A photograph of young corn plants in a field, with the plants in the foreground in sharp focus and the background slightly blurred. The plants are green and appear to be in the early stages of growth.

SmartSOIL FACTSHEET

RESIDUE MANAGEMENT: IMPROVING SOIL ORGANIC MATTER AND REDUCING SOIL EROSION

WHAT IS IT?

Crop residues are materials usually not taken away but rather left in a field or orchard after the crop has been harvested. They include stalks, stubble, leaves, roots and seed pods. Some crop residues are removed from the land to be used as straw in stables, as animal feed or as a source of energy and may or may not be returned to the land later (e.g. with manure). Crop residues remaining on the land supply additional SOM (SOC) to the soil, improving soil structure, root system development and plant growth. Additionally, residues kept at the surface will be less disturbed by using reduced tillage and they can help to reduce erosion and surface soil evaporation (the residues act as mulch).

WHAT ARE THE BENEFITS?



- Enhanced soil organic matter content
- Reduced soil erosion and slaking of soils
- Improved water infiltration and plant establishment
- Potential yield improvements

Soil Quality Enhancement

Residue incorporation can improve soil organic matter (SOM) and biodiversity which is key to maintaining soil structure. The contribution of crop residues to soil organic matter differs per crop. Crop residues high in carbon and low in nitrogen are usually less easily broken down than crop residues with relatively less carbon, e.g., grass-clover cuttings.

Reduced soil erosion and capping/slaking

Leaving crop residue on the field offers a layer of protection over the soil, which might otherwise be bare. The residue reduces the impact of wind and water causing soil erosion as well as soil capping or slaking, which may occur on finer soils.

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.

Improved water infiltration and plant establishment

Residues help to retain water on the soil, and by improving soil structure, they can improve water infiltration and storage in the soil. This is particularly important for cropping systems in drier climates. They also improve soil tilth, which aids root systems' development and therefore plant growth. This is particularly important for cropping systems in wetter climates. Residues offer protection through critical plant establishment phases.⁽²⁾

Co-benefits

Type of benefit	Size of effect	Type of effect
Erosion protection	+	Improved soil structure and cover to prevent wind and water erosion
Promote soil biodiversity	+	Promotes presence of earthworms and improves soil fertility
Promote above-ground biodiversity	+	Improved soil fertility contributes to crop growth
Reduce soil emissions (nitrous oxide and ammonia)	+/-	The impact on both types of emissions depends upon the residue's C:N ratio
Prevent nutrient leaching (N, P)	+/- 0	The impact on nitrate leaching also depends upon the residue's C:N ratio but there is no effect on P leaching

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

Potential yield improvements

Residue management helps improve soil structure, tillage and water use efficiency, which can lead to yield improvements due to better crop establishment and nourishment.

DRAWBACKS

Incorporation of residues can increase nitrate leaching and nitrous oxide emissions from the increased amount of organic matter with mineralisable N and therefore net benefits in terms of climate mitigation may be highest when residues with high N content are removed. For example, vegetable brassicas, sugar beets and potatoes can produce between 100–300 kg N per hectare, but alternative residues with a high C:N ratio (e.g., mineral fibre, wheat straw) can be added to immobilise the N.⁽³⁾ Additionally, composting these residues and then returning them to the soil may reduce the resulting nitrous oxide emissions

compared to incorporating them untreated. Another agronomic barrier identified is that crop residues are difficult to utilise under certain/extreme weather conditions. The practice helps in the Mediterranean through water retention and storage; however, care should be taken in wet climates to prevent fungal diseases and slugs that may occur in surface residues.

Therefore, three types of residue management can be distinguished, which have different effects on the carbon and nitrogen contributed to the soil:

- Leave crop residues on the field instead of burning or removal
- Remove, process and return (e.g. via composting) crop residues
- Remove, process and exchange or trade crop residues with other fields, farms or regions in need of more carbon inputs

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.



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.

Residue management can affect the need for fertilisers

Residue retention can reduce the need for N fertiliser in the long term, although more N may be needed for the first few years of higher residue levels to offset N immobilisation. N fertilisation should be managed by site-specific assessment of soil N availability. If N fertiliser management is combined with removal of residues, this can exacerbate SOC loss. When combined with increased residue application levels, N fertiliser can be managed to avoid N loss through volatilisation or run-off (e.g. by placing fertiliser below the residue).

WHAT ARE THE COSTS?

Implementation costs and cost-savings

Type of costs	Description of costs	Region					
		Denmark Avg (€/ha)	Italy Avg (€/ha)	Hungary Avg (€/ha)	UK Avg (€/ha)	Poland Avg (€/ha)	Spain Avg (€/ha)
Investment costs		0	0	0	0	0	0
Operational costs	Potentially more labour if the residue is removed, processed and returned to the field	0	0	0	0	0	0
Other costs	Loss of income from selling straw or costs for animal feed if stop using as fodder	53.7	20.4	47.5	105.8	154.3	58.8
Cost-savings	Potential long-term reduced fertiliser and pesticide use and fewer passes over the field	0	0	0	0	0	0
Total		53.7	20.4	47.5	105.8	154.3	58.8

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

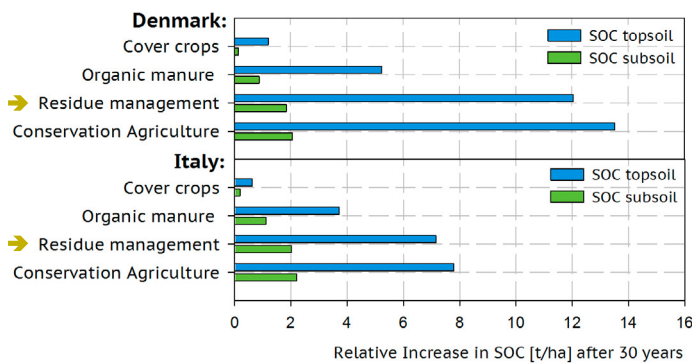
Impact on gross margin

As seen in the table above, there will likely be some short-term loss in gross margin if income is lost from not selling the residue (e.g., straw). Additionally, if the residue was being used as animal feed, alternative feed sources will have to be purchased if the residue is maintained on the field. It is important to note that the estimates in the table above are general for the case study regions. Depending on which option is chosen, there may be fuel and time savings with less passes over the field, but additional labour may be required to remove, process, and return residue to the field.

Long-term gains in SOC may result from retaining residues on the field, which could have positive yield impacts and thus benefit gross margins (see, for example, the Real-Life Case below). In determining short-term average values for the EU, however, the change in gross margin due to displacement of residues for sale or animal feed would be a decrease of around 53.60 €/ha.

This measure ensures the supply of organic matter on-farm and avoids the cost of bringing in extra off-farm organic matter. This is important where manure, for instance, is a scarce resource.⁽¹⁾

IMPACT ON SOC AND NITROGEN INPUT



	Denmark	Italy
SOC (0–100 cm) [t C/ha]	13,9 (16,3%)	9,2 (13,2%)
Productivity [t/ha]	0,2 (2,3%)	0,1 (1,4%)
Optimal N-rate [Kg N/ha]	-3 (2,5%)	-7 (7,6%)
Need for N-input [Kg N/ha]	-6,7	-8,7

The SmartSOIL Simple Model shows that **residue management** increases topsoil SOC levels over 30 years. However, the highest SOC gains can be achieved by combining the practice with cover crops and adding manure under conservation agriculture. The table gives an overview on **changes** which are expected from practicing residue management (compared to the reference scenario/ business as usual) using the regional examples of Denmark and Italy. High SOC gains from residue management can be observed in both regions. Small productivity increases may result, but importantly, much less N input per hectare would be necessary. The optimal N rate is lower due to residue management, 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?

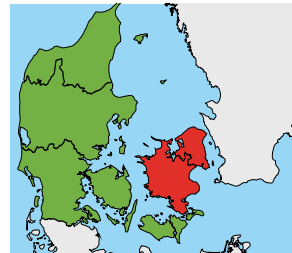
Farmer from Sjælland, Denmark

Farm system: Mixed farm (winter wheat, spring barley)

Farm size: 279 ha

BJARNE HANSEN

“Crop residues are rich in macro and micro nutrients and so residue retention and incorporation into the soil retained the essential nutrients to maintain the soil fertility.”



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What are the benefits you have gained from using these practices?

There is better soil structure, more soil organic matter and enhanced germination of grass and clover seeds, retention of phosphorus on-farm in the crop residues, better precipitation infiltration, reduced need for fungicides and higher number of earthworms and microbial activity. Due to better nutrient uptake,

I have maintained equivalent or higher yields compared to the conventional practice.

What challenges have you faced in implementing these practices?

Weed pressure is one of the issues, so I use glyphosate to eliminate the weeds well before the sowing period.

REFERENCES

- (1) SmartSOIL Deliverable 2.1
- (2) Residue Management Choices, A Guide to Managing Crop Residues in Corn and Soybeans, USDA Natural Resources Conservation Service and University of Wisconsin Extension. <http://clean-water.uwex.edu/pubs/pdf/residue.pdf>
- (3) Rahn, C.R., Bending, G.D., Turner, M.K., Lillywhite, R.D. (2003) Management of N mineralization from crop residues of high N content using amendment materials of varying quality. *Soil Use and Management* 19: 193–200.

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>