# Improving nitrogen management in reduced tillage systems by use of green manures and appropriate off-farm inputs: results of TILMAN-ORG

PETRA RIETBERG[1], GEERT-JAN VAN DER BURGT[1], LIINA TALGRE[2], VJATSESLAV EREMEEV[2], F. XAVIER SANS[3], WIJNAND SUKKEL[4], MEIKE GROSSE[5], THORSTEN HAASE[5], ALFRED BERNER[6], PAUL MÄDER[6], KOEN WILLEKENS[7], BERT VAN GILS[7], LIEVEN DELANOTE[8], ANNELOES BEEKMAN[8], JOSEPHINE PEIGNÉ[9], CHRISTOPHE DAVID[9], CHRIS KOOPMANS[1]

**Key words:** green manure, reduced tillage, nitrogen, NDICEA

## Abstract

*For a successful integration of reduced tillage techniques and green manures in organic cropping systems, a better understanding of nitrogen dynamics and management is essential. We present data of several long- and medium-term European experimental field studies from the TILMAN-ORG project. Nitrogen dynamics and crop performance were investigated in an Estonian and a Spanish trial. A Dutch and a Swiss trial were simulated with the NDICEA-model. The Estonian trial shows that the effect of green manure on yield of the subsequent crop is dependent on green manure and crop type. The Estonian and the Spanish trial indicate that effects of fertilization on crop performance are larger than those of green manure or soil cultivation. The results of the Dutch trial give no reason to assume that soil nitrogen availability is negatively affected by minimum tillage in organic or conventional systems. However also in the ploughed systems, low nitrogen availability in spring warrants attention.*

## Introduction

Reduced tillage and green manures are efficient conservation agriculture tools that can be applied to further improve organic crop production systems. For a successful integration of those techniques in organic cropping systems, a better understanding of nitrogen dynamics and management is essential. The adoption of reduced tillage and/or green manures strongly affects nitrogen quantity and availability during the vegetative period and throughout the crop rotation (Peigné et al. 2007). Specifically, changing soil and water conditions may affect the availability pattern of nitrogen, notably in spring (Berry et al. 2010). To date, few results on this issue have been presented in the scientific literature. We present data of several long- and medium-term European experimental field studies from the TILMAN-ORG project. In those field studies green manures and reduced tillage techniques are used in organic cropping systems.

## Material and methods

*Effect of grass-clover ley, green manure and off-farm inputs on nutrient dynamics and crop performance under reduced tillage*

Nitrogen dynamics and crop performance were investigated in an Estonian and a Spanish trial. The Estonian trial aimed at evaluating the effect of green manure with or without cattle manure on crop yield and nutrient dynamics in an organic crop rotation. The crop rotation included (green manure crops between brackets): winter wheat – (ryegrass) – peas - (winter oilseed rape) – potato – (winter rye) – barley – (red clover) – red clover. The crop rotations with green manures run since 2007, the crop rotation without green manures started in 2011. In the Spanish trial three factors with two levels each were investigated: soil tillage (conventional (ploughing) and reduced (chisel), fertilization (with or without fertilization) and green manure (with or without green manure). The crop rotation consisted of cereals and legumes for both human consumption and livestock forage. Green manure consisted of a mixture of oat (*Avena sativa* L.*),* white mustard (*Sinapsis alba* L.*),* bitter vetch (*Vicia ervilia* L. willd*)* and common vetch (*Vicia sativa* L.*)*. Nutrient budgets were made by considering the following inputs: N in (kg/ha) in seed or seedlings; manure/compost/cut-and-carry fertilizers; and aerial deposition. N removal by crop harvest was the sole

[1] Louis Bolk Institute, The Netherlands, www.louisbolk.org, e-mail: p.rietberg@louisbolk,nl,
[2] Estonian University of Life Sciences, Estonia, www.emu.ee, e-mail: berit.tein@emu.ee, anne.luik@emu.ee
[3] Agroecosystems research group, University of Barcelona, Spain, www.ub.edu/agroecologia, e-mail: fsans@ub.edu
[4] WUR-PPO, The Netherlands, www.wageningenur.nl/ppo, e-mail: wijnand.sukkel@wur.nl
[5] University of Kassel, Germany, www.uni-kassel.de, e-mail: meike.grosse@uni-kassel.de
[6] Forschungsinstitut für biologischen Landbau, Austria, www.fibl.org, e-mail: alfred.berner@fibl.org, paul.maeder@fibl.org
[7] ILVO, Belgium, www.ilvo.vlaanderen.be, e-mail: koen.willekens@ilvo.vlaanderen.be; bert.vangils@ilvo.vlaanderen.be
[8] INAGRO, Belgium, www.inagro.be, e-mail: lieven.delanote@inagro.be, annelies.beeckman@inagro.be
[9] ISARA Lyon, France, www.isara.fr, e-mail: jpeigne@isara.fr, davidc@isara.fr

output considered. Nitrogen use efficiency was calculated as N in harvestable product (kg/ha)/N inputs in manure, compost and/or cut-and-carry fertilizer (i.e. external N-inputs, kg/ha).

*Calibration of NDICEA model for nitrogen and carbon*
Within the TILMAN-ORG project, the decision support tool NDICEA (Van der Burgt et al. 2006) is calibrated for reduced tillage systems with the incorporation of green manures and off-farm inputs in The Netherlands, Belgium and Germany and also for different pedo-climatic zones across Europe. This will support farmers to make more rational use of green manures and off-farm inputs and to assess the effects of reduced tillage on soil water and nitrogen dynamics. Here, NDICEA-simulations of two European trials are being presented and discussed.

Nitrogen and water dynamics was simulated by NDICEA for a Swiss and a Dutch long-term trial. The Swiss trial had two factors with two levels: soil cultivation (ploughing and rototilling) and fertilization (slurry only or manure and slurry). The crop sequence consisted of spring wheat – sunflower – spelt – clover-grass – silage maize – winter wheat. In order to be able to differentiate the pace of organic matter decomposition between the lay phase and the arable phases, modeling was done for three separate periods: 2003-2005 (wheat-spelt), 2006-2007 (clover-grass) and 2008-2009 (silage maize – winter wheat). Scenarios were calibrated on soil organic matter content, and by doing so, a soil cultivation factor was included and adapted for the rototilled scenario's, indicating a slower decay of soil organic matter and freshly added organic materials.

Within a six-year organic and conventional rotation, the Dutch trial covers three types of soil cultivation: ploughing, reduced tillage and minimal tillage. The organic crop rotation consisted of seed potato – clover grass – cabbage – spring wheat, undersown with clover – carrots – peas. The conventional crop rotation consisted of spring barley – onion – seed potato – sugar beet. The experiment has four replicates and started in 2009. NDICEA scenarios were built for ploughing and minimum tillage. Regular soil mineral nitrogen measurements were used to assess the quality of the simulation.

## Results

*Effect of green manure and off-farm inputs on nutrient dynamics and crop performance under reduced tillage*
In the Estonian trial, potato yield was highest in the treatments without fertilization, and green manure did not affect yield. Mean wheat yield increased in the order no green manure < green manure without fertilization < green manure with fertilization – however red clover was preceding wheat in all treatments including those without green manures. Nitrogen budgets (Table 1) were negative for all winter wheat treatments including the one with fertilization (- 45 kg N/ha for the latter). In potato, nitrogen budget showed a small surplus (17 kg N/ha) for the treatments with fertilization. The budget was negative for the treatments without fertilization (-91 kg N/ha and -87 kg N/ha for the treatment without and with green manure, respectively). Nitrogen use efficiency could only be calculated for the trials that included the use of cattle manure, thus a comparison of the systems with or without green manures wasn't possible. Nitrogen use efficiency was 1,9 for winter wheat and 0,81 for potato in 2011/2012, reflecting differences in fertilization and in nitrogen use efficiency between crops.
In the Spanish trial, spelt grain yield was enhanced by fertilization but unaffected by cultivation. Nitrogen surpluses were larger in systems with fertilization than in systems without fertilization, but crop yield was negatively affected in systems without fertilization. These results indicate that nitrogen surpluses alone may not give an adequate impression of agronomic feasibility when crop performance is not taken into account. A slightly higher crop nitrogen harvest in the treatments with reduced fertilization resulted in a slightly lower nitrogen use efficiency in those systems (0,38) compared to systems with conventional tillage (0,36).

**Table 1. Nitrogen budget in kg * ha$^{-1}$ for two crops and three treatments in 2011/2012 in the Estonian trial. Output values are means ± standard deviation, n=4. NF: no fertilizer, NG: no green manure, F: fertilizer, G: green manure.**

| **Crop** | **Winter Wheat** | | | **Potato** | | |
|---|---|---|---|---|---|---|
| Treatment | NF NG | NF G | FG | NF NG | NF G | FG |
| **Inputs** | | | | | | |
| Seed or seedlings | 2,93 | 2,93 | 2,93 | 5,5 | 5,5 | 5,5 |
| Manure | | | 43,46 | | | 86,91 |
| N-deposition | 3 | 3 | 3 | 3 | 3 | 3 |
| Total inputs | 5,93 | 5,93 | 49,39 | 8,50 | 8,50 | 95,31 |
| **Outputs** | | | | | | |
| Crop harvest | 70,28 ±12,37 | 81,82 ±9,26 | 93,90 ±10,55 | 99,82 ±13,93 | 95,25 ±11,45 | 77,42 ±9,98 |

*Calibration of NDICEA model for nitrogen and carbon*

In the Swiss trial, both simulated and measured data showed an increase of soil organic matter content in the rototilled treatments compared to the ploughed treatments (Figure 1), and a slight increase in the treatments with slurry and manure compared to the treatments with slurry (not shown). However, given the limited number of soil organic carbon measurements, the results should be interpreted with care. These results indicate that reduced soil tillage enhances soil organic matter content, as does the addition of solid manure.

In the Dutch trial, little differences were found in both measured and simulated soil mineral nitrogen dynamics between ploughing and minimal tillage (Figure 2). Simulated soil organic matter content decreased in both conventional and organic systems irrespective of soil cultivation, but the decrease was less in the organic systems.

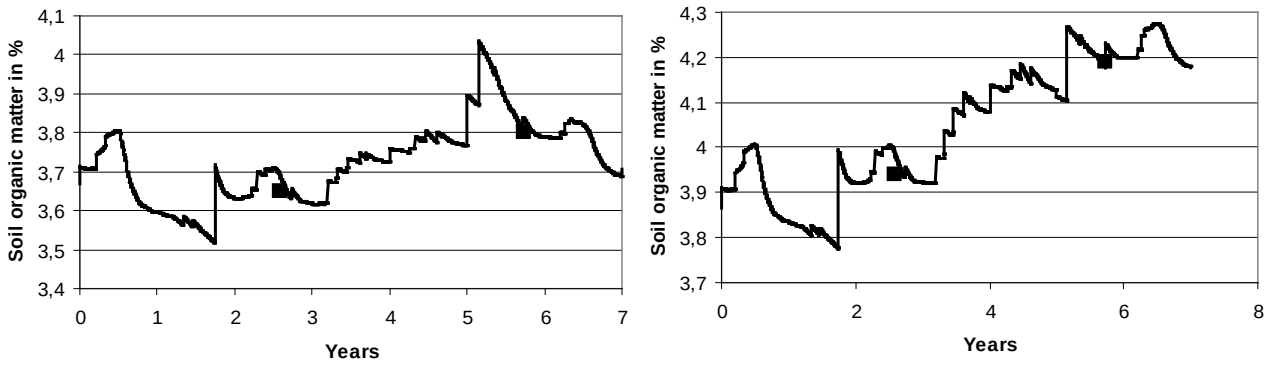


**Figure 1. NDICEA-simulated (line) and measured (squares) soil organic matter % in rototilled (right) and ploughed (left) treatments of the Swiss trial. Years indicate time lapse since the start of the experiment, year 0=2003.**

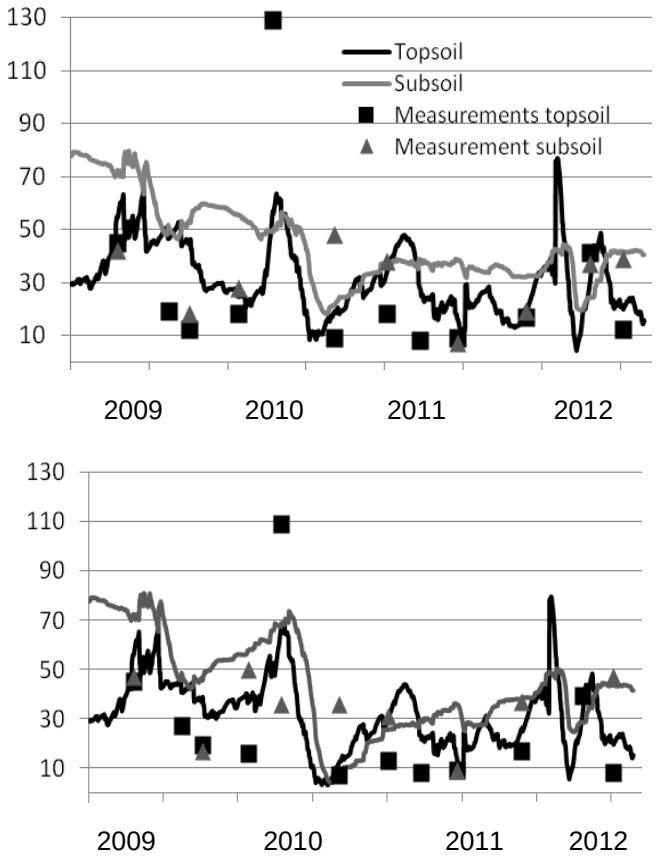


**Figure 2. Measured and NDICEA-simulated soil nitrogen content in topsoil (0-30 cm, black line) and subsoil (30-60 cm, grey line) for the Dutch trial, in the minimal tillage (left) and ploughed (right) treatments of the organic crop rotation.**

## Discussion

The Estonian trial shows that the effect of green manure on yield of the subsequent crop is dependent on green manure and crop type. Moreover, the Estonian and the Spanish trial indicate that effects of fertilization on crop performance are larger than those of green manure or soil cultivation.

No conclusive effects of reduced soil tillage on soil carbon content were found across the different trials. In order to increase the validity of the modelling, a better understanding of soil carbon dynamics under reduced tillage in organic systems is desirable. Including a soil cultivation factor in NDICEA seems to be an adequate measure to capture the effects of no-till on organic matter decomposition when this decomposition is reduced.

The results of the Dutch trial give no reason to assume that soil nitrogen availability is negatively affected by minimum tillage in organic or conventional systems. However also in the ploughed systems, low nitrogen availability in spring warrants attention.

## Acknowledgements

This research was carried out within the frame of TILMAN-ORG project (www.tilman-org.net) funded by CORE Organic II Funding Bodies, being partners of the FP7 ERANet (www.coreorganic2.org). The TILMAN-project aims to develop robust and sustainable arable crop production systems via the introduction of reduced tillage techniques combined with a strategic use of green manures in organic crop rotations, while maintaining and improving soil quality and crop productivity parameters.

## References

Berry P, Sylvester-Bradley R, Philipps L, Hatch D, Cuttle S, Rayns F, Gosling P (2002): Is the productivity of organic farms restricted by the supply of available nitrogen? Soil Use and Management 18, 248-255.

Burgt G van der, Oomen G, Habets A en Rossing W (2006). The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutrient Cycling in Agroecosystems 74: 275-29

Mäder P, Fließbach A, Dubois D, Gunst L, Fried P, Niggli U (2002): Soil fertility and biodiversity in organic farming. Science 296, 1694-1697.

Peigné J, Ball B, Roger-Estrade J, David C. (2007): Is conservation tillage suitable for organic farming? A review. Soil Use and Management 23, 129-144.