This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 289694.

SmartSOIL FACTSHEET

BOOSTING SOIL ORGANIC MATTER CONTENT BY APPLYING MANURE AND COMPOST

WHAT IS IT?

Organic fertilisers, including cattle manure, pig slurry, poultry manure, biogas digestate and compost, provide valuable nutrients (in the form of N, P, and K) to enrich the soil organic matter content and enhance soil quality.[1] Applying organic fertilisers on the farm can reduce the need for mineral fertilisers while also stimulating crop growth and improving crop performance. When spread in optimum amounts at the appropriate time, manure and compost can offer a less expensive and effective alternative for nutrient management on the farm.

WHAT ARE THE BENEFITS?

- Enhanced soil nutrient composition, soil productivity and structure
- Reduced inputs (primarily mineral fertilisers) and therefore lower costs
- Increased crop growth and potential yield improvements
- Closing mineral cycles on farm (or regional) level

Soil quality

Soil quality refers to soil attributes, soil functions and to the associated services delivered by soils. The soil quality may be described in terms of chemical, physical and biological properties. These characteristics determine the soils functions in terms of water and nutrient supply to plants as well as providing the physical and biological environment to reduce crop stresses and losses from diseases and pests. Soil quality therefore contributes to a range of ecosystems services that include sustaining crop yield, buffering water, recycling nutrients, reducing emissions of greenhouse gas and pollutants.

Soil Quality Enhancement

Manure and compost are important resources for improving and maintaining soil quality and productivity. Manure, in particular, readily provides essential nutrients for crop growth and also adds soil organic matter (SOM) to soils, improving soil organic carbon (SOC) both in the short and long term.

Both manure and compost contribute to improving and maintaining soil structure, increasing the ability of the soil to retain moisture and water infiltration, which improves drought and flood resilience and helps prevent compaction and crusting. Improved soil structure helps to stabilise the soil as well, lessening erosion and run-off.

Reduction of Inputs

Proper manure management and compost application offers potential economic benefits. Particularly if manure is readily available either on the farm or locally from a nearby livestock farmer, manure and compost can provide valuable resources as nutrient-rich inputs.

If manure or compost is strategically applied, purchasing additional inputs of mineral fertilisers may not be necessary or require lower quantities, resulting

Co-benefits

Type of benefit	Size of effect	Type of effect
Promote soil biodiversity	+	Increases soil nutrient content and organic matter. Enhances microbial activity.
Erosion protection	+	Manure reduces the risk of soil erosion by creating a protective layer and stimulating plant growth.
Prevent nutrient leaching (N, P)	0/--	Manure application can substantially increase N and P losses (both immediately and over time due to building soil nutrient pools), which necessitates proper application with appropriate quantities and techniques as well as timing.
Reduce soil emissions (nitrous oxide and ammonia)	+/-	Depends on application and type of manure, but nitrous oxide emissions may be 1) enhanced due to more degradable C that fuels denitrification or 2) decreased over the long term due to improved soil structure.
Promote above ground biodiversity	+/0	No significant effect observed for manure, but adding compost increases the microbial community that may help with nutrient provision as well as disease and pest suppression.

Legend: ++ maximum positive effect, + positive effect, 0 no effect, - negative effect, -- maximum negative effect

in cost savings. Manure nutrient content needs to be assessed to appropriately match soil nutrient availability and timed with the appropriate crop growth stage and in calculated amounts to match the plants' nutrient needs.

Potential yield improvement

Especially where soil is poor or degraded, adding manure or compost provides an economical alternative to mineral fertilisers and helps to build SOM and SOC.

Improvements in soil quality due to manure or compost application have been shown to boost soil productivity and stimulate crop growth rates, resulting in potential yield improvements. Among SmartSOIL case studies, it was observed that farmers in Hungary growing winter wheat and maize who applied animal manure saw a net increase (up to 85%) in yield on their farms. Various scenarios from across Europe have also shown that, on average, a yield gain of 22% may result from manure application (though conservative estimates have also shown that a reduction of 9% is possible).

Soil organic carbon (SOC) in soil organic matter (SOM)

SOM is composed of plant residues and microorganisms which breakdown and transform organic materials. This decomposition process produces or modifies SOM and increases SOC stocks in the soil. The process, which removes carbon dioxide from the atmosphere and adds carbon to the soil (via plant photosynthesis and decomposition and transformation), is called soil carbon sequestration. The amount of SOC gained depends on location (due to climate), crop productivity and crop type, amount of roots, crop residue and soil management.

More carbon benefits the formation of soil structure (stable aggregates) and results in: better aeration, more water availability, lower bulk density, friability and improved drainage. These in turn aid soil workability, reduce soil compaction and enhance infiltration capacity, thereby reducing run-off and erosion.

DRAWBACKS

Implementation of this measure may have a significant impact on whether the nutrients are harnessed and SOM is built or manure and nutrients are lost through leaching, emissions and run-off. The heavy machinery used to spread and incorporate the manure may increase the risk of soil compaction and thereby cause potential yield losses. Timing application to match the crop growth stage as well as determining soil nutrient levels and plant needs is crucial. High ammonia volatilisation may occur if manure is not incorporated or worked into the soil within less than 6 hours after application. Injecting cattle slurry may reduce soil disturbance but it may also cause higher nitrous oxide emissions.[2] Additionally, failing to incorporate shortly after application may cause run-off losses due to rainfall, and run-off may also occur if manure is applied during periods of frost, on frozen ground, before heavy rains, or on saturated ground. Application must be avoided during those times to comply with the Nitrates Directive.

Losses of ammonia may also result from storing and composting manure; thus, closed systems are recommended.[3] Proper composting management is required to avoid creating anaerobic conditions within the piles, including regular aeration. Modifying the C:N ratio may also be possible and allow for reduced environmental impacts, but this requires more time and labour as well as technical knowledge. For example, application of manure containing too much straw may enhance the C:N ratio and reduce the N available for uptake. Over-application of manure or compost could also cause environmental pollution issues due to losses of excess nutrients leached to groundwater or through run-off to water ways.

Relationship between SOM/SOC, N fertiliser and water

N fertilisers and irrigation can help SOM (SOC) accumulate through increased crop production (increased organic input to the soil primarily through more root biomass and crop residues). The extent of the effect depends on having appropriate management in place (choice of tillage, cropping system, rotation), soil type, residue quality and on the response to weather and climate. In particular, fertilisation can help SOM accumulate in soils with low SOM levels and in poorly drained soils. Efficient N management is important and can lead to reduced emissions per unit of produce. However, irrigation combined with fertilisation or poorly timed irrigation may increase emissions, particularly of N_2O, and losses of N require additional fertiliser input later on.

Manure application can affect the need for fertilisers

If manure and fertiliser are applied in combination, less N fertiliser may be needed to support crop production. A nutrient management plan will help optimise nutrient additions as well as reduce the risk of over-application of N and of losses through leaching and emissions to air. Reducing applications by enhancing resource use efficiency also reduces a farm's operational costs.

WHAT ARE THE COSTS?

Implementation costs and cost-savings*

Type of costs	Description of costs	Region				
		Italy Avg (€/ha)	Hungary Avg (€/ha)	UK Avg (€/ha)	Poland Avg (€/ha)	Spain Avg (€/ha)
Investment costs		0	0	**0**	**0**	**0**
Operational costs	Application on the field and incorporation Fuel costs for tractor passes Increased labour and time to handle and store manure or maintain compost	75	75	**75**	**75**	**75**
Other costs		0	0	**0**	**0**	**0**
Cost-savings	Avoided or reduced purchase of mineral fertilisers	-112.2	-81.6	**-164.6**	**-145.7**	**-157**
Total		**-37.2**	**-6.6**	**-89.6**	**-70.7**	**-82**

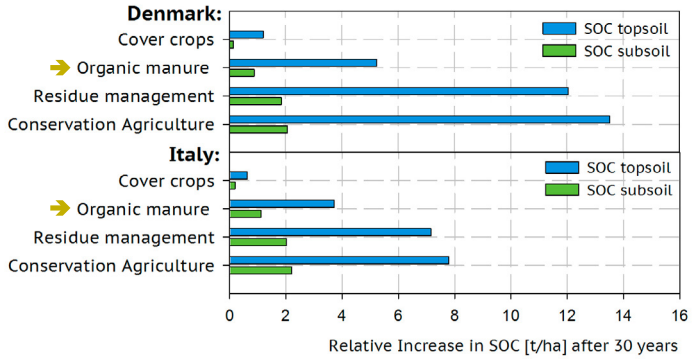
Calculations are based on data from EU Member States (FADN, SmartSOIL case studies, Natural Water Retention Measures project, 2014)
**Calculated based on data from EU Member States (FADN, SmartSOIL case studies, 2014)*

Impact on gross margin

As seen from the country calculations above, gross margin can significantly increase from adding manure due to the cost-savings from less mineral fertiliser application. These would also contribute to changes in gross margin, which will likely far outweigh the costs of manure or compost application and handling. It is important to note that the estimates in the table above are general for the case study regions. The exact magnitude of change in gross margin depends on a variety of factors that are regionally specific, including the availability of manure, the technique used for manure application, and costs associated with manure storage.

In determining average values for the EU, gross margin impacts depend on whether high, middle or low yield scenarios are considered. The range of outcomes shows that adding manure may increase gross margin by as much as 228.40 €/ha or decrease gross margin by 21.30 €/ha, but on average it is estimated that gross margin will increase by 64.60 €/ha.

IMPACT ON SOC AND NITROGEN INPUT



	Denmark	Italy
SOC (0-100 cm) [t C/ha]	6,1 (7,2%)	4,8 (7,0%)
Productivity [t/ha]	0,1 (1,3%)	0,06 (0,8%)
Optimal N-rate [Kg N/ha]	-2 (1,6%)	-4 (4,3%)
Change in need for N-input [Kg N/ha]	-3,5	-5,4

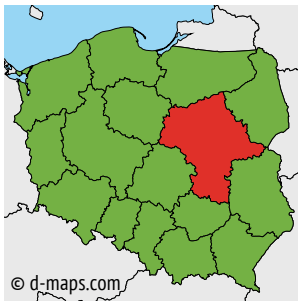
*The SmartSOIL Simple Model shows that **adding organic manure** increases topsoil SOC levels over 30 years. However, the graph shows that even higher levels of SOC can be achieved by retaining crop residues and the highest by combining the practices under conservation agriculture. The table gives an overview on changes which are expected from adding organic manure (compared to the reference scenario/ business as usual) using the regional examples of Denmark and Italy. Gains in SOC from adding organic manure can be observed in both regions. Small productivity increases may result, but importantly, less N input would be necessary. The optimal N rate is lower due to adding organic manure, which means the N level where the highest yield is achieved decreases and adding more N will not increase the yield response. In consequence, costs can be saved through lower N input. It is important to consider that the impacts vary among the regions according to their specific conditions.*

WHAT DO FARMERS SAY?

Farmer from Mazovian Voivodeship, Poland
Farm system: Arable (maize, wheat, rape, lupin)
Farm size: 220 ha

JAN RYKALSKI

"Thanks to using manure, I could reduce the amount of mineral fertiliser I applied by half in two years.



What are the benefits you have gained from using this practice?
Organic fertilisation has positive impacts in both the short and long term. Without it I would not be able to maintain such high yields for such a long time. Fertilising with manure has boosted my yields by about 30%, with the greatest benefit seen on the worst quality soils. I can now cultivate more demanding plants thanks to organic fertilisation.

What challenges have you faced in applying manure?
In the case of organic fertilisation on this farm, the biggest problem is getting the organic fertiliser. I use chicken manure and pig slurry because that's what is available locally. I get them free of charge from the owners of local chicken farm and pig farm. This helps them deal with their surplus of manure, creating a win-win solution.

REFERENCES

(1) Taghizadeh-Toosi, A., Christensen, B.T., Hutchings, N.J., Vejlin, J., Kätterer, T., Glendining, M., Olesen, J.E. (2014) C-TOOL: A simple model for simulating whole-profile carbon storage in temperate agricultural soils. Ecological Modelling 292: 11–25.

(2) Möller, K. and Stinner, W. (2009) Effects of different manuring systems with and without biogas digestion on soil mineral nitrogen content and on gaseous nitrogen losses (ammonia, nitrous oxides). European Journal of Agronomy 30: 1–16.

(3) Jiang, T., Schuchardt, F., Li, G.X., Guo, R., Zhao, Y.Q. (2011) Effect of C/N ratio, aeration rate and moisture content on ammonia and greenhouse gas emission during the composting. Journal of Environmental Sciences 23: 1754–1760.

For more detailed information about the practice implemented, benefits, and economic data, please refer to the Real-Life Cases in the SmartSOIL Toolbox:
http://smartsoil.eu/smartsoil-toolbox

Photos | P.1: © Gunnar Assmy/Fotolia.com; P.3, 4: © Zbigniew M. Karaczun