VDLUFA is based on static parameters on the impact of production systems of different crop categories (e.g. legumes, cereals, row crops) on organic matter demand, and on parameters on effective OM supply of different organic inputs. The VDLUFA method is a typical agronomical HBM that is not sensitive to site impacts or changes in effect size over time (approximation to steady state). HU-MOD-2 calculates humus balances based on a coupled quantitative C and N balance of the soil-plant system. In order to avoid the demand for comprehensive soil data, N uptake of crops is used as a proxy of N release in OM mineralization. The contribution of other N sources and potential N losses are considered as site-dependent processes in the calculation.

We assume that:

SOMchange = f (environmental site conditions, initial SOM level, management) *(eq.1)*

From a methodological point of view, quantification of SOM level changes thus is dependent on a sensitivity of a HBM to these drivers. Further, the ability to quantitatively analyze the impact of management on SOM levels requires that a method is able to aproximate steady state under a continuous treatment over time. Most 'agronomical' methods do not or insufficiently fulfill these criteria, and can therefore not be applied to quantify SOM changes. Yet, if we assume that environmental site conditions and initial SOM levels to be constant at a defined spatial unit, than eq. 1 becomes

SOMchange_defined site = management + constant site impact *(eq.2)*

Under these conditions, SOM change can be related to 'agronomical' humus balances.Even though it is still not possible to interpretate humus balances quantitatively, HBM should be able to differentiate between management scenarios with regard to their impact on SOM levels. Substituting space for time, we evaluate HBM by their ability to reproduce the variation of SOM levels between treatments in the long-term field experiments.The evaluation criterion is that balances are positively correlated with SOM changes.

3 Results

Figure 1 shows the correlation between humus balances and SOM dynamics in the OAFEG and Darmstadt. Both HBM succeed in differentiating treatments in the OAFEG, even though the absolute deviation between balances and SOM changes were different for the methods. HU-MOD-2 balances were comparably close to SOC and STN change values, while VDLUFA succeeded in differentiating the treatments without a close quantitative link to SOM changes. This situation is in compliance with the considerations in the material and methods section. At Darmstadt, both methods, again, were able to differentiate the treatments. The quality of the method performance was much lower than in the OAFEG, though. At Darmstadt, HU-MOD-2 considerably overestimated the effective OM supply to soils. In the experiment, decreasing SOM levels can be observed despite of comparably high OM inputs.

This may be due to a very pronounced differentiation of SOC levels already in the first crop rotation cycle (Abele 1987). As the sandy soil in the Darmstadt experiment has a low capacity for SOC stabilization, OM applications increased turnover much stronger than the retention of C and N in soil organic matter (Heitkamp et al. 2011).

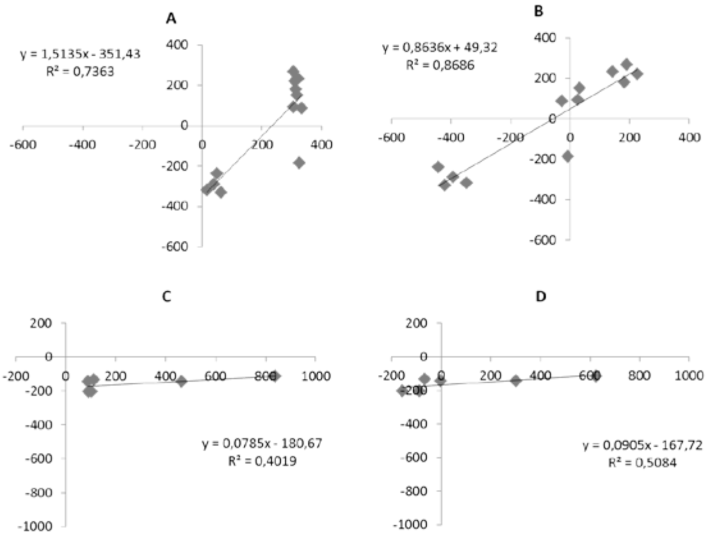

Figure 1 Relation between humus balances (*x, kg SOM-C or 'humus equivalents'* $ha^{-1}a^{-1}$) according to VDLUFA (A,C) and HU-MOD-2 (B,D) and SOC change (*y, kg SOM-C* $ha^{-1}a^{-1}$) in the OAFEG (A,B) and Darmstadt (C,D) long-term field experiment.

4 Conclusions

Humus balance methods can only quantitatively assess SOM level changes if they are sensitive to environmental drivers of OM turnover in soils. Still, HBM that are only sensitive to management (which lowers data demand and thus improves applicability in practice) can be used to analyse the relative impact of different management scenarios on SOM dynamics at a defined site on an ordinal scale (negative/no/positive impact). However, the tolerance (error) of predictions has to be defined, which requires a more comprehensive evaluation of HBM in (long-term) field experiments.

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