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CARBON BALANCE AND ECONOMICS: TRADE-OFFS OR SYNERGIES IN THE CASE OF ANAEROBIC DIGESTION OF CEREAL STRAW?

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Abstract: *Straw is known to crucially contribute to the carbon supply of arable soils, essential for long-term soil fertility and productivity. However, straw also has become an important commodity for material or energetic utilization. A complete straw removal from the field may threaten carbon reproductive capacities and soil fertility. In anaerobic digestion, the carbon is partially returned to the field via digestate, potentially avoiding negative priming effects of carbon depletion or nitrogen immobilization by the wide C:N-ratio of undigested straw. The article at hand evaluates the anaerobic digestion of straw compared to leaving it on the field with regard to carbon dynamics and economic performance in stockless organic farming systems based on scenarios for different soil-climate conditions in Germany. Assuming justified yield increases by integrating a spatio-temporal flexible fertilizer (biogas digestate) into stockless organic farm systems, both carbon stocks as well as economic revenues may be improved, regardless of soil or climatic conditions and despite higher logistic costs. Thus, straw removal, subsequent anaerobic digestion as well as return of biogas digestates may be able to contribute to both preserving soil functions as well as economic sustainability.*

Introduction: Considering changing political framework conditions (in Germany) straw has become an attractive commodity for energetic use, e.g. in anaerobic digestion. Likewise, straw is seen as one of the most important field residues for carbon replacement and securing soil organic carbon and therefore long-term soil fertility (Powlson et al. 2008). In contrast to the complete removal from the agricultural system by material use or combustion, part of the carbon is returned to the field when used in anaerobic digestion. Instable carbon compounds are turned into methane during anaerobic digestion, however, stable carbon fractions are not degraded and are returned to the field via digestate to foster buildup of soil organic matter (Six et al. 2002). Moreover, reducing the amounts of easily degradable carbon compounds also reduces microbial priming effects to decompose humified carbon fractions (Fontaine et al. 2003). In addition, the high carbon content of straw leavings may immobilize large amounts of nitrogen inavailable for plant nutrition (Johansen et al. 2013).

In order to analyze the conflict of objectives of straw utilization the project SOMenergy (Maintaining soil organic matter levels in arable farming with straw removal for bioenergy production, FKZ 22408412 and 22402914, 2016-2019) analyzed carbon dynamics as well as economics of straw logistics and utilization. In addition, an integrated humus balance and economic analysis for model crop rotations in two scenarios (straw leaving on the field; straw anaerobic digestion) was conducted.

Material and methods: Based on expert knowledge from science, agricultural counselling and practitioners, model crop rotations were developed for different soil and climate conditions (table 1). The crop rotations were analyzed regarding two straw management strategies, *a. leaving the straw on the field* and *b. straw anaerobic digestion and return of digestates to the field*. In scenario b. straw was co-digested with solid chicken manure to enable proper digestion functioning. In order to exclude impacts from manure fertilization, stockless farm types without any fodder-manure-cooperation were assumed.

Figure 1: Cropping proportion of various crop groups in the basic crop rotations of different soil/climate conditions

Humus balancing was carried out with the model HU-MOD (Brock et al. 2012, Knebl. et al. 2015) (kg C ha^{-1} a^{-1}). The HU-MOD model was adapted to fit carbon dynamics from data collection of field and lab trials in the SOMenergy project. The economic assessment is based on the net return (€ ha^{-1} a^{-1}) and includes costs and performances of cropping (market performance, direct costs, variable and fixed machinery and labour costs), as well as straw and digestate logistics and costs and income from straw digestion (scenario b). The straw digestion scenario considers conservatively assumed 10 % yield increases of non-legume cash crops due to increased availability of mobile nitrogen fertilizer as well as improved synchronization of nutrient demand and provision (e.g. Siegmeier et al. 2015).

Results: Regarding the different environmental conditions, the anaerobic digestion of straw in all cases leads to improved carbon balances as well as enhanced economic results (Figure 1).

Figure 2: Calculated carbon balance (kg C ha^{-1} a^{-1}) and net return (€ ha^{-1} a^{-1}) of two alternative straw management practices (a. straw leaving in field; b. straw anaerobic digestion) for different model crop rotations in various soil and climatic conditions (loamy sand, luvisol, rendzina).

Based on the carbon modelling two reasons for the positive impact of straw anaerobic digestion on organic matter supply of soils could be identified: narrowing of the C/N-ratio in the fermentation process as well as a supply of organic matter high in nitrogen content (dried chicken manure) as co-substrate in the biogas scenarios. As organic arable systems are usually N-limited systems any supply of nitrogen from external sources leads to an increase of N-dependent system processes. This includes both the turnover as well as the buildup of soil organic matter by a more efficient utilization of organic substrates. Nitrogen deficiency does not only have a yield depressing effect on cash crop yields but also crucially impacts the efficiency of microorganisms building up soil organic matter. Therefore, despite of presumed yield increases in the displayed scenarios entailing higher N exports, the increased N supply in the biogas scenarios has a positive effect on soil organic matter supply. Soil organic matter balancing therefore indicates a favourable option of straw utilization in anaerobic digestion.

The anaerobic digestion of straw enables especially stockless farms the utilization of liquid/solid manures, which is very likely to improve both harvest yields and economic results of crop rotations. Despite additional costs for straw and digestate logistics as well as costs for power generation via anaerobic digestion, financial surpluses may be generated by power and heat sales from straw digestion for most analyzed scenarios (few scenarios with low yield potential and specific crop constellations display higher additional costs than revenues). The more advantageous the respective site conditions (soil, climate, yield potentials), the higher are also the economic benefits from straw digestion. This is due to the fact that increased yields lead to higher straw input for anaerobic digestion and the respective biogas/methane potentials.

Discussion: Based on the assumptions for the presented model crop rotations in the displayed scenarios no conflicts of objectives between carbon supply of soils and economic feasibility can be detected when using straw in anaerobic digestion. Thus, an optimization of humus management is realizable from an interdisciplinary point of view. Despite the extraction of part of the carbon via methane in the power-generating process, an optimized carbon balance combined with increased economic results seem viable. This can especially be attributed to an improved nitrogen availability as well as an avoided nitrogen lockout due to the application of a fertilizer (digestate) with a closer C:N-ratio, better matching most soil conditions than undigested straw with a very wide C:N-ratio.

However, a comprehensive sustainability assessment of the ecologic effects of straw use options is not feasible based on humus balancing alone. From the presented results it cannot be deduced that the energetic straw use in anaerobic digestion also represents the ecologically most favourable option. In order to come to a better understanding of the involved soil function processes, future research must therefore thoroughly analyze the multiple ecologic effects of straw leaving or removal from the field.

References: Fontaine, S., Mariotti, A., Abbadie, L., 2003. The priming effect of organic matter: a question of microbial competition? Soil Biol. Biochem. 35, 837–843.

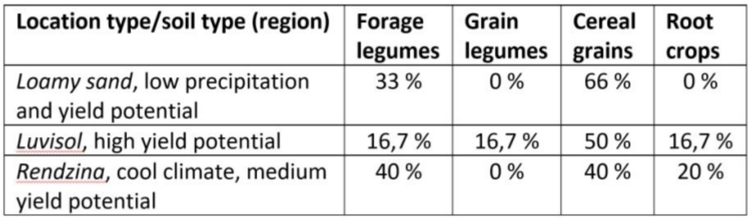
Johansen, A., Carter, M.S., Jensen, E.S., et al., 2013. Effects of digestate from anaerobically digested cattle slurry and plant materials on soil microbial community and emission of CO2 and N2O. Appl. Soil Ecol. 63, 36–44.

Powlson D.S., Riche A.B., Coleman K., Glendining M.J., Whitmore A.P., 2008. Carbon sequestration in European soils through straw incorporation: Limitations and alternatives. Waste Management 28, 741-746

Siegmeier, T., Blumenstein, B., Möller, D., 2015. Farm biogas production in organic agriculture: System implications. Agricultural Systems 139, 196-209

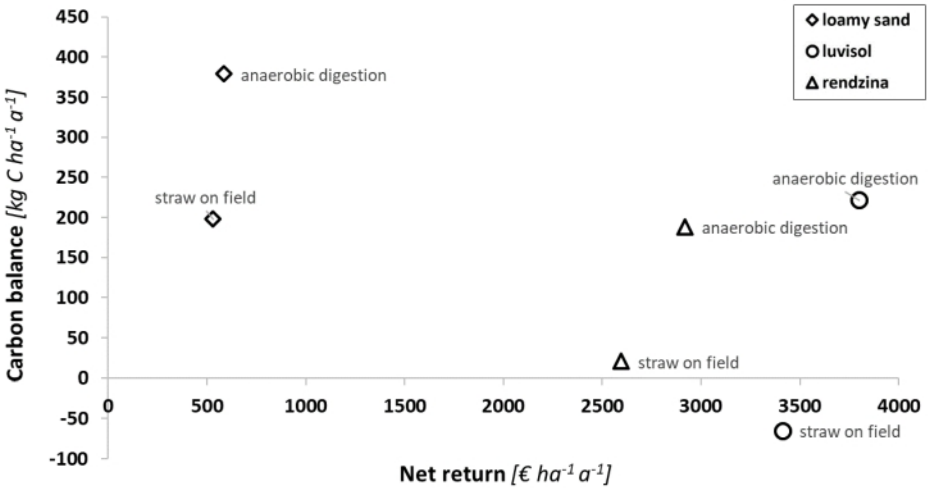
Six, J., Conant, R.T., Paul, E.A., Paustian, K., 2002. Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. Plant Soil 241, 155–176.

Image:



Location type/soil type (region)	Forage legumes	Grain legumes	Cereal grains	Root crops
Loamy sand, low precipitation and yield potential	33 %	0 %	66 %	0 %
Luvisol, high yield potential	16,7 %	16,7 %	50 %	16,7 %
Rendzina, cool climate, medium yield potential	40 %	0 %	40 %	20 %

Image 2:



Disclosure of Interest: None Declared

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