OPTIMIZE SOIL ORGANIC MATTER CONTENT IN RELATION TO STOCKING / ANIMAL DENSITY ON LIVESTOCK FARMS

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Description

The aim is to optimize soil organic matter (SOM or C_{org} = humus) conditions and esp. humus contents of the soils in respect to economical (➔ efficiency) , ecological (➔ consistency) and social (➔ sufficiency) aspects of agricultural biomass production esp. for feed, food and energy.

Applicability

The measures aim to optimize soil organic matter (SOM) conditions in respect to decomposable SOM_{dec} contents (i.e. hot water soluble SOM_{hws}), thickness of the humus layer (on arable soils: tillage depth), qualities and SOM types as shown in **Tab. 1** for arable soils [4,5]. **Tab. 2** shows the classification and loamy soils in respect to decomposable SOM_{dec} (C_{hws} and N_{hws}) with common arable farming and average climate conditions. SOM balances (input minus needs) are the tools to enhance and maintain optimum SOM [2-7]. Those balanced optimum SOM / humus supplies are shown in **Tab. 3** with 22 long-term arable field experiments in Europe [1-5, 9-11]. It is very important that the optimum (and maximum) input of animal manure of 10 t ha^{-1} yr^{-1} correspond to a optimum (and maximum tolerable) animal density of 1 AU (500 life weight) per ha agricultural area with optimum C, N, P, K (and S) balances. 1 AU is sufficient for the healthy nutrition of 10 capita with animal food equivalent to 0.1 AU· $capita^{-1}$[2-5]. Only <10, <10, 32 and <8% of C, N, P, S input with organic matter (OM) is incorporated in SOM respectively and about 90, 70, > 0 and 96% are lost /emitted to the environment respectively **(Tab. 4)**. **Tab. 5** shows the environmental aspects of SOM management of agricultural soils related to the nutrients C, N, P, S affecting the natural (near) ecosystems by emissions of reactive C, N, P, S. In any case conversion of grassland to arable land and the intensive cultivation of organic soils like bogs and fens should be avoided, especially in respect to the enormous and long lasting (30-100 years) C, N, P, S emissions by those cultivation measures. Vice versa conversion of arable land to grassland retains C, N, P, S. Enrichment of soils with SOM over the optimum, shown in **Tab. 1 and 2,** and therefore not “sequestration” but retardation of C, N, P, S are more or less and earlier or later chemical time bombs (CTBs) of C, N, P, S.

Effectiveness, including certainly

Optimization of SOM and correspondingly of stocking densities on livestock farms are together with optimization of overall stocking rates (see factsheet) fundamental prerequisites to balance both economic (yield) environmental (esp. emissions of C, N, P, S) and social (human health) aspects within the entire sustainable nutrition system of agriculture with plant nutrition and animal nutrition, human nutrition and waste as well as wastewater management. These measures will be most effective in countries and agriculture with too high stocking densities (> 1 AU· ha^{-1}) and overall stocking rates (> 0.1 AU· $capita^{-1}$).

Time frame

Effect getting optimized SOM depends on the initial SOM levels of the soils. For instance in soils with too high C_{org}-contents (e.g. 1.44% in dm) it could continue about 30 years to get the optimum C_{org}-content (e.g. 1.29% C in dm) with a SOM/humus balance of ± 0 kg humus-C· ha^{-1} · yr^{-1} **(Fig. 1)** [12].

Environmental side-effects / pollution swapping

There are only positive and no negative side effects or pollution swapping from measures to optimize both SOM as well as stocking densities on livestock farms and overall stocking rates. Stocking densities will affect emission densities which are important for the emissions and their effects of C_{org}, DOC, (in)organic N, P and S to hydrosphere as well as NO and NH_3 to atmosphere and pedosphere, but not for the emission and effects of the climate relevant gases CO_2, CH_4 and N_2O.

Relevance, potential for targeting, administrative, handling, control

These options getting optimum SOM conditions and livestock densities are relevant for all fields where humus-C-status and livestock densities are far off from their optimums. They have only restricted relevance for the EU cross compliance (Article 5/EC No 1782/2003/ Annex IV) targeting only minimum humus-C-levels. The control of the SOM conditions must be done long lasting supported by humus balances within short time frames.

Costs: investment, labour

There are no additional labour costs or investments. But more agricultural area is needed if stocking densities are > 1 $AU \cdot ha^{-1}$ or overall stocking rates must be adjusted with corresponding reduced income for the farmer which should be compensated by corresponding higher prices for animal products with a tax levy model (see factsheet "Optimisation of overall stocking rates on livestock farms").

References

[1] Beuke, K. 2006. Überprüfung der Humusbilanzierung anhand von Dauerversuchen in verschiedenen Klimaregionen Europas. Diplomarbeit, Universität Trier, Fachbereich VI, Geographie/Geowissenschaften.

[2] Isermann, K. and R. Isermann. 2004. International conference "Nutrient Management": European Experiences and Perspectives" of the European water Association (EWA) during Aquatech Amsterdam, September 28-29, 2004 Proceedings, 139-158

[3] Isermann, K. and R. Isermann. 2004. Healthy human nutrition especially with animal food and optimised soil organic matter (SOM) as qualifications for sustainable nutrient management and soil use. Proceedings Eurosoil Congress, September 4th to 12th, 2004, Freiburg i.Br. (Germany) (www.bodenkunde.Uni-freiburg.de) abstract, 221.

[4] Isermann, K. 2006. Present and future needed EU and national legislation to optimise both soil organic matter (SOM) in agricultural soils and human nutrition. International Conference: "The role of long-term field experiments in agricultural and ecological sciences" and "Practical solutions for managing optimum C and N content in agricultural soils III. Czech University of Agriculture, Praha 6-Suchdol in June 22nd -24th, 2005. Proceedings 2006, 98-108

[5] Isermann, K. and R. Isermann. 2007. Role of (inter-)national legislation for the management of sustainable optimum soil organic matter (SOM) in agricultural soils. Abstracts International Workshop on practical solutions for managing optimum C and N content in agricultural soils IV, Prague 20th to 22nd June 2007, abstract, 26

[6] Körschens, M. 1998. Soil organic matter and sustainable land use. Advances in GeoEcology 31, 423-430

[7] Körschens, M., Weigelt, A. and Schulz, E. 1998. Turnover of soil organic matter (SOM) and long-term balances - Tools for evaluating sustainable productivity of soils. Z. Pflanzenernaehr. Bodenkd. 161 (4), 409-424

[8] Körschens, M. 2000. Carbon and nitrogen dynamics as well as nitrogen utilization in Dependence on soil texture. Conference at the Royal Swedish Academy of Agriculture

and Forestry April 12th 1999. Kungliga Skogs- och Lantbruksakademiens tidskrift 139, 43-58
[9] Körschens, M. 2008. The IOSDV-Series an important basis of climate relevant humus research. Conference International Society of Soil Fertility within the IUSS on 25th February 2008 in Rauischholzhausen, 31 p.
[10] Powlson, D.S.; Smith, P.; Coleman, K.; Smith, Jo U.; Glending, M.; Körschens, M. and Franko, U. 1998. A European network of long-term sites for studies on soil organic matter. Soil and Tillage Research 47, 263 – 274
[11] Rasmussen, P.E.; Goulding, K.W.T.; Browns, J.R.; Grace, P.R.; Janzen, H. H. and M. Körschens. 1998. Long-Term Agroecosystems Experiments: Assessing Agricultural Sustainability and Global Change. Science 282, 893 – 896
[12] Reinhold, J. 2008. Coherence of humus balance and humus contents on arable soils. Personal communication

Tab. 1: Optimum soil organic matter conditions (SOM or C_{org} = humus) of groundwater-remote sandy and loamy soils under common arable farming and average climatic conditions in Europe derived from 26 long-term field trials in Western Europe (Average yearly temperatures: 6-10°C, average yearly precipitation: 400 –800 mm)

(Körschens 1995/1997, Schulz 1997, Körschens and Schulz 1999, Isermann and Isermann 1999, 2003a-b, Isermann und Körschens 2001, Isermann 2002, 2003, Benbi et al. 2003; completed)

Individual parameters	*Respective optimum conditions of SOM*
1. Contents / Quantities 1.1 Total SOM	Total SOC= C_{org}: 0.7 % (sandy soil) up to 2.5% (black soil) dependent on the clay content (0.7-21%) Total SON= N_{org}: 0.07% (sandy soil) up to 0.25% (black soil) dependent on the clay content (0.7-21%)
1.2 Decomposable $SOM_{dec.}$ Hot water soluble SOM_{hws} (SOM thickness: 30 cm)	Decomposable SOC= C_{dec}: 0.4 (0.2-0.6)% = 16 (8-24) $t \cdot ha^{-1}$ => C_{hws}: 25-30 $mg \cdot 100$ g soil $matter^{-1}$ Decomposable SON= N_{dec}: 0.04 (0.02-0.06) % =1.6 (0.8-2.4) $t \cdot ha^{-1}$
1.3 Mineralised SOM_{min} (e.g. Central Germany: 4% of SOM_{dec})	Mineralised SOC= C_{min}: 680 (320-960) $kg \cdot ha^{-1} \cdot a^{-1}$ Mineralised SON= N_{min}: 68 (32-96) $kg \cdot ha^{-1} \cdot a^{-1}$
2. Thickness (tillage depth)	<35 (e.g.: black soil) up to > 20 cm (e.g. sandy soil)
3. Qualities: 3.1 SOC/SON= C_{org}/N_{org} 3.2 SOC/SOS= C_{org} / S_{org} 3.3 SOC/SOP= C_{org} / P_{org}	 10/1 (> 8/1 up to < 12/1) 100/1 (> 70/1 up to < 140/1) 150/1 (> 100/1 up to < 200/1)
4. Types	raw humus ➔ moder ➔ mull
5. Maintenance of optimal SOM balance (Mineralisation = Immobilisation)	2 t reproduction-efficient organic susbtance (ROS) $\cdot ha^{-1} \cdot a^{-1}$ = stable manure / liquid manure of 2 t of dry matter / 10 t of raw mass farmyard manure from 1 gross weight unit (GWU) or 1 life weight heavy lifestock unit (LFU) of 500 kg life weight (LW) re0518

Tab. 2: Classification and assessment of groundwater-remote sandy and loamy soils in respect to decomposable SOM_{dec} (C_{hws} and N_{hws}) with common arable farming and average climate conditions (Average yearly temperatures: 6-10°C; average yearly precipitation: 4 00-800 mm)

(Körschens and Schulz 1999, completed by Isermann 2007)

Classification of soils	**C_{hws} 1) [mg (100 g)$^{-1}$] (Körschens and Schulz 1999)**	**N_{hws} 1) [mg (100 g)$^{-1}$]**	**Assessment**
1. very low	**< 20**	**< 2.0**	**Negative consequences for soil functions and yields and low efficiency of C, N, P, S**
2. low	**> 20 – 25**	**> 2.0 – 2.5**	
3. medium = optimum 2)	**> 25 – 30**	**> 2.5 – 3.0**	**Optimum in respect to safety of yields with low risks of losses / emissions and high efficiency of C, N, P, S**
4. high	**> 30 – 40**	**> 3.0 – 4.0**	**Negative consequences for yields and enhanced risks of losses /emissions and low efficiency of C, N, P, S**
5. very high	**> 40**	**> 4.0**	

1) According to the well-known enormous variability, tolerances of ± 50% can be accepted
2) Therefore e.g. optimum amounts of farmyard manure are 10 $t \cdot ha^{-1} \cdot yr^{-1}$ equivalent to 1.0 Animal Units (1 AU = 500 kg life weight)

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Tab.3: Balanced optimum humus supplies [t farmyard manure (fym) · ha^{-1} ·yr^{-1}] for the optimum variant with combined organic and mineral fertilization of 22 long-term arable field experiments in Europe
[Clay content of soils: 3-27%; average yearly temperatures: 6-14,5°C and precipitation: 430-1397 mm]
(according to Koerschens 2008, Beuke 2006)

Location (Country)	Starting year	Number of years	Humus supplies [t fym·ha^{-1}·yr^{-1}]	Location (Country)	Starting year	Number of years	Humus supplies [t fym·ha^{-1}·yr^{-1}]
Bad Lauchstädt (D)	1902/1978		10	12. Bad Salzungen (D)	1966	40	10
Methau (D)	1966		10	13 Puch (D)	1983	12	10
Spröda (D)	1966		10	14. Berlin(Dahlem) (D)	1984	12	10
Müncheberg (D)	1982		8	15. Dülmen (D)	1984	11	<10
Braunschweig (D)	1952		10	16. Dikopshof (D)	1904	n.d.	12
Groß Kreutz (D)	1967		10-15	17. Madrid (E)	1985	15	0 (7)
Thyrow (D)	1938		10	18. Livada (Ro)	1961	10	10
Speyer (D)	1958/1983		15	19. Wien (A)	1986	12	10
Seehausen (D)	1966		12	20. Jable (Slo)	1992	10	<10
Halle (D)	1949	10	<10	21. Rakican (Slo)	1992	10	<10
Rauischholzhausen(D)	1984	9	<10	22. Keczthely (Hu)	1984	9	<10
				Average (1-22)	**1902/1986**		**10**

ese average values correspond to a yearly optimum (and maximum) input of animal manure of 1 Gross weight unit (GWU= LWU= AU) of) kg life weight (LW) per ha agricultural area, in respect to optimum C, N, P, K balances and sufficient for the healthy nutrition of 10 pita with animal food corresponding to 0.1 GWU · capita^{-1} (Isermann and Isermann 1999/2008)

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Tab.4: Balance of the nutrients C, N, P, S and their efficiency in SOM incorporation by the input of organic matter (OM) e.g. by farmyard manure (FYM)
(average values)

Balance	**Nutrients (% or kg· ha^{-1} · yr^{-1})**			
	C	**N**	**P**	**S**
A) Input of OM (e.g.FYM) into the soil	100[1)]	100[1)] (Excretion: 156)	100	100
B) Output with OM (e.g.FYM)	100	100	100	100
1. Yield (Net)	-	30	20 (long term<100)	4
2. Environment …off it:	**> 90**	**> 70**	**80 (long term > 0)**	**< 96**
2.1 Soil: **2.1.1 % in organic fraction** (Schröder 1969)	< 100	> 98	40 (25-60)	80 (60-95)
2.1.2 SOM: Efficiency of C, N, P, S incorporation	**< 10**	**< 10**	**32**	**< 8**
2.2 Atmosphere	> 90 (CO_2 >> CH_4)	20 [1)] (N_2> N_2O < NO)	< 0.5 (wind erosion)	< 1 (wind erosion)
2.3 Hydrosphere	< 1 (DOC)	40 (NO_3^->NH_4^+~ DON)	< 1 (Inorg. P>> DOP)	95 (SO_4^{2-}>>DOS)

1) Additional losses e.g. of N by volatisation of ca. 56 kg NH_3-N · ha^{-1} · yr^{-1} in housings, during storage and application of FYM

➔ - Only about <10, <10, 32 and <8% of C, N, P, S input with OM is incorporated in SOM respectively
- and about 90, 70, > 0 and 96% are lost / emitted to the environment respectively:
➔ Avoidance of not tolerable inputs of OM, especially of OM with close C:N:P:S relations , (straw better then FYM)

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Tab. 5: Environmental aspects of SOM management of agricultural soils related to the nutrients C, N, P, S

Environmental aspects affecting natural (near) ecosystems	Involved Nutrients			
	C	N	P	S
1. Source aspects 1.1 Acidification: a) Terrestrial and (semi-) subhydric soils b) Groundwater and surface water	CO_2 Changes: ➢ Woodland ➔ grassland ➔ arable land (esp. fire clearing) ➢ Grassland ➔ arable land	NH_3 > NO	-	SO_4
1.2 Eutrophication: a) Terrestrial and (semi-) subhydric soils b) Groundwater and surface water	CO_2 -	NH_3 > NO NO_3	(In)Organic P	-
1.3 Climate change	CO_2 CH_4 Reduced CH_4-Oxidation by NH_3	N_2O Indirectly: NH_3 > NO	-	-
2. Sink aspects 2.1 Sequestration 2.2 "Retention", Retardation (Emission delays)	- SOM - C	- SOM - N	- SOM - P	- SOM-S

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Fig. 1

Tab. 5: Adjustment of flowing C-equilibriums with different humus balances on arable Fields with previously t high humus contents (Humus balance: + 400 kg humus-C/ ha · yr) (Reinhold (2007)