Czech Republic study site experiment: EFFECTS OF TILLAGE AND FERTILISATION ON CROPS

The problem

Inappropriate tillage practices have led to soil compaction and decreases in liming and organic fertilization in recent years have caused decreases in soil organic carbon and deterioration of the soil structure. The consequence of these effects is limited water infiltration into the soil, resulting in erosion and water run-off. These threats led to a need to explore the utility of reduced tillage.

The proposed solution

The aim of this experiment was to compare different soil tillage intensities and fertilisation practices on soil properties and arable crops. The practices used were:

- Mouldboard ploughing up to 22 cm - turning crop residues into soil (CT)
- Chisel ploughing up to 10 cm - min. 30% of crop residues on surface (MT)
- No treatment - all residues on surface (ZT)

These practices have been implemented since 1995. The experimental plots were located at the Crop Research Institute, Prague-Ruzyne area (altitude 360m, continental climatic zone).

Experimental design

The experiment treatments were comprised of 3 soil tillage x 5 fertilization = 15 TREATMENTS

Conventional tillage (CT)	Minimum tillage (MT)	Zero tillage (ZT)

1: Control (0 kg N/ha)
2: 2 x Calcareous ammonium nitrate (CAN)
3: 2 x Urea
4: 2 x Urea with urease inhibitor (UREAstabil, in figures „Us“)
5: Calcareous ammonium nitrate + Urea ammonium nitrate

The crop rotation was: pea -winter wheat - oilseed rape –winter wheat

The following measurements were taken:

- Physical - bulk density, aeration, humidity, temperature
- Chemical - pH, mineralization ability, nutrients distribution
- Biological -SOC content, microbial biomass activity

CT	MT		ZT	
1d	1d		1c	
3d	3d	O	2d	O
5d	5d	T	4d	T
		H		H
		E		E
4d	4d	R	3d	R
2d	2d			
		P	5c	P
3c	3c	R	2c	R
1b	1b	O	1b	O
		J	3c	J
4c	4c	E	4c	E
2c	2c	C	5b	C
5c	5c	T		T
3b	3b		2b	
4b	4b			
			4b	
5b	5b		3b	
2b	2b			
1a	1a		1a	
5a	5a		5a	
4a	4a		4a	
3a	3a		3a	
2a	2a		2a	

Conventional tillage

Minimum tillage

Zero tillage

SoilCare is funded by the EU's Horizon 2020 research and innovation programme. Grant agreement No. 677407

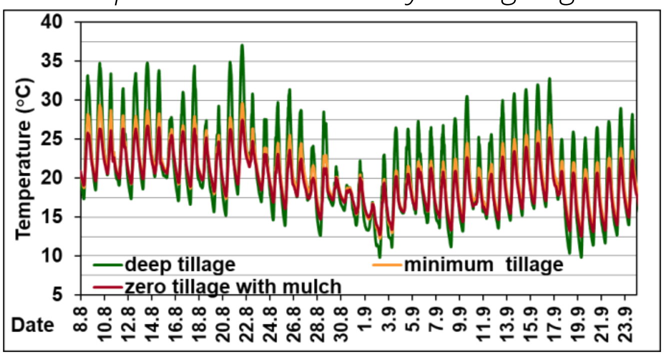
SoilCare

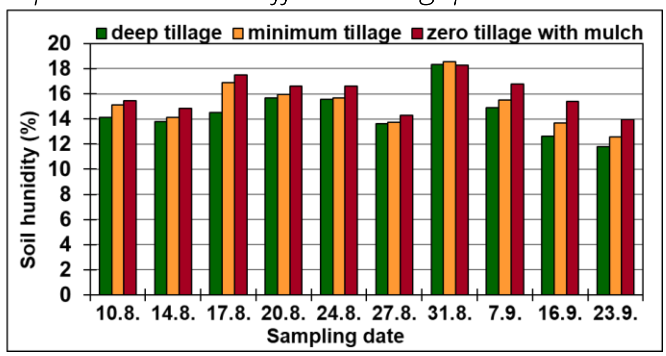
Results

Soil temperature and humidity

Minimum soil tillage, and especially plant residues on the soil surface, reduced water and wind erosion, evaporation, and warming of the soil in the summer months. Higher humidity of soil under minimum or zero tillage during summer and autumn led to better conditions for the emergence of winter crops. Minimum tillage led to faster and more balanced emergence than conventional tillage. Under zero tillage, higher humidity favoured the emergence of crops, whilst lower soil temperatures had the opposite effect.

Soil temperature and humidity during August and September under different tillage practices



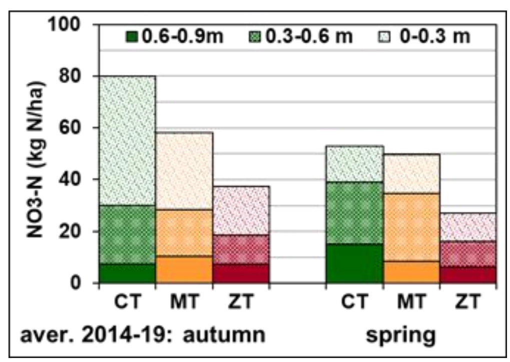


Nutrients mineralization

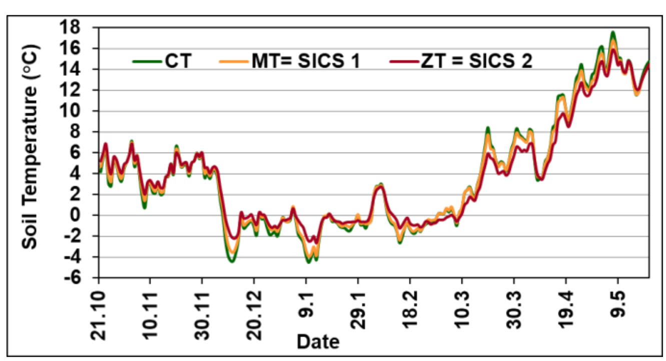
Lower intensity of soil tillage led to lower mineralization of nutrients.

Slow warming of the soil and mineralization of nutrients at ZT resulted in a later and slower emergence of spring crops. Early application of the regenerative dose of nitrogen was more significant here than under CT and MT. In the long-term observation, the biomass of winter wheat (plants) and nitrogen uptake by plants under ZT was significantly lower than under CT or MT at the beginning of stem elongation (phase). During vegetation, the lower temperature and high humidity of soil under ZT affected plants growth positively, especially in dry and warm years. The grain yields obtained at tested tillage systems did not differ much at fertilized treatments. (

Nitrate nitrogen content in soil profile before and after winter



Soil temperature (5 cm depth) under different tillage during winter wheat vegetation

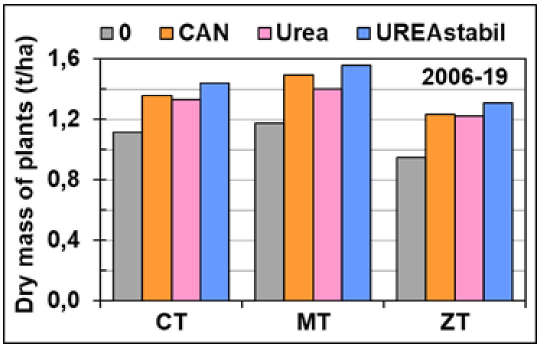


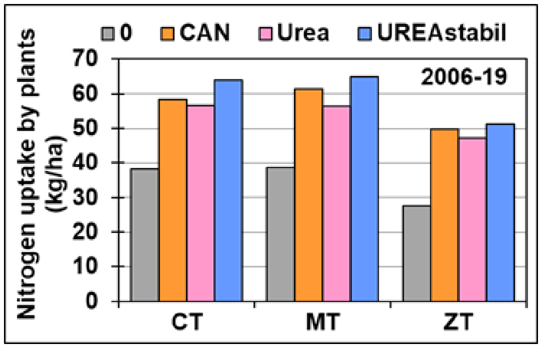
SoilCare is funded by the EU's Horizon 2020 research and innovation programme. Grant agreement No. 677407

Czech Republic study site experiment:
EFFECTS OF TILLAGE AND FERTILISATION ON CROPS

Results

Biomass of winter wheat and nitrogen uptake by plants at the beginning of stem elongation

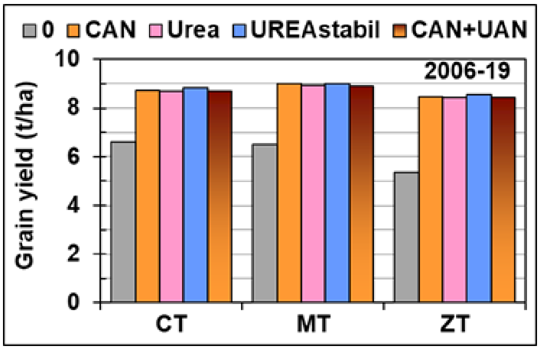


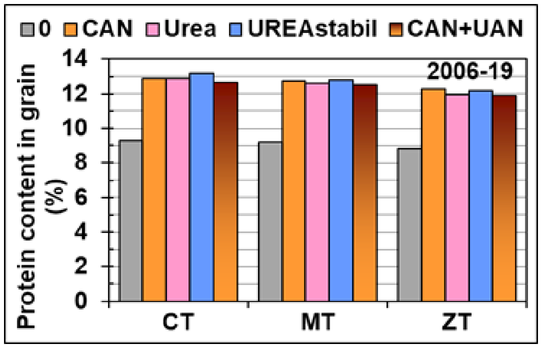


Nitrogen fertilization

The increase in crop yields and nitrogen content after the application of mineral N fertilizers was most significant under ZT due to low mineralization of soil nutrients. The differences between control and fertilized variants under CT and MT were not statistically significant. In the long-term observation, the highest yields were achieved under MT due to the best combination of mineralization intensity, soil aeration, moisture and temperature of all tested tillage systems. The effect of individual fertilizers was mainly influenced by precipitation after applications. In the long-term observation, the best results (yield and nitrogen/protein content in products) occurred where fertilisers with a mobile form of nitrogen (nitrate – N, amidic-N with urease inhibitor) were applied.

Yield of winter wheat grain and protein content





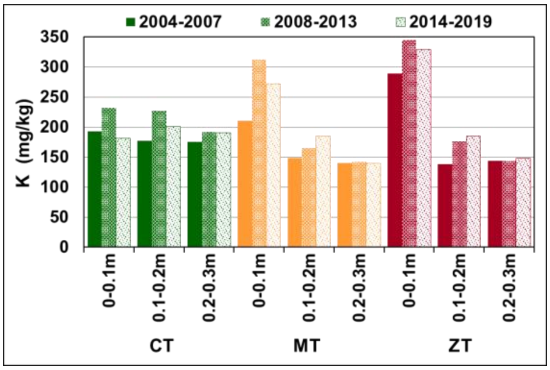
Distribution of nutrients in the soil profile

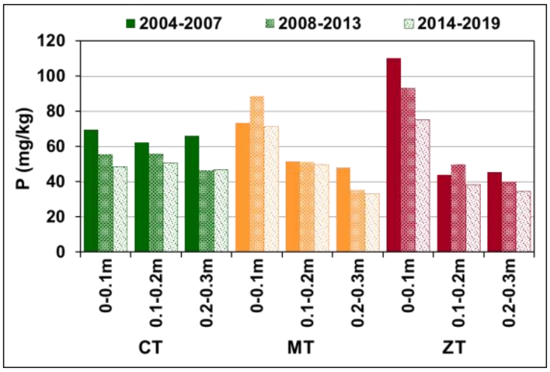
Reduced and zero tillage, whilst successful for preserving soil organic carbon, also has negative aspects. Fertilizers (P, K, Mg, S) applied in the autumn were incorporated into soil by ploughing up to 22 cm (at CT), mixed in 10 cm layer of soil (at MT) or stay on the surface (ZT). All nitrogen fertilizers during vegetation were applied without incorporation. The surface layer is stressed by repeated application of fertilizers. Mobile nutrients (e.g. Mg, Ca, NO_3-N) are shifted by precipitation into the soil profile. Accumulation of low-moving nutrients (e.g. P, K) in the surface layer of the soil occurs when the soil is not turned. In general, acidification of the surface layer of the soil occurs as a result of mineralization and nitrification processes in the soil accelerated after fertilizer applications.

SoilCare is funded by the EU's Horizon 2020 research and innovation programme. Grant agreement No. 677407

Results

Potassium and phosphorus distribution in soil profile



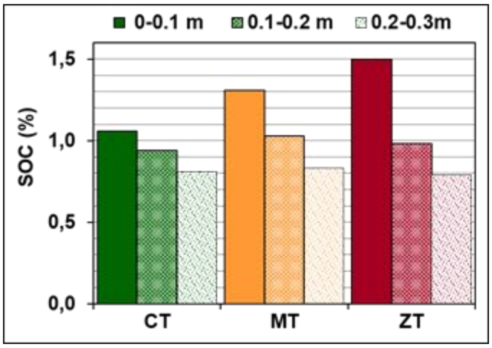


The detailed analysis of 10 cm layers of soil showed that P and K concentrations increase in the upper soil layer (0-0.1) with decreasing soil tillage intensity and duration of experiment. Between 2014-2019, the average concentration of phosphorus and potassium was by 65% and 50 % respectively and was higher under ZT than CT. In soil under CT, their concentrations were fairly balanced in all analyzed layers but sharply decreased in deeper layers under MT and ZT.

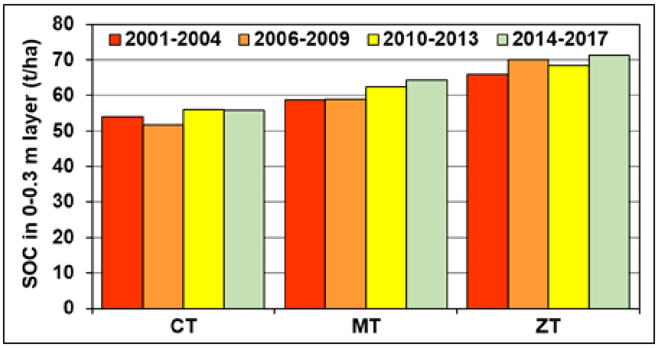
Soil organic carbon

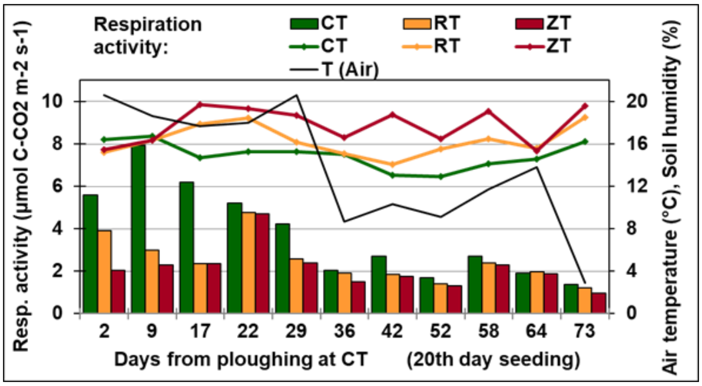
The most important benefit of minimum (SICS1) and/or zero (SICS2) tillage systems against conventional ploughing was the increases in soil organic carbon. The largest differences were found in the surface layer up to 0.1 m, which is ploughed and turned (CT), only loosened without turning (MT) or left without processing (ZT). After more than 20 years of implementation of these systems, the content of organic carbon in the soil layer up to 0.3 m was increased by 10 and 15 t/ha under MT and ZT respectively (in comparison with CT). This is, in part, due to lower mineralization, thus reducing CO_2 losses.

SOC distribution in soil profile (May 2020)



SOC under different tillage systems (aver. In 0-30 cm layer)





← Reduction of intensity or omission of soil tillage significantly reduces respiration activity and CO2 emissions from soil.

SoilCare is funded by the EU's Horizon 2020 research and innovation programme.
Grant agreement No. 677407

SoilCare

Czech Republic study site experiment:
EFFECTS OF TILLAGE AND FERTILISATION ON CROPS

Economic findings

- No specialised agricultural machinery was required for these experiments, so there were no investment and maintenance costs calculated for this trial.
- The use of ploughing up to 22cm was the least economic option, with using shallow cultivations leading to reduced labour and fuel costs.
- SICS2, where tillage was replaced with glyphosate, was cheaper in terms of fuel and machinery but the production costs were the same as SICS1 due to the requirement to apply more chemical inputs.
- The table below provides an overview of the economic aspects of this experiment, with costs displayed as euro per ha.

	AMT control	AMT SICS 1	AMT SICS 2
Agricultural management technique	Conventional ploughing	Minimum tillage	Zero tillage
Investment costs	0	0	0
Maintenance costs	0	0	0
Production costs	604	565	567
Benefits	983	1135	1016
Summary = benefits - costs	379	570	449
Percentage change		50.4	17.5

Stakeholder feedback

Czech farmers preferred SICS 1 - minimum tillage due to several advantages when compared against conventional tillage:

- Lower evaporation, higher soil humidity, better emergence of crops
- The best combination of mineralization intensity, soil aeration, moisture and temperature of soil resulted in the highest crop yields and benefits in the long- term view
- Lower CO_2 emissions, higher SOC content increased by 10 t/ha in layer up to 0.3 m after more than 20 years of SICS 1 implementation
- Shallower soil tillage = lower fuel consumption, less wear and tear of work tools, labour savings

There are, however, disadvantages to minimum tillage, the practice favoured by stakeholders:

- Higher content of nutrients with low mobility in soil in the tilled 10 cm surface layer
- The need to avoid undermining or deeper processing before sowing/planting of root crops. This leads to the loss of saved carbon from the soil supply.

The share of land treated with minimum tillage in agricultural practice is rising, in part because the pressure on farmers to reduce CO_2 losses and manage soil organic matter more efficiently is growing. In the future, the amount of support paid to farmers will depend on the amount of carbon they store in the soil. Our farmers are looking for ways to help them meet these legislative requirements without experiencing a negative impact on production, i.e., without reducing yields or increasing costs.

SoilCare is funded by the EU's Horizon 2020 research and innovation programme. Grant agreement No. 677407

Czech Republic study site experiment:
EFFECTS OF TILLAGE AND FERTILISATION ON CROPS

Conclusions

The SICS 2 zero tillage system is not used in this region as it is not suitable for the heavy soils where special disc seed drills are needed. It also cannot be used in crop rotations where root crops occur (e.g., potatoes and beets). This system was the most effective in storing carbon in the soil: after more than 20 years of implementation of ZT, the content of organic carbon in the soil layer up to 0.3 m increased by 15 t/ha when compared against conventional ploughing. Two tillage operations were replaced by one weeding spray in this system. This saved fuel and labour, but increased the environmental impact of chemicals.

Minimum tillage was less effective for increasing SOC (after more than 20 years the content of organic carbon in the soil layer up to 0.3 m was increased by 10 t/ha in comparison with control CS). Part of the post-harvest residues on the soil surface and shallower tillage without turning had a positive effect on soil temperature and humidity as well as reducing CO_2 emissions. The best combination of mineralization intensity, soil aeration, moisture and temperature of soil resulted in the greater year-on-year stability of crop yields and highest crop yields and benefits in the long- term view. Implementing this SICS does not require investment costs. Minimum tillage is most suited to drier areas where cereals, oilseeds, legumes or corn are cultivated.

A disadvantage of reducing or eliminating tillage is the resulting accumulation of nutrients in surface soil layer, especially those with low mobility. The application of calcium (or magnesium) is necessary to maintain the suitable value of ration of mono- and divalent cations important for soil structure, aggregate stability or water infiltration into soil. Growing catch crops and liming can help to ameliorate this issue.

Key findings

Minimum and zero tillage resulted in:

- Increased SOC, thus resulting in lower CO_2 emissions (+)
- Reduced soil warming and inefficient evaporation due to post-harvest residues on the soil surface (min. 30% at MT, all at ZT) (+)
- Reduction of water and wind erosion (+)
- Earlier and more balanced emergence of plants in sol with high moisture esp. at MT (+)
- The later onset of mineralization processes and spring vegetation of crops due to slower warm-up of soil covered by post-harvest residues at ZT (-)
- Lower mineralization at ZT = less accessible nutrients for plants (-)
- Greater year-on-year stability of crop yields esp. at MT (+)
- Accumulation of nutrients with low mobility in soil in the surface layer (-)
- Risk of acidification of the surface layer in consequence of mineralization and nitrification processes in the soil accelerated after fertilizer applications (-)
- Fewer operations in the crop rotation at ZT = fuel saving, labour savings (+)
- Lower CO_2 emissions and lower fuel consumption, esp. at ZT = lower carbon footprint (+)

Fact sheet authors

Helena Kusá, Pavel Čermák, Jane Mills, Charlotte Chivers

Contact information

Project website: soilcare-project.eu

Study site leader: pavel.cermak@vurv.cz

Project coordinator: Dr. Rudi Hessel, rudi.hessel@wur.nl

SoilCare is funded by the EU's Horizon 2020 research and innovation programme. Grant agreement No. 677407

SoilCare