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SmartSOIL FACTSHEET
CONSERVATION AGRICULTURE: BUILDING SOIL ORGANIC MATTER AND REDUCING PRODUCTION INPUTS

WHAT IS IT?

Conservation agriculture is characterised by three principles[1]: i) Continuous minimum soil disturbance (minimum tillage) ii) Permanent organic soil cover (crop residues, mulches and cover crops); and iii) Diversification of crops grown (crop rotations, combinations). Conservation agriculture improves on-farm soil organic matter, providing nutrients for crops and helping stabilise soil structure. This practice can save time, labour and fuel inputs compared to conventional farming. Once established, conservation agriculture can reduce the need for fertiliser and pesticide inputs, whilst stabilising yields.[1]

WHAT ARE THE BENEFITS?

- Enhances soil quality and SOC
- Reduces inputs of pesticides and fertilisers
- Saves time, labour and fuel
- Potential to improve yields
- Reduces erosion

Enhances Soil Quality

Minimum tillage can increase soil organic matter (SOM) and soil organic carbon (SOC) in the upper layers of the soil. The effect depends on working depth, intensity of cultivation, and extent of soil inversion. Residue retention and cover crops can enhance SOC, improve above- and below-ground biological activity and biodiversity and soil structure. They also provide soil cover to protect against nutrient losses and enhance the supply of nutrients and moisture retention for the crops.[2]

Reduces input of pesticides and fertilisers

The concept of conservation agriculture is based on reducing the need for external inputs (water, fertiliser, pesticide). The use of pesticides and mineral fertilisers tends to decline to a level below that of the original "conventional" farming system once the farmer has learnt to manage the cropping system. Incorporating cover crops into the crop rotation is important to control pests and weeds as it interrupts the infection chain between subsequent crops.

> ***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.*

Saves time, labour and fuel inputs

Conservation agriculture involves a change in management and practice, but once established it can provide cost-savings in terms of operational costs. By not tilling (or reducing tilling) the soil, farmers can save between 30 and 40% of time, labour and fossil fuels as compared to conventional cropping.[1]

Potential to improve yields

Over the medium to longer term there is potential to increase yields and reduce yield variance. Reduced tillage improves soil structure, potentially enhancing

Co-benefits

Type of benefit	Size of effect				Type of effect
	Reduced tillage	Residue Mgmt	Cover Crops	Crop Rotation	
Erosion protection	+	+	+	+	Reduced soil erosion and run-off to water bodies by reducing soil disturbance and maintaining cover
Reduce soil emissions (nitrous oxide and ammonia)	+	+/-	+/0	0/+	Reduced tillage limits emissions by reducing N decomposition, which is supplemented by cover crops
Promote soil biodiversity	+	+	+	+	Enhances microbial activity and biological control of pests and diseases
Prevent nutrient leaching (N, P)	+/0	+/- 0	+/0	+/0	Reduced tillage decreases nitrate leaching but the residue's C:N ratio may cause negative impacts – leguminous catch crops may harness the N; there is no effect on P
Promote above ground biodiversity	0	+	+	+	Residues and cover crops provide

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

crop rooting and uptake of fertiliser. Evidence from SmartSOIL's case studies has shown this to be the case, with yields comparable to conventional agriculture, whilst improving long-term soil quality. Average calculations show that there may be a 20% increase in yields from cover crops, but a reduction of 10% is also possible. Minimum tillage may increase yields by 12% but a decrease of 8% is also possible.[3]

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.

Reduces erosion

Combinations of soil cover and minimum tillage encourage high water infiltration capacities, reducing surface run-off and thus soil erosion significantly. This improves the quality of surface water by reducing pollution from soil erosion.

DRAWBACKS

The benefits are long term. Applications of pesticides and fertilisers may need to be higher in the conversion phase and in the short term there may be yield declines. Additionally, the conversion phase involves a fundamental change in management which requires intensive learning and support. Depending on local conditions and residue management, conservation agriculture can potentially increase nitrous oxide emissions.

Reduced or no tillage requires special management suited to different climates: Mediterranean soils can suffer from water deficit, while in cool Northern European soils, lower yields can result. Additionally, benefits can be reversed if there is rotational ploughing due to weeds or compaction – which are common problems.

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.

Reduced tillage can affect the need for fertilisers

Reduced tillage can reduce the need for fertiliser. Ploughing the soil less (frequency, intensity and depth) reduces the rate of SOM (and N) decomposition. Sustaining higher levels of SOM enhances the long term availability of nutrients for crop growth. Reduced tillage improves soil structure, potentially enhancing crop rooting and uptake of fertiliser and controls erosion so avoids loss of SOM and N from the surface. When N fertiliser is combined with reduced tillage it leads to greater SOC accumulation than with ploughing.

WHAT ARE THE COSTS?

Implementation costs and cost-savings

Type of costs	Description of costs	Region											
		Denmark Avg (€/ha)				Poland Avg (€/ha)				Spain Avg (€/ha)			
		Residue mgmt	Cover/ catch crops	Min till	Crop rotation	Residue mgmt	Cover/ catch crops	Min till	Crop rotation	Residue mgmt	Cover/ catch crops	Min till	Crop rotation
Investment costs	Purchase of seeds for cover/catch crops	0	100	0	0	0	67.3	0	45.10	0	40.7	0	0
Operational costs	Extra passes on the field, time and labour to establish cover/ catch crops and for different types of tillage	0	22	43	0	0	21	77	33.80	0	0	73.4	0
Other costs	Loss of income from selling straw or costs for animal feed if stop using as fodder	53.7	78.2	0	0	154.3	0	0	0	58.8	0	0	0
Cost-savings	Potentially fewer passes over the field, reduced inputs, e.g. fuel, fertiliser, pesticides, labour	0	0	-89	-47.70	0	0	-159	-54.50	0	-25.5	-84.7	-33.20
Total		**53.7**	**200.2**	**-46**	**-47.70**	**154.3**	**151.9**	**-82**	**24.40**	**58.8**	**15.2**	**-11.4**	**-33.20**

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

Impact on gross margin

The practices which uphold the principles of conservation agriculture show varying results in terms of their impacts on gross margin. Reduced tillage typically results in a positive impact for gross margin due to the reduced inputs of fertiliser and pesticides, as well as less labour and fuel due to fewer passes over the field. These cost-savings will generally outweigh the operational costs that must be contributed in order to implement the different types of reduced tillage (e.g., direct drilling, non-inversion tillage). Crop rotation, cover/catch crops and residue management may result in varying costs for the operation due to the purchase of additional seeds and the loss of income from selling the residues or using them as livestock fodder. However, the results seen by the farmers featured in the Real-Life Cases in the SmartSOIL Toolbox demonstrate that conservation agriculture may provide significant benefits due to the increase in SOM, reduced nutrient losses and improved N and P efficiency, and improved workability and soil structure which can stabilise and potentially enhance yields. Cost-savings from reduced fertiliser and fuel use are part of the benefits as well.

In determining average values for the EU, gross margin impacts depend on whether high, middle or low yield scenarios are considered.

For **minimum tillage**, gross margin may improve by up to 164.80 €/ha under the high yield scenario, though the lowest yield estimate shows that gross margin could decrease by 5.30 €/ha. On average, gross margin would improve by 62.70 €/ha from implementing minimum tillage.

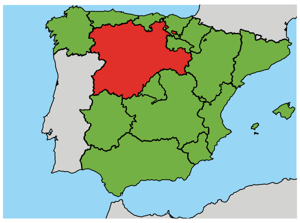
Incorporating **residue management** as a component of conservation agriculture will on average decrease gross margin by 53.60 €/ha due to the foregone income from selling the residue or needing to purchase livestock feed to replace the residue formerly used as fodder.

Adding cover/catch crops may increase gross margin by 16.60 €/ha or decrease gross margin by 270 €/ha, but on average it is estimated that gross margin in the short term will decrease by 174.50 €/ha. The percentage change in gross margin depends on whether the cover/ catch crop is implemented during the winter or spring, what kind of crop is used (e.g., legume, rye) as they may have varying yield impacts, and the region under consideration. Consulting with an advisor to select a cover/catch crop is recommended.

Crop rotation, specifically those which integrate legumes, may increase gross margin by as much as 80.70 €/ha under a high yield scenario and still by 76.90 €/ha if low yields are factored into the calculation. Thus, the average for adding legumes into the crop rotation is 78.90 €/ha.

WHAT DO FARMERS SAY?

Farmers from Valladolid and Palencia, Castilla-León, Spain
Farm system: Arable (cereal, legumes, sunflowers)
Farm size: 150–200 ha



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JUAN RAMÓN ALONSO GARCÍA AND CARLOS GARRACHON

> *The impact of the practices is most noticeable in the net margin (increases about 30%) and in the short term (about 3 years), especially fuel and fertiliser cost reductions.*

How is conservation agriculture included in your farming system?
We usually rotate crops including about 50% cereal – 25% legume - 25% oleaginous. For example, 100 ha with 50 ha of wheat or barley and 50 ha of vetch and sunflower or alfalfa. We mainly apply minimum tillage. However we need to use the decompactor every 5 to 8 years, especially when we are going to cultivate sunflower as the clay soils can become tight making root system development more difficult.

Why did you decide to practice conservation agriculture?
We have the Mediterranean weather influences here with irregular precipitation which makes water a limiting factor. We both implemented conservation agriculture about 14 years ago. We both belong to the Association of Conservation Agriculture of Valladolid (AVAC), so part of it was personal conviction. However, we both want to be cutting-edge farmers and reduce our costs.

What are the benefits you have gained from implementing conservation agriculture?
These practices increase soil organic matter and enhance soil structure with more workability, less erosion, decrease of run-off and leaching and more worms which naturally till the soil.

The yield is usually equal to surrounding farms in conventional management but higher than them during water scarcity periods. This is due to the residues which improve soil water retention and reduce the evapotranspiration. The impact of the practices is most noticeable in the net margin (increases about 30%) and in the short term (about 3 years), especially fuel and fertiliser cost reductions. From the fifth year, production is clearly increased and the costs are reduced.

What challenges have you faced in implementing conservation agriculture?
You have to learn how to use and calibrate the new machinery for direct seeding. The machinery is expensive and is not adapted to local conditions (e.g. different soil types) and I had to make some modifications to it.

What advice would you give to other farmers about to implement conservation agriculture?
You need a change of mentality as it is something unknown for you and you have to take responsibility. Start small, seek advice and talk to other farmers. To start with I adopted the practices in only a few fields, as I wanted to test their effectiveness. After about two years I adopted the practices across the whole farm.

Lessons Learned

- Seek advice from other farmers
- Be prepared to learn and take a different approach
- Benefits may be more significant in the long term, but savings and yield resilience are seen in the short term

REFERENCES

(1) Sustainable agriculture and soil conservation (SoCo) project 2009. Conservation agriculture. Fact sheet 5 http://eusoils.jrc.ec.europa.eu/projects/SOCO/factsheets.html (see JRC website for 10 factsheets in 20 languages)
(2) SmartSOIL Deliverable 2.1
(3) SmartSOIL Deliverable 3.2

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

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