Final report

for the CORE Organic II funded project

“Reduced tillage and green manures for sustainable organic cropping systems – TILMAN-ORG”

TILMAN-ORG
A European Network

Period covered: Sep 1, 2011 – Aug 31, 2014

Project acronym:	TILMAN-ORG			
Title:	Reduced tillage and green manures for sustainable organic cropping systems			
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Start of Project:	Sep 1, 2011	End of project:	Aug 31, 2014	

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Overview on work package and task participation of TILMAN-ORG participants

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	FiBL	ISARA	HMGU	WIZ	LBI	WUR-APR	OC-ILVO	CRP-GL	UNEW	ORC	EULS	CIRAA	SSSA	UB	FiBL-AT	**Work Package Manager, Co-Manager Task Manager**
WP0	**PC**	**PCC**														**Paul Mäder, Christophe David**
Task 0.1	**WPM**	**WPCM**														Paul Mäder, Christophe David
Task 0.2	**TM**	P		P		P	P	P	P	P	P	P	P	P	P	Helga Willer
WP1	**WPM**	P	P	P	P	P	P	P	**WPCM**	P	P	P	P	P	P	**Paul Mäder, Julia Cooper**
Task 1.1	**TM**	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Paul Mäder
Task 1.2	P	P	P	P	P	P	P	P	**TM**	P	P	P	P	P	P	Julia Cooper
WP2	P	**WPCM**	P	P	P	P	P	P	**WPM**	P	P	P	P	P	P	**Joséphine Peigné, Julia Cooper**
Task 2.1	P	**TM**		P		P	P	P	P	P		P	P	P	P	Joséphine Peigné
Task 2.2	P	P		P			P	P	**TM**		P	P	P	P	P	Julia Cooper
Task 2.3	P	P	P	P	P	P	P	P	**TM**	P	P	P	P	P	P	Julia Cooper
WP3	**WPCM**	P	**WPM**	P		P	P	P	P	P	P	P	~~P~~		P	**Michael Schloter, Andreas Fliessbach**
Task 3.1	P	P	**TM**	P				P								Michael Schloter
Task 3.2	**TM**	P	P	P			P	P	P			~~P~~				Andreas Fliessbach
Task 3.3	P	P	**TM**			P					P	P			P	Michael Schloter
Task 3.4	P	P	**TM**													Michael Schloter
Task 3.5	**TM**		P			P	P	P								Andreas Gattinger
Task 3.6			P					P	**TM**	P			~~P~~			Julia Cooper
WP4	P	P	P	P		P		P		P	P	P	**WPM**	**WPCM**	P	**Paolo Bàrberi, Xavier Sans-Serra**
Task 4.1	P	P		P		P		P			P	P	**TM**	P	P	Paolo Bàrberi
Task 4.2			P	P		**TM**				P		P	P	P	P	Wijnand Sukkel
WP5	P	P		P	**WPM**	P	**WPCM**	P				P				**Geert-Jan van der Burgt, Koen Willekens**
Task 5.1		P		P	**TM**	P	P	P								Geert-Jan van der Burgt
Task 5.2	P	P		P	**TM**		P					P				Geert-Jan van der Burgt
WP6		**WPM**			P	**WPCM**						P	P	P	P	**Joséphine Peigné, Wijnand Sukkel**
Task 6.1		**TM**			P	P						P	P	P		Joséphine Peigné
Task 6.2		**TM**			P	P						P	P	P	P	Joséphine Peigné

PC: project coordinator, PCC: project co-coordinator, WPM: work package manager, WPCM: work package co-manager, TM: task manager, P: participant; underlined: new task participation, striked: task participation ceased

Projects website: **http://www.tilman-org.net/**

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Post/mid-term project summary suitable for web publication

- All partners defined their activities in the six work packages on data collection from field trials (WP1), crop yields and quality (WP2), soil fertility (WP3), weed management (WP4), nutrient dynamics (WP5), and farm prototyping (WP6).
- Most of the TILMAN-ORG research activities were based on 20 replicated field trials that were classified as long-term (older than seven years), mid-term (three to seven years), and short-term (younger than two years or starting) in WP1. Four new field trials with reduced tillage and green manures as factors have been set up.
- Field trial data and data from literature were collected in WP1 and used for a meta-analysis on the crop, weed and soil effects of reduced soil tillage under organic farming in WP2.
  - *Analyses conducted confirm that reduced tillage increases soil carbon content and weeds, but produces lower yield as compared to the plough system. The meta-analysis stated that weeds were not the main reason for lower crop yield. Interestingly the reduction in ploughing density only increased soil carbon without compromising crop yields.*
- More than 159 farmers from ten European countries were interviewed and expressed their views and experiences with reduced soil tillage and green manures in WP2.
  - *The most important motivations of farmers to reduce soil tillage were related to soil fertility preservation and they saw problems mainly with crop management, machinery and yield performance. Three groups of farmers were identified: "Soil conservationist" farmers were motivated by minimizing soil and environmental impacts. "Agro-technically challenged" farmers mainly expressed agronomic problems. Green manure and no-tillage were more frequent in Northern Europe whilst reduced tillage was more frequent in Southern Europe.*
- Soils from treatments of seven field trials were analysed for a previously defined minimum data set in WP3, which was part of the Handbook of Methods. Soil strata were sampled according to the soil tillage depths in each field trial down to the layer below the plough pan.
  - *Carbon stocks were influenced by the form of tillage at all sites in the uppermost soil layer, but were additionally driven by the time of tillage management and the form of fertilization. Over the whole soil profile, carbon stocks were not significantly different.*
  - *In depth analyses were based on DNA and phospholipid fatty acids as molecular markers to describe microbial community structure and functions. Effects of the three sites Thil*

(FR), Scheyern (DE) and Frick (CH) and soil depths as well as a development of microbial communities under reduced and plough systems were clearly reflected in the analyses.
    - *Greenhouse gas emissions were measured at the three sites Frick (CH), Scheyern (DE) and Merelbeke (BE). They revealed mainly event-based emissions and tended to stimulate higher nitrous oxide emissions in soils of reduced soil tillage depending on the pre-crop. How far the higher emissions are compensated by soil carbon build-up is matter of current evaluations.*
- Weed control may be the most challenging work for organic farmers, who want to implement reduced soil tillage without herbicides.
    - *Based on 13 field trials across Europe, it was found in WP4 that despite elevated weed density, biomass, and diversity in reduced tillage treatments as compared to ploughing, crop yield was rarely reduced. Where green manure types were tested across the tillage treatments, certain green manure species were found suitable to suppress weeds.*
- Nitrogen use efficiency and nitrogen dynamics in reduced tillage was analysed in WP5 using datasets from nine field trials.
    - *Yields were found to be lower under reduced tillage as compared to the plough and likewise the nitrogen use efficiency was also lower.*
    - *The effect of green manure on crop yields was positive, but left a large amount of N unused, which is prone to loss.*
- Nutrient dynamics were modelled with NDICEA based on data sets from five field trials in WP5. As the model output was not satisfying, the model was recalibrated with data sets from TILMAN-ORG field trials and a new "decay factor" was introduced. Still the model was not reflecting the measured data to the desired precision.
- Results from six field trials, the literature review and farmer interviews were used for a multi-criteria assessment (MASC) farm prototyping in WP6.
    - *Conservation of micro- and macro-fauna was improved in reduced tillage and also when green manures were used. More problems occur with respect to weed control, pests and diseases. No economic problems were identified.*
    - *A weed module was included in the MASC model in collaboration with WP3.*
- TILMAN-ORG was disseminated actively to the public (website, print media, videos), to the farmers (articles, presentations, field days), and the scientific community (conferences, peer reviewed articles). A complete session at the Organic World Congress in Istanbul was devoted to TILMAN-ORG as a final display of achieved results, which received a lot of attention. All partners participated in disseminating TILMAN-ORG wherever possible.

Pre-project summary

Organic farming systems contribute to ecosystem services such as the maintenance of soil quality and biodiversity. Reduced tillage and green manures are efficient conservation agriculture tools that can be adapted to further improve organic crop production systems. The TILMAN-ORG project's overall goals are to design improved organic cropping systems with: (a) enhanced productivity and nutrient use efficiency, (b) more efficient weed management and (c) increased biodiversity, but (d) lower carbon footprints (in particular increased carbon sequestration and lower GHG emissions from soils). These goals will be achieved by adapting and integrating conservation agriculture techniques (in particular reduced tillage and improved use of green manures) into organic farming systems to intensify biological soil functions like nutrient cycling, soil carbon build-up, and biological nitrogen fixation, while at the same time optimising management protocols for weeds (which are the main challenge when introducing minimum tillage systems). Optimum techniques for organic systems will be identified using an integrated approach:

I. Farmers' experiences and perceptions about reduced tillage and green manures will be assessed in semi-structured interviews. Existing data from medium and long-term trials on reduced tillage and green manures provided by the consortium and the published existing peer reviewed and grey literature, will be evaluated with respect to yield stabilisation, soil quality and biodiversity (WP1 and WP2).

II. Experimental Case Studies on soil quality and greenhouse gas emissions, weed management and functional biodiversity, and improved nutrient management will be carried out, and carbon stocks under reduced tillage compared to ploughing will be measured (WPs 3-5). Data from long-term tillage trials across Europe will be exploited to calibrate NDICEA, a decision support tool to predict soil organic carbon and nitrogen fluxes in the soil – plant system.
III. Design of optimised cropping systems by modelling approaches based on results from the literature and case studies (WP6). This will also involve the preparation of guidelines focused on helping farmers to address weed management challenges, and temporary shortages of nitrogen supply in order to improve yields and yield stability, thus improving both the environmental and economic sustainability of organic farming systems.

The project's dissemination activities will target farmers, advisors, and the scientific community, but also the agricultural support industries and policy makers. The main innovative strategy of the project is to adapt conservation agriculture approaches to organic farming drawing on existing field experiments across Europe.

1. Main results, conclusions and fulfilment of objectives

1.1 Summary of main results and conclusions

TILMAN-ORG is a network of 15 partners from 11 EU-countries collaborating on the impact of introducing reduced soil tillage and green manures in arable organic farming systems. Data were assembled from field experiments, farm surveys, on-farm experiments, farmer interviews and from the scientific evidence from published and unpublished results. In each of the participating countries field experiments on reduced tillage and/or green manure were used as cases to analyse effects on yield, soil quality, soil carbon stocks and soil-borne greenhouse gas emissions, weed populations and N-dynamics. Modelling exercises were undertaken to describe soil nitrogen dynamics and crop yield as well as soil carbon stocks using NDICEA. Farmers, advisors, scientists, and other experts in organic farming and cropping systems participated in prototyping discussions to develop new and more sustainable farming systems. The outcomes of these events as well as the results from field studies were then evaluated by using the multi-criteria assessment tool MASC.

Farmers' perception and currently applied conservation tillage practices of organic farmers

159 farmers located in 10 European countries were interviewed with respect to their experiences with no-tillage, reduced tillage and green manures. The most important motivations to adopt reduced tillage were related to soil fertility preservation and challenges were mainly linked to crop management, machinery and yield performance. Two groups of farmers were identified: "Soil conservationist" farmers were strongly motivated by soil preservation and minimizing environmental impacts. "Agro-technically challenged" farmers mainly expressed agronomic problems and challenges. This study demonstrated that research priorities related to reduced tillage in organic farming should address agronomic problems and weed control in particular. The same survey delivered data for the management of winter cereals. 89% of the interviewed farmers used reduced tillage, 27% no-tillage, and 74% used green manure. Green manures were more frequently used in northern Europe than in the south, and reduced tillage was more applied in south. Farmers expressed the need for tillage improvement without soil inversion and biological weed control.

Crop Yield

The results and raw data from 15 field trials and hundreds of refereed and not refereed sources were included in a **meta-analysis** to compare yields in reduced tillage with other forms of soil management. Six classes of tillage intensity were identified: deep inversion tillage (>25 cm depth), double-layer ploughing, shallow inversion tillage (<25 cm depth), non-inversion tillage (10-25 cm depth), shallow non-inversion tillage (<10 cm depth), and no-tillage. Soil types,

climate, and crop rotation types were included in the data base as modifying factors. The dataset was further subdivided into those studies that included deep inversion tillage and those that used shallow inversion as a control.
On average across all environments and management practices (901 observation pairs) there was a **reduction of 7% in yields** in organic systems when reduced tillage was compared to deep inversion tillage. There was no yield reduction, however, when tillage was reduced relative to shallow inversion tillage (178 observation pairs). This result suggests a reduction in tillage depth to be sufficient for a farmer, who wants to reduce tillage intensity at small risk for yield loss. Yields were 22% lower when tillage was reduced as compared to deep inversion tillage in a humid continental climate (US, CAN, CH). Smaller yield reduction (5%) as compared to deep or shallow inversion tillage was found in the humid oceanic climate (FR, NL, DE, UK). For the Mediterranean climate the data base was small but point towards high yield losses, when tillage was reduced as compared to deep inversion, however, when compared to shallow inversion reduced tillage increased yields. Yield reductions were most significant in cold climate regions, where soil temperature in spring tends to be lower in reduced tillage systems and crop development was retarded by slow mineralisation of nitrogen in soils. Soil type did not significantly (overall 5-7%) change the effect of reduced tillage compared to deep inversion as the control. For the 14 comparisons of reduced tillage and shallow inversion on sandy soils, there was a yield reduction of 17% for all tillage systems, which may be related to compaction, and the lack of clay to form stable soil aggregates. Sandy soils also contain much less earthworms that are crucial in no-till and reduced tillage systems for incorporating crop residues and manure, and to form macro-pores.
Crop rotations assigned to intensive arable (i.e. no ley crops), arable with ley periods, intensive horticulture (i.e. no ley crops) and horticulture with ley periods did not show any significant change in the effect of reduced tillage on crop yield. Grain crop yields were strongly reduced when reduced tillage was compared to deep inversion, but less so when compared to shallow inversion. When no tillage was compared to shallow inversion, yields of grain crops increased. Green manures and grass-clover leys were performing better during drought periods in reduced tillage systems of the Frick trial.
Results from TILMAN-ORG case study sites coincided with findings of the literature to a large degree. In 62% of the cases in which crop yield was assessed, there was no significant difference between plough and reduced tillage. As an average yields were 7% lower as compared to plough when reduced tillage was applied, which is well supported by the findings of the literature review.

Scientific evidence:
- In the oceanic and the Mediterranean climate, reduced soil tillage performs well with respect to yield.
- In the humid continental climate reduced soil tillage cannot be recommended. Here the use of green manures has advantages.
- Related ecosystem services provided by reduced tillage need to be considered (i.e. increased biodiversity, and soil C-stocks mitigating climate change)

Challenges and uncertainty:
- Incorporation of large amounts of biomass from green manure or grass-clover termination
- Solutions for sustainable tillage systems on sandy soils

Research needing verification:
- Breeding of varieties adapted to reduced tillage conditions

Soil and climate
The **meta-analysis** revealed that reducing tillage intensity increased soil C-stocks compared with deep inversion tillage (183 observation pairs). However, soil C stocks were only higher when no -tillage was compared to shallow inversion tillage (74 observation pairs).

TILMAN-ORG case studies were based on field trials in different pedo-climatic regions of Europe. Soils from seven field trials comparing tillage treatments and green manures were analysed for soil carbon stocks and in four field trials biological soil quality was assessed. In Gallecs (ES) and Luxembourg, new field trials were started and baseline data were measured. In soils from three field trials (Scheyern (DE), Frick (CH), Thil (FR)) comparing tillage treatments, in depth analyses of soil microbial communities were performed. Greenhouse gas (N_2O, CH_4, CO_2) measurements were done in Frick (manual closed chamber, weekly) and Scheyern (automated closed chamber, continuous) and a new setup for N_2O and CH_4 measurement was tested in Luxembourg and compared to the technique used in Frick. The soil sampling protocol was designed in order to measure the changes over the soil profile down to 50 cm, the deepest sampled layer being below the deepest soil tillage depth.
Soil carbon stocks were found to be higher in the top soil layer of reduced and no-tillage systems as compared to plough tillage at all sites except the one in Scheyern (DE). Results on carbon stocks over the profile down to 50 cm showed the same trend, but the statistics didn't show significant differences between tillage treatments. **Soil quality indicators** typically showed an increase of organic and microbial carbon and nitrogen in top soils of reduced or no-tillage as compared to ploughing. The values decreased with soil depth and so did also the difference between reduced and plough tillage. Selected soils from the field trials in Frick, Scheyern and Thil were analysed for their **microbial community structure**. The communities in the uppermost soil layer were different in their composition of taxonomic units as defined by DNA fragments or phospholipid fatty acids. Going down the soil profile the microbial communities were becoming more and more similar and thus unaffected by the tillage operations. Large differences were found between the sites.
Greenhouse gas emissions monitored in Frick clearly showed peak emissions after slurry application, green manure and ley destruction and any soil disturbance. Compost resulted in N_2O emission peaks after incorporation. There was a trend to increased N_2O emissions under reduced tillage as compared to ploughing in the cropping sequence grass-clover – winter-wheat, concomitant with higher soil carbon, and microbial activity in the uppermost soil layer. The GHG monitoring in Scheyern was done in minimum and plough tillage plots under wheat after potatoes and alfalfa as preceding crops. Soil disturbance was identified as a major driver for pulse emissions, but after potatoes, ploughing stimulated N_2O emission as compared to minimum tillage, whereas after alfalfa minimum tillage induced higher emission than ploughing.

Scientific evidence:
- Soils under reduced and no-tillage are more stratified than ploughed soils with respect to soil organic carbon and microbial activity.
- Reduced and no-tillage systems have more fertile top soil layers and different microbial communities than plough systems.
- Greenhouse gas emissions are driven by soil disturbance and organic fertilisers and tend to be higher in reduced tillage.

Challenges and uncertainty:
- Gravimetric soil analyses of soil organic carbon are showing larger differences than volumetric or area based data

Research needing verification:
- Differences in carbon stocks across the whole soil profile lack statistical proof. It may be necessary to increase the number of replicate samples because of large variability and to follow the time course over whole crop rotations.
- Effects of occasional ploughing in the rotation on carbon stocks and labile organic matter fractions need to be investigated.
- Modelling carbon balances of various tillage systems, including carbon stock changes, GHG emissions and fuel consumption may present a clearer picture on the climate footprint of tillage systems.

Weeds

Weeds were also part of the **meta-analysis** stated above in the crop section. Apart from this weed infestation, coverage and community were analysed in 16 field experiments across Europe. Nine were located in continental Europe, four in the Mediterranean, two in the Oceanic and one in the eastern continental (Baltic) zones. Ten trials were carried out on stations and six on farms. 14 field trials had tillage as the only factor, four had green manure as a factor, and nine included both tillage and green manure as factors. Six out of 16 trials were older than seven years, seven trials were between three and seven years old and three were younger than three years. Trials included 20 crops, with a slight prevalence of maize, spring oats, winter wheat, grass-clover ley and sunflower. As for direct weed control, spring-tine harrowing was most often used, followed by hoeing. Other direct weed control methods were flame weeding, mowing and hand hoeing/weeding. Seven field trials did not use any direct weed control.

In the majority of **field trials** having tillage as the only factor, weed abundance in various reduced tillage treatments and ploughing were not significantly different. Twelve trials had significantly higher weed abundance under reduced tillage, whereas two had higher abundance under ploughing. In many trials, a clear effect of tillage on the weed community was found. Green manure did not appear to influence the weed community significantly. *Lamium purpureum*, *Poa annua*, *Viola arvensis*, Polygonaceae and volunteer potato were favored by ploughing. Annual grasses, perennials and volunteer crops (especially from leys) were typically favoured by reduced tillage. In some cases *L. purpureum*, *P. annua* and *Polygonum aviculare* appeared to be also favoured by reduced tillage, thus showing a high degree of adaptation among various types of soil disturbance.

The unexpected results obtained in this work package underline the scientific value of field trials, especially considering the high level of coverage in terms of crops, treatments, geographical zones and environmental conditions. However, these data need to be further explored to establish possible cause-effect relationships related to e.g. crop type, age of trial and climatic conditions.

The main innovative concept is that weeds can be reasonably controlled in conservation tillage organic systems without jeopardizing crop yield. This is a relevant finding because it is a good refutation to criticism towards organic farmers being dependent on ploughing, which so far has been considered a ‘must’ to control weeds in organic systems.

Scientific evidence:

- Higher weed abundance in organic reduced tillage systems as compared to plough
- Weeds can be controlled in organic reduced tillage systems without jeopardizing crop yield
- Weed communities tend to shift to perennials in reduced tillage system

Challenges and uncertainty:

- Weeds need to be kept under control in order to avoid increasing pressure
- Techniques to suppress or combat perennial weeds

Research needing verification:

- Cause-effect relationships for weed abundance need to be better understood

Nitrogen

On nine organic farming experiments across Europe comprising tillage and green manure, effects on yields, nitrogen dynamics and N use efficiency were assessed over two years. Conventional mouldboard tillage was used as reference treatment, and systems without green manure served as reference for green manure application.

Across all sites and treatments reduced tillage treatments produced 92% of the yields of the plough systems. However there were also cases with higher yields under reduced tillage in the Netherlands, where spring wheat was increased by 7% and grass-clover by 23%.

The yield reduction was explained by decreased mineral nitrogen (-15%) in spring in reduced tillage plots. These results are in line with claims of farmers, who observed clear symptoms of nitrogen deficiency in reduced tillage plots. When the crops were planted after a green manure yield depression due to reduced tillage has been balanced. It is concluded that early applications of nitrogen in form of e.g. slurry, and green manures should be part of the system. N-use efficiency as calculated for a single crop went down from an average of 278% to 160% in treatments with green manures. However carry over effects to subsequent crops are not included in this calculation, calling for N use efficiency calculations over a whole crop rotation. The model simulations with NDICEA showed that the effect of green manures on yield of the subsequent crop is depending on the type of green manure and the main crop. NDICEA was calibrated to reduced tillage systems, using data from four TILMAN-ORG experiments, and this newly adapted version of NDICEA was tested at an additional site. However from the simulation no conclusive effects of reduced tillage on soil carbon content were found across the set of trials. In order to increase the validity of the modelling, a better understanding of soil carbon dynamics under reduced tillage is needed. Currently carbon dynamics under reduced tillage is modelled by mechanistic models using DAYCENT in a follow up project.

Scientific evidence:
- Even after including a new module into the model results were not precisely reflecting the measured data.
- Yields and N-use efficiency were lower under reduced soil tillage

Challenges and uncertainty:
- Carbon and nitrogen dynamics in various pedo-climatic conditions

Research needing verification:
- Nitrogen fixing green manure crops adapted to dry climates

Prototyping of farming systems

New organic cropping systems are needed to keep pace with the growing demand for organic food. Those systems should ideally increase yields and be safe for the environment. Current innovations such as non-inversion tillage with cover crops are promising, but investigations usually do not take farmers view into account. Therefore, research work should include farmer participation to maximise success. A method to help farmers in designing innovative cropping systems has been applied and tested within TILMAN-ORG with researchers. Prototypes were designed with 19 partners during 2 workshops. After defining the objectives for prototyping farms, crop rotations were designed according to the defined strategy and more management factors were included step by step.
This participatory tool is used to exchange views and knowledge. The main benefits of the method are (1) the involvement of volunteer farmers in the design process, (2) the combination of farmer knowledge and scientific knowledge, and (3) the use of various methodological supports.

Scientific evidence:
- Platform of structured interaction between research and practice

Challenges and uncertainty:
- The prototypes offer potentials of crop performance and environmental impact.

Research needing verification:
- Verification by MASC is most valuable, but the assessment of the implementation of optimised systems in the real world needs to be done.

Recommendations to end-users

For farmers – not only organic – the results of TILMAN-ORG are encouraging. Weeds can be controlled when applying reduced tillage, and green manures are a good strategy in that context. Overall, yields were not impeded substantially if fertilisation regimes were adapted. Further development is needed to optimise the timing of nutrient supply, to improve the machinery and to adapt a farm specific reduced tillage system where weeds remain under control in the long-term. Reduced tillage is especially advantageous for semi-arid regions. Shallow ploughing is recommended, showing positive effects on soil organic carbon, without compromising yields and without increasing weeds. In humid climates, a hybrid system with mostly reduced tillage but occasional ploughing (e.g. for ley destruction or in sandy soils) is promising, but effects on soil organic carbon need to be further studied.
For scientists, the expected stratification of organic matter in reduced tillage was confirmed. The higher soil organic matter in the uppermost soil layer increases water infiltration and thus reduces risk of erosion. A new research area could be the in-depth analysis of the microbial response to tillage and pre-crops including green manures, which could be managed to optimise nutrient turnover in the future. Also, the identification of functional traits of weeds is a new area that needs further development and can help farmers benefit from within-field biodiversity. In this approach, positive traits of weeds such as serving as a feed source for pollinators or beneficial insects, or negative traits are categorised and quantified for more than 150 weeds. Organic no-tillage systems are promising in Mediterranean regions particularly, where crops can benefit from improved water relations.

Relevance
These results can be easily adopted by conventional farmers and help them to reduce their use of fertilizers and pesticides. NT with herbicides is widely spread in semi-arid regions e.g. in the US or Australia. A reintegration of green manures and a reduced intensity of tillage could help reduce the negative long-term effects of herbicides on the environment while still preserving the benefits in erosion control.

1.2 Fulfilment of objectives
The declared objectives of the TILMAN-ORG were:

i. to summarise existing knowledge and experiences on reduced tillage and green manures in organic systems in a wide range of soils and climates across Europe;
ii. to stimulate bio-geochemical processes governed by soil microorganisms and soil carbon build-up via reduced tillage and strategic integration of green manures into organic rotations;
iii. to improve weed control by integrating management techniques such as green manures, mechanical weeding and crop diversification, while evaluating impacts on weed diversity and their functional role in agro-ecosystems;
iv. to increase the efficiency of nutrient use by green manures (including N_2-fixing legumes), thereby reducing off-farm inputs;
v. to design viable organic cropping systems applying reduced tillage and green manures at the farm level for major European regions.

All these objectives were fulfilled by the project, although some of them still require additional research efforts due to the complexity of the peculiar issues and limited availability of resources. For the first time, the existing knowledge on the application of reduced tillage and green manures in organic farming was collected and summarised by gathering the information on the most important field experiments carried out in Europe on these two topics. The meta-analyses of the literature on the topics and the farmers' survey allowed building a robust state of the art focussing the application of conservation agriculture technique in organic farming. Stakeholder communities being involved in the project from its start scrutinized the data provided by researchers, allowing them to draw robust conclusions, closely related to farmers' practice. The partners made any endeavour in collecting information on crop management options, machinery and agronomic strategies already available on farmers' networks and the most important ones were evaluated from different angles (e.g. effect on weed abundance, soil quality, etc.). Research station experiments allowed project partners to study some specific issues in detail,

such as weed dynamics, diversity and functionality in conservation agriculture systems, or the effect of reduced tillage and green manures on soil biota and microbial activity, as well as on C and N dynamics. Discussion with stakeholders, on the other hand, allowed calibrating experimental results on the basis of farmers' viewpoints, highlighting steps for future research in this field. The prototyping of improved cropping systems was mainly done by researchers, but was performed in addition with farmers in a pilot country.

2. Milestones and deliverables status

Milestones:

No	Milestone name	Planned delivery month	Actual delivery month	Means of verification
M0.1	Organisation of kick-off meeting (in month 3)	2	2	Minutes, Book of Posters, Book of abstracts
M0.2	Organisation of stakeholder workshops in selected countries	3	3	Minutes
M0.3	Organisation of interim meeting (in month 16)	13	13	Minutes, Invitation, Book of Posters
M0.4	Organisation of final project meeting (in month 34)	30	30	Minutes, Invitation, Book of Posters, Book of abstracts
M0.5	Draft handbook of methods, including parts crops, soils, weeds	2.5	5	Handbook of Methods
M1.1	Draft overview on field trials and identification of main sites	2	2	TILMAN-ORG Trial document
M1.2	Existing data of mid-term and long-term trials provided for meta-analyses	6	18	Entries in templates received by UNEW
M1.3	Newly assessed data provided for NDICEA and prototyping	26	24	Entries in templates received by UNEW
M2.1	Interviews with farmers completed	6	14	Entries in templates of semi-structured interview forms
M2.2	Data collected from mid-term and long-term trials	7	19	Data compiled in UNEW database
M2.3	Data collected from peer reviewed literature, "grey literature" and farmer interviews	8	18	Data compiled in UNEW database
M3.1	Soils collected and distributed for analyses among partners	5	7	Filled in sampling protocols
M3.2	Data on diversity and activity of soil biota under the different management forms	14, 32	14, 32	Data collection at HMGU and FiBL
M3.3	Influence of the different management forms on carbon and nitrogen stocks in soil	14, 32	14	Data collection at HMGU and FiBL
M3.4	Results on GHG emissions from the different field sites	31	30	Power point presentations, Posters, Abstracts, Proceedings
M4.1	List of agro-ecological services potentially	3	3	List of weeds

	associated with weed populations completed			available
M4.2	Pros and cons of conservation tillage/green manure systems on weed management highlighted	31	31	List
M4.3	Pros and cons of innovative machines for direct weed control highlighted	32	32	List
M5.1	Assessment of first-year experimental results completed	13	24	Data assembled in database
M5.2	Calibration of NDICEA model for different agro-climatic zones across Europe completed	14	32	NDICEA adjustments documented and a program update is available on public server
M5.3	Assessment of second-year experimental results completed	27	34	Data assembled in database
M6.1	Multi-criteria assessment of existing experiments (including data collected before the beginning of the project	14, 32	18	Compiled list of assessment analyses
M6.2	Co-design and prototyping in workshops involving researchers	31	32	Workshop minutes
M6.3	In selected areas, co-conception of adapted prototypes with farmers and advisors	32	32	Conception documented

Deliverables:

No[1]	Deliverable name and language	Nature	Dissemination level and link to the document	Planned delivery month	Actual delivery month
D0.1	Report on project implementation	Report	INT	6	8
D0.2	Interim report	Report	INT	18	18
D0.3	Final report	Report	INT	36	38
D0.4	Public project Web page established	Report	PU	3	2
D0.5	Handbook of methods: parts crops, soil and weeds compiled	Protocol	INT	5	6
D0.6	Project brochure	Booklet	PU	6	15 (Draft 6)
D0.7	Three articles in English, targeted to consumers/farmers/end users	Articles	PU	17, 34	15, 36
D0.8	Leaflets/technical guides on reduced tillage and green manures	Leaflet	PU	35	36 (Draft)
D1.1	Trial over-view document	Booklet	INT	4	3
D1.2	Interim report	Report	INT	16	18
D1.3	Final report	Report	INT	34	36
D2.1	Report on farmers perceptions and experience	Report	INT	7	17 (leaflet) 25 (article)
D2.2	Handbook of methods - part crops	Protocol	INT	2	4
D2.3	Report on project implementation	Report	INT	5	5

D2.4	Manuscript on reduced tillage and green manure	Manu-script	PU (after acceptance)	14	35
D2.5	Interim report	Report	INT	16	16
D2.6	Final report	Report	INT	34	34
D3.1	Handbook of methods: part soil	Protocol	INT	2	4
D3.2	Report on project implementation	Report	INT	5	5
D3.3	Interim report	Report	INT	16	16
D3.4	Final report	Report	INT	34	35
D4.1	Handbook of methods for weed sampling and weed functional biodiversity assessment	Protocol	INT	2	4
D4.2	Report on project implementation	Report	INT	5	5
D4.3	Interim report	Report	INT	16	16
D4.4	Final report	Report	INT	34	34
D5.1	Report on project implementation	Report	INT	5	5
D5.2	Interim report	Report	INT	16	16
D5.3	Final report	Report	INT	34	34
D6.1	Interim report	Report	INT	16	16
D6.2	Final report	Report	INT	34	35

Additional comments (in case of major changes or deviation from the original list)

M 1.2. More work than planned was needed to mine data from on-going field trials within TILMAN-ORG. Moreover field trial data from affiliated partners – not participating in TILMAN-ORG – in Germany and Switzerland have been included. The delay finally did not compromise the elaboration of a manuscript on the meta-analysis on reduced tillage in organic farming.

M 2.1. The development of questionnaires for interviews of farmers by the TILMAN-ORG team was time consuming. Also the interviews with the farmers were taking more time than expected and resulted in a very large data set. At the end, two manuscripts have been written: one on conservation agriculture practices currently performed by organic farmers in Europe, and one on the perception of organic farmers with respect to elements of conservation agriculture.

M 2.2.-2.3.It was a challenging task to agree on meaningful parameters and to develop common data formats in WP2 and WP6. Moreover, data collection for field trials was extremely labour-intensive. Nonetheless the careful choice of methods and their standardised assessment allowed for a data analysis across the experiments in various European countries.

M 5.1. In WP5 emphasis so far is laid on WP 5.2. Due to this, the work on the first-year experimental results is not yet completed. It was accomplished in month 24. Two years data of experiments including reduced tillage combined with green manure were submitted as a manuscript.

M 5.2. Month 14 as a milestone for calibrating the NDICEA model was too optimistic. Although the datasets and calculations were complete, the model results were somehow contradictory. Including a second year dataset from all experiments within this work package were used to assess this problem. The calibration was finished in month 32.

D 0.8 A draft of the leaflet is written, but we realised, that we have to work more closely with advisors to finalise the leaflet in order to give practical recommendations to the farmers.

As major dissemination tool to farmers, we produced a series of videos and commented slide shows on specific aspects of conservation tillage.

D 2.4. The delivery of the manuscript on reduced tillage and green manures was delayed until month 35, to allow the core group of authors to analyse and review the data and the manuscript (The MS was sent for internal review in month 29). The author list for this publication is very long (total of 28), which presents challenges when waiting for feedback and incorporating revisions from such a large group. A final version will be ready for submission to a peer-reviewed journal (Bioscience), by Nov 31, 2014.

3. Work package description and results:

WP 0	**Coordination and Dissemination**
Responsible partner: 1 FiBL Paul Mäder (PC), 2 Christophe David (PCC)	
Original description of work: *Task 0.1 Coordination* FiBL, ISARA The project organisational structure consists of a coordinator (PC), a deputy-coordinator (PCC), work package managers, a management board (MB), and a stake holder group (SG). All project participants are part of the General Assembly. The roles of each of these are described below. The Coordinator of TILMAN-ORG is Paul Mäder (FiBL). He coordinates several national projects and one international project and has participated in several EU and CORE Organic projects (Agtec-Org and Path-Organic). Christophe David (Deputy Coordinator, ISARA) currently coordinates Agtec-Org, and will transfer this experience to TILMAN-ORG. The coordinator will be responsible for project management and administration, including: (a) establishing a consortium agreement with all TILMAN-ORG partners where all tasks, milestones and deliverables are agreed, (b) ensuring efficient collaborations within the team and that all participants comply with their contractual obligations, (c) acting as the contact point between the TILMAN-ORG consortium and CORE Organic II, (d) facilitating within-project communications i.e. project website, kick-off meeting (month 3), project meetings (month 16, 33), and exchange visits among the partners and the coordinator, and (e) organisation of the report on project implementation, the interim and the final report. The WP-managers report to the co-ordinator and are fully responsible for all the tasks in their respective WPs. Within a WP each task is led by a task leader. The WP-manager guarantees that all milestones and deliverables are provided on time, and prepares scientific WP reports for delivery to the coordinator. All WP-managers are members of the management board. The Management board (MB), consisting of the coordinator, the deputy coordinator and the WP managers, monitors the effective and efficient implementation of the project, arranges the meetings and sets the agenda for meetings of the general assembly. Decisions of the MB will be taken on a consensus basis where possible and otherwise by voting, with the coordinator holding the deciding vote in the case of a tie. Work package participants (WPP), under the supervision of the WPM, will contribute to (a) the specific tasks within each work package, (b) scientific reporting on their activities to the WPM, (c) peer-reviewed publications and (d) project meetings. All WPP are members of the General Assembly. WPP will be included in decision making processes at the occasion of the general assembly. The Stakeholder group (SG), consisting of scientists, advisors and farmers from partner countries with experience and expertise in conservation agriculture and/or organic farming, will advise the management board on the general direction of the project and alert them to new developments in the field that may impact on project outcomes. The stakeholder group will be established in the first two months of the project, and will be organised by the coordinator with the help of national feedback from all TILMAN-ORG partners. *Task 0.2 Dissemination (Helga Willer)* FiBL, ISARA, WIZ, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT The aim of task 0.2 is the optimised and rapid communication of project deliverables to stakeholders through appropriate dissemination channels. These channels will include: (a) a project web site (including intranet) for dissemination of project results and publications, (b) the archiving of project publications such as articles in conference proceedings and peer reviewed publications on Organic Eprints, (c) a project brochure, (d) technical leaflets to be written by project partners and to be translated/adapted to national conditions, and (e) three articles in English, targeted to consumers/farmers/end users. In addition, the individual parts of the Handbook of Methods (WP2) will be assembled and disseminated among all	

partners via the project web folder.

Report on results obtained and changes to the original plan/WP aims:

A- results obtained:

Task 0.1 Coordination (Paul Mäder)

The following activities have taken place in TILMAN-ORG:

(a) Establishing a consortium agreement. The consortium agreement has been elaborated together with all 15 partners of TILMAN-ORG, where all tasks, milestones and deliverables were agreed.

(b) Ensuring efficient collaboration. There were mutual visits, phone and skype meetings to facilitate collaboration among partners. In particular the co-ordinator visited ORC, UB, LBI, DLO-PPO/PRI, WIZ, and received visitors from various countries (ISARA, HMGU, ILVO, CRP-GL, and FiBL-AT).

(c) Acting as the contact point between the TILMAN-ORG consortium and CORE Organic II. The co-ordinator was in contact with CORE Organic II in all relevant phases of the project.

(d) Facilitating within-project communication. The kick-off meeting in month 2 of the project (FiBL, Frick), the interim meeting in month 16 (Birmingham, in conjunction with the Organic Farmers conference), final meeting in month 34, and two monthly skype meetings with all management board members were organised (minutes on SharePoint-meetings).

(e) Organisation of the report on project implementation, interim report, and final report. The implementation report was finalised in time and posted on the TILMAN-ORG SharePoint, and the interim report was submitted in time, and accepted after revision. The final report was submitted in December 2014.

Task 0.2 Dissemination (Helga Willer)

(a) Project web site. The project website http://www.tilman-org.net/ was set-up in November 2011. It informs about the project in general, its partners, the work packages and gives access to the project publications (via Organic Eprints). Furthermore it has a link-list and a project news section, which was continually updated. The project website will be maintained by FiBL in the next couple of years.

(b) The project intranet SharePoint tool was used for the internal communication and file sharing. It has an archive that documents the partners outreach activities.

(c) Archive of project publications on Organic Eprints. Project publications are archived at http://orgprints.org/view/projects/tilman-org.html. Access is directly via Organic Eprints or via the www.tilman-org.net website.

(d) The project brochure was available as a draft in month 6 and ready in its final form in January 2013. A Dutch version was provided by the Flemish project partner (Instituut voor Landbouwen Visserijonderzoek.). The brochure can be downloaded from http://www.tilman-org.net/2443.html.

(e) Technical guides
- A technical guide on Earthworms was produced in 2014 (http://orgprints.org/26331/).
- A second technical guide on green manure and reduced tillage written by a group of contributors is almost ready.
- Furthermore a German technical guide on reduced tillage was provided by FiBL in collaboration with the TILMAN-ORG project (http://orgprints.org/26269/).

(f) Articles in English, targeted to consumers, farmers, and end users. One article describing the project and presenting first results has been published in the British farmer magazine Organic Farming (http://orgprints.org/23582/). Furthermore an article appeared in International innovation (http://orgprints.org/24401/). A third article is ready to be submitted to Ecology & Farming.

(g) A Handbook of Methods on crop, weed and soil analyses was compiled by the expert participants of WPs 2, 3 and 4 and distributed to all partners in month 5 of the project to guarantee analytical quality and comparability of results obtained in the numerous

participating institutions.

(h) At the kick-off meeting in Nov 2011 all partners presented their tasks and the work was discussed and fixed. Most of the scientific work is based on field trials of long and short duration. Each of these field trials was presented as a poster. A video was produced which can be accessed via www.tilman-org.net.

(i) The interim meeting took place on Jan 20 to 22, 2013 in conjunction with the 7th Organic Producers Conference in Birmingham. First results were presented and discussed within the consortium and also with more than 60 farmers and advisors attending the conference (2013ConferenceOverview)[1]. 15 posters from TILMAN-ORG were presented at this conference. Abstracts of all presentations are archived on Organic Eprints. A video has been produced about this workshop summarising the first results of task 2.1 and 2.3 and including statements of UK-stakeholders.

(j) In order to better reach the target groups in participating countries, videos describing the project in Italian, French and Spanish have been produced at the interim meeting in Birmingham. All videos are available at http://www.tilman-org.net/to-videos.html and on the websites of the project partners involved.

(k) A press release, which was well received, was launched at project start. Most project partners translated a version for their countries (all documented on the project intranet).

(l) Work on the address list for key stakeholders was finalised early 2014.

(m) At the Organic World Congress (Oct 13-15, 2014 in Istanbul), a TILMAN-ORG session was organised, where 13 presentations were given by TILMAN-ORG partners.

B- comments on deviations from the original plan:

Much more attention was given to dissemination activities via videos. In total, 21 short videos related to reduced tillage and green manure have been produced during the lifetime of TILMAN-ORG. 13 videos have been produced at the three project meetings. At the 1st meeting, 1 project video was produced, and at the final meeting 8 different videos in 4 different languages were produced using the English, French, Italian and Spanish project partners as narrators. The partners also provided additional pictures and clips to better visualise their activities. Eight videos have been produced on practical field demonstrations in cooperation with different Swiss partners (in German and French). The number of views varies between 500 and 12'000 for the project videos and between 2000 and 70'000 for the videos on field demonstrations depending on the language and the date of upload. This approach allowed for an efficient and low-cost production of videos for dissemination.

WP 1	**Management of mid-term and long-term experiments on reduced tillage and green manure across Europe**
Responsible partner: 1 FiBL Paul Mäder (WPM), 9 UNEW Julia Cooper (WPCM)	
Original description of work: FiBL, ISARA, HMGU, WIZ, LBI, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT Mid-term and long-term experiments on reduced tillage and green manures are a valuable tool to assess the impacts of these practices on yield, soil quality and biodiversity (1). Because these impacts are highly dependent on soil and climate, study sites have been selected in different pedo-climatic regions in Europe (Central, North-eastern, Atlantic, and Mediterranean). The goals of WP1 are to (a) give an overview of existing field trials with reduced tillage and green manures across Europe in the partner countries, including recently established trials, and (b) provide data for WP2 (meta-analysis), the case studies (WPs3-5) and WP6 (cropping system prototyping).	

[1] Organic Research Centre (2013): 2013 Organic Producers' Conference. Making producer-led innovation a reality. The website of the Organic Research Centre, Hamstead Marshall. Availlable at http://www.organicresearchcentre.com/?go=Information%20and%20publications&page=2013ConferenceOverview

Task 1.1: Short-term, mid-term and long-term trials with reduced tillage and/or green manure (Paul Mäder)
FiBL, ISARA, HMGU, WIZ, LBI, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT
FiBL will be responsible for the overview of trials represented by the partners and coordinate the selection of data on individual experiments to be included in the analysis in task 1.2. A first overview of existing trials, including 7 long-term trials (> 7 years) 6 mid-term trials (> 3 years) and 11 short-term trials) with reduced tillage and green manure has been generated by the TILMAN-ORG team during preparation of this proposal. The list will be updated during the project as partner ISARA, WIZ, CRP-GL, and UB start new experiments, and other partners such as UNEW introduce new factors into their experiments. In addition, 20 on-farm strip experiments with reduced and conventional tillage performed by FiBL, ISARA, CRP-GL, and FiBL AT will also be incorporated into the list. UB owns a data set of 22 field surveys on organic farms, identifying key factors for weed occurrence and biodiversity and crop yield, which will be exploited in WP2 and WP4.

Task 1.2: Data transfer for meta-analysis, case studies, and prototyping (Julia Cooper)
FiBL, ISARA, HMGU, WIZ, LBI, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT
UNEW will coordinate the transfer of data from all partners running short-term, mid-term and long-term trials for activities in WP2 (meta-analysis), case studies WPs3-5, and WP6 (prototyping). The TILMAN-ORG partners involved in these tasks have agreed on the requirements for a minimal data set, which consists of site characteristics, management practices and measurement data. Each individual partner will be responsible for ensuring that data is delivered from project partners to the main database managed by UNEW, on schedule.

Report on results obtained and changes to the original plan/WP aims:

A- results obtained:

Task 1.1: Short-term, mid-term and long-term trials with reduced tillage and/or green manure (Paul Mäder)
We have collected descriptions of short-term, mid-term and long-term trials that built the grounds for our research. Based on data provided by the partners, the TILMAN-ORG team decided, which existing trials fulfilled the requirements to be included in the meta-analyses (task 1.2, task. 2.3). At the kick-off meeting in Frick all experiments were presented as posters. At the interim meeting in Birmingham, results from field trials were also presented as posters. At the final TILMAN-ORG meeting in Lyon, the work process was presented orally by WP coordinators and specific tasks were presented as posters. All posters are accessible to the partners on the TILMAN-ORG SharePoint.

Task 1.2: Data transfer for meta-analysis, case studies, and prototyping (Julia Cooper)
The transfer of data from project partners was a long-lasting process. A total of ten trials for data-inclusion have been identified from the project partners. Two additional trials from affiliated partners in Switzerland and Germany have been identified, as well as a trial from Canada. An Access database has been constructed and data have been entered from all selected trials. The data were used in the meta-analysis in WP 2.
For each experiment information is collected on: site environment, number of years the experiment has been running, annual weather, treatment details including crop rotation, tillage, weed control, fertility management, and key response variables. The project has identified potential 35 response variables; however, early indications are that the variables common to most experiments, that will be suitable for meta-analysis, will be: crop yield and soil carbon (either as concentration or stocks). UNEW has also been collecting more detailed crop management information for transfer to partners in WP6, for use in system prototyping activities.

B- comments on deviations from the original plan:
Task 1.2 was delayed due to the number of partners that had to deliver large data sets. The database was finally completed by month 19, with impacted the completion of the meta-

analysis. Nevertheless, all tasks have been finalised within the project period.

WP 2	Effects of reduced tillage and green manure on crop performance (yield and quality indicators), weed management and soil quality: a state of the art analysis

Responsible partner: 9 UNEW Julia Cooper (WPM), 2 ISARA Joséphine Peigné (WPCM)

Original description of work:

FiBL, ISARA, HMGU, WIZ, LBI, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT

Peer reviewed literature on reduced tillage and green manure under organic farming conditions is extremely scarce, although there are a considerable number of on-going projects in European countries. The goal of WP2 is to assemble the existing knowledge in this research field and to publish a "state of the art analysis". For this compilation, data provided by partners of WP1 will be used in a multi-site/multi-year analysis that includes tillage, green manure and site as factors. The findings from these trials will be supplemented by the experiential data collected from farmer interviews and by findings from the peer reviewed and grey literature.

Task 2.1: Farmer interviews on the use of reduced tillage and green manure in organic farming (Joséphine Peigné)

FiBL, ISARA, *WIZ*, WUR-APR, *ILVO*, *CRP-GL*, UNEW, *CIRAA, SSSA,* UB, FiBL-AT

ISARA will lead the collection of data on farmers' perceptions about reduced tillage and the strategic use of green manures. Farmer opinions on the main risks, potential and obstacles associated with these techniques will be documented and analysed.

Task 2.2 Handbook of methods and data collection protocols for minimum data sets - part crops (Julia Cooper)

FiBL, ISARA, WIZ, ILVO, CRP-GL, UNEW, EULS, CIRAA, SSSA, UB, FiBL AT

UNEW will write a handbook of methods for collecting and reporting the minimum crop production data sets (e.g. site properties, management practices, measured response variables) from short-, mid- and long-term trials provided by WP1 (both historic and new data). Established database formats developed at UNEW will be used for collecting data, to allow for flexibility in the analytical approach.

Task 2.3 Statistical analysis of data on reduced tillage and green manure and publication of findings (Julia Cooper)

FiBL, ISARA, HMGU, WIZ, LBI, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, SSSA, UB, FiBL AT

The data collected in task 2.2, compiled in a database will be analysed using appropriate mixed effects models. This analysis will be supplemented by data from peer reviewed journals and the "grey literature". Where sufficient data is available, data will be processed in a meta-analysis (20). UNEW will be the lead author of a manuscript for a peer reviewed journal on the potential of reduced tillage and green manure practices in organic farming to maintain yields and provide ecosystem services.

Report on results obtained and changes to the original plan/WP aims:

The survey of organic farmers within this task was completed during the previous reporting period. Results were compiled and analysed and have been presented at the Organic Producers Conference in Birmingham (January 2013). Since that time, partners at ISARA have prepared two manuscripts for publication in peer reviewed journals: (1) 'Innovations in organic farming: farmers motivations and challenges for adopting conservation agriculture in Europe' by Casagrande *et al.* (resubmitted to *Agriculture and Human Values*), (2) 'How organic farmers practice conservation agriculture in Europe' by Peigné *et al.* (submitted to *Renewable Agriculture and Food Systems* journal). Main results have been presented at ISOFAR 2014 conference in October 2014.

A- results obtained:

Task 2.2 Handbook of methods and data collection protocols for minimum data sets - part crops (Julia Cooper)

This task was completed on time in the early months of the project.

2.3 Statistical analysis of data on reduced tillage and green manure and publication of findings (Julia Cooper)

A very comprehensive review of the literature on the use of reduced tillage in organic farming systems was conducted as part of this activity and combined with results from partner field trials (15 trials). This resulted in a total of 901 observation pairs being used for the meta-analysis on the effect of reduced tillage intensity (compared to deep inversion tillage) on yields in organic farming. A smaller set of data (178 observation pairs) was used for the meta-analysis where tillage intensity was reduced relative to shallow inversion tillage. Analysis was also conducted on the effects of reduced tillage intensity on weed pressure and soil C stocks in organic farming systems. Figure 1 shows one of the key results – that on average yields under reduced tillage intensity in organic farming systems are about 7% lower than when deep inversion tillage is used. The manuscript was completed in draft form ready for review by a core set of authors by month 29. Further revisions and improvements to the analysis were conducted in the subsequent months. By month 35 a full version of the manuscript was circulated to all authors (a total of 28) for comment. Currently these comments are being compiled and the final draft is being prepared. The general impression of the manuscript by authors has been very positive, and it has been agreed to submit it to a relatively high-impact journal (*Bioscience*). This submission is expected by end of October 2014.

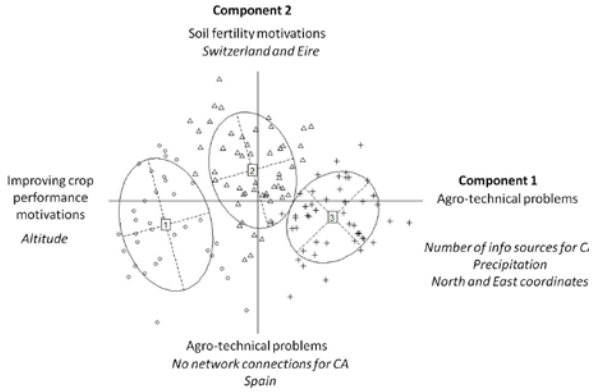

Figure 1: Distribution and grouping of the 138 farmers using reduced tillage on a PCA map. Italic variables are significant supplementary variables ($p<0.005$). Individuals from groups 1 (indifferent farmers), 2 (soil conservationists farmers) and 3 (agro-technically challenged farmers) are respectively represented by dots, triangles and crosses.

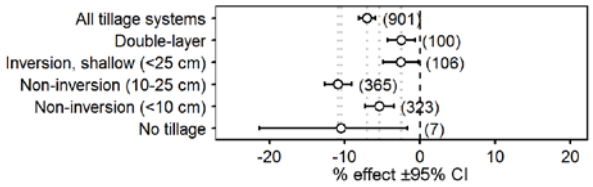

Figure 2: Overall effect of reduced tillage and effect of each tillage method relative to deep inversion tillage on: crop yields in organic farming systems. Mean values and 95% confidence intervals of the back-transformed response ratios are shown. Sample sizes (i.e. the number of control-treatment pairs) are shown on the right of the confidence intervals.

B- comments on deviations from the original plan:

As described in section 2, there have been some delays in delivery of the manuscript from the meta-analysis task due to the volume of data sourced during the process and the logistics of fairly soliciting and incorporating comments and suggestions from all authors. A manuscript ready for submission to *Bioscience* is anticipated by the end of October 2014.

WP 3	**Impact of reduced tillage and green manures on soil quality and greenhouse gas emissions**
Responsible partner: 3 HMGU Michael Schloter (WPM), 1 FiBL Andreas Fliessbach (WPCM)	
Original description of work: FiBL, ISARA, HMGU, WIZ, WUR-APR, ILVO, CRP-GL, UNEW, ORC, EULS, CIRAA, FiBL AT Reduced tillage systems and green manures mainly affect the distribution and quality of carbon and nitrogen stocks in the short term, but long-term predictions are largely unknown. The goal of WP3 is to characterize soil quality and greenhouse gas (GHG) emissions from long-term experiments of the partners (comparing reduced and conventional tillage systems and systems with or without green manures). Specifically, analysis of the interactions between management factors (rotation, tillage, fertilization and crop protection) will provide further understanding of and predictions for changes in physical, chemical and biological soil quality parameters and GHG emissions.	

Task 3.1 Minimum data set, handbook of methods - part soil (Michael Schloter)
FiBL, ISARA, HMGU, WIZ, CRP-GL
HMGU will define a minimum data set of soil quality parameters to be measured by all WP3 partners. Most methods used to assess soil quality have not been standardized, which makes comparisons between different labs difficult. Task 3.1 will define soil analysis protocols that will be used by all partners. Furthermore centralized training will provide scientists with the practical skills to perform the techniques. To monitor proper use of the methods throughout the project each year small inter-laboratory tests will be performed to cross validate the methods between the labs.

Task 3.2: Carbon stock analyses in long-term trials (Andreas Gattinger)
FiBL, ISARA, HMGU, WIZ, ILVO, CRP-GL, UNEW
Carbon stocks will be measured in different soil layers in reduced and conventional tilled plots of existing medium- and long-term trials represented by the TILMAN-ORG partners. Soil organic carbon and soil bulk density will be measured in the soil layers 0-10 cm, 10-20 cm, 20-40 cm, and 40-60 cm soil depth. The exact procedure for a harmonised sampling and analysis will be described in task 3.1. CRP-GL will analyse all soil samples of this study for soil organic carbon. A final decision on suitable sites will be made at the kick-off meeting.

Task 3.3 Case studies: Soil biota (Michael Schloter)
FiBL, ISARA, HMGU, WUR-APR, EULS, FiBL AT, *CIRAA*
To understand the impact of agricultural management on the soil biota, this task will investigate microbial functional diversity, as well as the induction of certain traits to link microbial performance to nutrient fluxes and other ecosystem services. Molecular techniques will be used to analyse the dynamics of microbial communities and their activities in time and space. In addition simple indicators will be identified to support farmers' management decisions that may impact the soil biota.

Task 3.4 Case studies: Carbon and nitrogen quality (Michael Schloter)
FIBL, ISARA, HMGU
Microbial performance and emissions of greenhouse gasses (GHG) are closely related not only to the amount of available carbon and nitrogen, but also to its quality. In this task the total amount of the different C and N pools (labile and stable) will be measured using standard techniques. In addition quality of carbon and nitrogen will be measured using fluorescence spectra as well as nuclear magnetic resonance (NMR) techniques for soil organic matter.

Task 3.5 Case studies: greenhouse gas emissions (Andreas Gattinger)
FiBL, HMGU, WUR-APR, ILVO, CRP-GL
Management practices to mitigate GHG emissions (CO_2, N_2O, CH_4) from agricultural soils are of key importance. The interactions and trade-offs between humus accumulating (i.e. carbon sequestering) practices and GHG production during organic matter decay, are poorly understood (23, 24). In this task GHG fluxes from soils in the long-term trials will be measured using closed chambers. Emissions will be quantified using (a) the long-term monitoring of GHG fluxes in the field with measurements at regular intervals and (b) event-oriented measurements after tillage, green manure incorporation, fertilisation, drying-rewetting and freezing-thawing cycles. Stable isotope techniques will be used to determine the GHG production potential of individual cover and green manure crops in crop rotations typical for organic farming systems.

T*ask 3.6 Case studies: Interactions between rotation, tillage, fertilisation and crop protection protocols (Julia Cooper)*
HMGU, CRP-GL, UNEW, ORC
The aim of task 3.6 is to elucidate the effects of the introduction of reduced tillage under different rotation and fertilisation regimes on soil organic matter dynamics and pools such as total organic carbon, hot water extractable carbon, and fractions separated by density fractionation. A long-term factorial trial at UNEW will be used, where systems with contrasting fertilisation, crop protection and rotations are established. In addition, partner CRP-GL will set up new tillage experiments, where combined tillage and green manure applications will be studied.

Report on results obtained and changes to the original plan/WP aims:

Main focus of WP3 was to describe effects of different forms of tillage management on chemical, physical and biological indicators of soil quality depending on i) tillage operations in

field trials across Europe ii) the interaction of soil management with soil depth and iii) the sensitiveness of the used methods to detect changes.

A- results obtained:

We used a hierarchical approach based on three classes of parameters allowing for a broad spectrum of sites in our *class-1* survey based on soil organic carbon and nitrogen, pH, and bulk density. This improved our understanding on direct effects of different forms of management on microbial biomass and activities (*class-2* parameters) and on microbial communities (*class-3* based on DNA and PLFA probes) at selected sites. We analysed several hundreds of soil samples from long-term and short term experiments as well as baseline analyses for field experiments at start. Soil samples were subdivided into soil layers that were defined by the applied tillage depths as well as the layer below the deepest tillage depth down to 50 cm. Sampling was done before agricultural management started in spring 2012.
The different forms of tillage management influenced carbon and nitrogen stocks at all sites (*class-1*). The gravimetric soil carbon content in top soils of reduced or no-tillage treatments was higher than under plough tillage. Volumetric or area based figures, however, lacked significance albeit higher values in reduced tillage soils. No differences were found in deeper soil horizons, which ascertained our sampling design down to the undisturbed soil layer to be appropriate.
Only long-term field trials, where different forms of tillage management had been performed for more than 8 years were selected for in depth analysis. The degree to which microbial biomass reacted to the tillage treatments was slightly more sensitive as we also found higher values for reduced and no-tillage in the deeper soil layers, but hardly ever in the layer below the deepest tillage depth (*class-2*) (Figure 3).
We selected the long-term trials Thil (FR), Frick (CH) and Scheyern (DE) for analysis of *class-3* parameters**.** They showed the strongest differences for a detailed analysis of microbial diversity. We analysed differences in bacterial and fungal communities using molecular fingerprinting approaches and phospholipid fatty acids (PLFA). Despite clear differences in carbon and nitrogen stocks in response to the different tillage forms, the overall richness of bacteria and fungi was surprisingly not affected significantly. However, in the Scheyern trial pronounced shifts in bacterial and fungal community structure among the tillage treatments were observed and also some dependence on the preceding crops. In the Frick trial only fungal communities responded to the treatments. PLFA analyses showed a similar pattern over all experiments: in the deepest soil layer communities were largely identical among the treatments, but they developed to distinct communities when looking at the soil layers close to the surface. In all analysed soils microbial community structure changed with soil depth and in the Thil trial tillage management left the microbial communities unchanged. Overall our data clearly indicate that microbial communities are highly resilient in response to the different forms of tillage management. However more data on functional traits and transcription profiles are needed to prove if these observations indicate stable turnover process and transformation rates.

As a showcase for specific functional traits of microbial communities greenhouse gas emissions were measured at Frick (CH) and Scheyern (DE) site. Emissions of CH_4, N_2O and CO_2 have been monitored over two years to analyse temporal and spatial dynamics of greenhouse gas emissions as influenced by management practice events and weather effects and the creation of an impact study comparing the minimum tillage system with the conventional tillage system. The GHG emissions were mainly related to events caused by management (slurry application, tillage) as well as temporal dynamics related to rainfall and temperature, and the pre-crop. Compost fertilisation led to higher N_2O peaks after tillage, when the mineralisation of organically bound nitrogen was stimulated. The overall yearly emissions are comparable between sites with different forms of tillage management also if the results are related to the obtained yields.

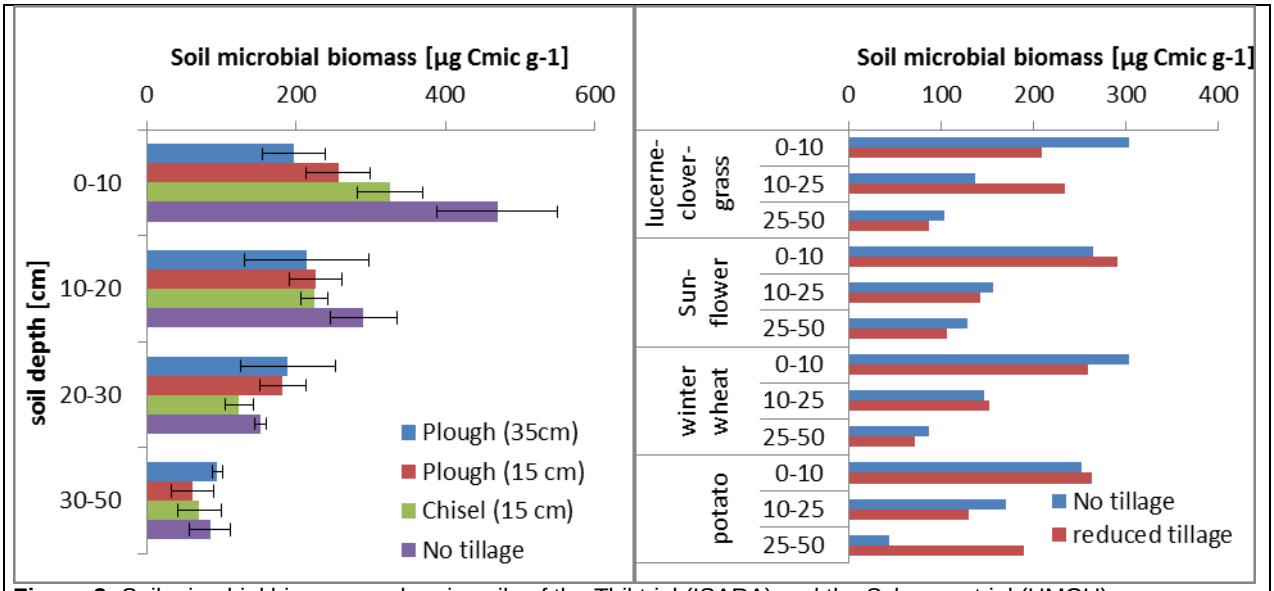

Figure 3: Soil microbial biomass carbon in soils of the Thil trial (ISARA) and the Scheyern trial (HMGU).

A reduced tillage factor was included in the Nafferton field trial comparing organic and conventional production in a fully factorial design in autumn 2011. Weed populations, crop yields and soil quality were monitored in winter barley.

B- comments on deviations from the original plan:
No major deviations from the original plan.

WP 4	**Improved weed management and functional weed biodiversity under conservation methods**

Responsible partner: 13 SSSA Paolo Bàrberi (WPM), 14 UB Xavier Sans Serra (WPCM)

Original description of work:
FiBL, ISARA, HMGU, WIZ, WUR-APR, CRP-GL, ORC, EULS, CIRAA, SSSA, UB, FiBL AT
Weed management is often the most troublesome technical problem faced by organic farmers, who commonly keep weeds under control by ploughing and post-emergence mechanical methods. Weed management is expected to become more challenging in organic systems based on reduced tillage, especially for perennial weed species. The goal of WP4 is to optimise weed management under conservation agriculture systems by adjusting three components: (a) crop sequence, including green manure/dead mulches and living mulches, (b) green manure destruction method and minimum tillage system for the subsequent cash crop, and (c) direct weed control in the cash crop. Besides weed suppression, the different technical solutions will be evaluated with respect to changes in the composition and functional role of the weed community. This will extend the evaluation of the systems regarding the support of other ecosystem services (e.g. biological pest and disease control by increased crop diversity, biodiversity and soil fertility).

Task 4.1 Weed community dynamics and functional weed biodiversity (Paolo Barberi)
FiBL, ISARA, WUR-APR, CRP-GL, EULS, CIRAA, SSSA, UB, FiBL-AT, WIZ
Weed abundance and weed community composition will be assessed in the different tillage/green manure management systems at early and late growth stages of green manures and subsequent cash crops. This will allow an evaluation of the impacts of these conservation methods on weed communities characterised by given traits (e.g. perennials). A functional analysis of weed communities based on the ability of weed species to potentially support other ecosystem services for plant production (e.g. biological pest control) or the environment (e.g. plant biodiversity, pollination) will be performed. Results will be checked against those originating from weed databases generated in long-term experiments managed by the consortium partners.

Task 4.2 Improved weed suppression by innovative machines for direct weed control (Wijnand Sukkel)
HMGU, WIZ, WUR-APR, ORC, CIRAA, SSSA, UB, FiBL-AT
Innovative machines for destruction of green manures and direct (post-emergence) weed control in

various crops like cereals, sunflower, onions and carrots in reduced tillage/cover crop (green manure/dead mulch) systems will be tested. Their effects on weed control, weed abundance, community composition and the level of soil disturbance will be assessed. Crop agronomic performance and operational/economic characteristics of the machines (e.g. working speed, energy consumption, cost per hectare, and per yield unit) will also be assessed. Furthermore a survey among the project partners' experiments and practicing farmers in the Netherlands will establish the state of the art of weed control in organic reduced tillage systems.

Report on results obtained and changes to the original plan/WP aims:

A- results obtained:

Hereafter, WP4 results are mainly summarised by focusing on the main effects of either the tillage or the green manure factor. Those trials in which both tillage and green manure were included as factors showed some significant interactions but usually no consistent pattern. Nevertheless, these interactions allowed to identify which tillage×green manure combination was 'best' at a given site and therefore are of interesting practical value (details can be found in D4.4).

Figure 4 shows that the majority of trials (16 out 30) having tillage as the only factor surprisingly resulted in non-insignificantly different weed abundance between reduced tillage (various treatments) and ploughing. Twelve trials had significantly higher weed abundance under reduced tillage whereas two of them had higher abundance under ploughing.

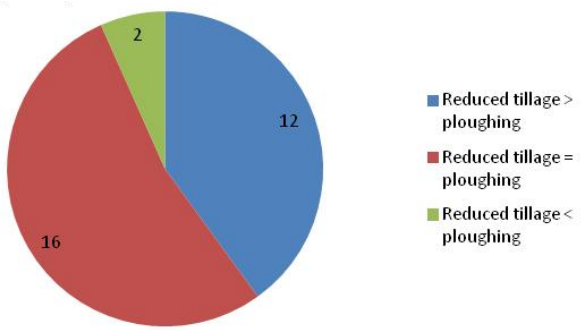

Figure 4: Differences in weed abundance in field trials.

Green manure significantly reduced weed abundance in 50% of the trials which focused exclusively on green manure as experimental factor, whereas in the other 50% there was no significant difference.

In 8 out of 14 cases there was a clear effect of tillage in differentiating weed community composition, whereas there was no clear effect of green manure. *Lamium purpureum*, *Poa annua*, *Viola arvensis*, Polygonaceae and volunteer potato were the species which turned out to be favoured by ploughing. Annual grasses, perennials and volunteer crops (especially ley crops) were typically favoured by reduced tillage. It is interesting to note that *L. purpureum*, *P. annua* and *Polygonum aviculare* in some cases came out to be also favoured by reduced tillage, thus showing a high degree of adaptation to various types of soil disturbance.

Species richness and Shannon's diversity index did not appear to be reliable indicators of the effect of tillage on weed community diversity, since they showed inconsistent trends.

Unexpectedly, in 62% of the cases in which crop yield was assessed there was no significant difference between ploughing and reduced tillage and in 2 cases yield was even higher under reduced tillage. Interestingly, this trend seems independent of trial age. The effect of green manure on crop yield was significant only in one case out of three.

In summary, the commonly accepted hypothesis that reduced tillage in organic farming should worsen weed problems and reduce crop yield does not seem to be true in many circumstances. This opens up interesting opportunities to improve the sustainability of organic cropping systems through fine-tuned use of reduced tillage and green manure, although the interactions between these two factors need to be better explored.

The unexpected results highlighted in the previous paragraph underline the scientific value of WP4 trials, especially considering the high level of coverage in terms of crops, treatments, geographical zones and environmental conditions. However, these data need to be further explored to establish possible cause-effect relationships related to e.g. crop type, age of trial and climatic conditions.

The main innovative concept stemming from WP4 results is that weeds can be reasonably

controlled in conservation tillage organic systems without jeopardising crop yield. This is a relevant finding because it is a good argument to reject one of the criticisms commonly related to organic systems, i.e. their high level of fossil fuel consumption and greenhouse gases emissions due to the continuous recourse to ploughing and cultivation, which so far has been considered a 'must' to control weeds in organics.

B- comments on deviations from the original plan:
A few trials needed some adaptations compared to the original work plan in terms of crop, number or typology of treatments, parameters assessed (type and frequency) due to unexpected local conditions or unfavourable weather pattern. These changes neither appreciably altered the overall WP4 work plan nor negatively affected outcomes, thus they can be considered as standard necessary adaptations in on field research.

WP 5	**Improved nutrient management in reduced tillage systems by use of green manures and appropriate off-farm inputs**

Responsible partner: 5 LBI Geert-Jan von der Burgt (WPM), 4 ILVO Koen Willekens (WPCM) replacing Thorsten Haase

Original description of work:
FiBL, ISARA, WIZ, LBI, WUR-APR, ILVO, CRP-GL, CIRRA
The goal of WP5 is a more rational use of green manures and off-farm inputs in reduced tillage systems to optimise N utilisation. The adoption of reduced tillage and/or green manures strongly affects N quantity and availability during the vegetative period and throughout the crop rotation. Experiments on incorporation of green manures, fodder legume crops, carbon rich composted off-farm inputs, and on- or off-farm produced N-rich plant residues will be assessed with respect to their effect on N dynamics in subsequent crops in reduced tillage systems. The effect of tillage systems and nutrient management (including green manure and fertilization treatments) on N cycling and carbon pools will be simulated using the NDICEA model.

Task 5.1: Effect of grass-clover ley, green manure and off-farm inputs on nutrient dynamics and crop performance under reduced tillage
ISARA, WIZ, LBI, WUR-APR, ILVO, CRP-GL (Geert-Jan van der Burgt)
LBI and ILVO will study the impact of green manures on N dynamics, N use efficiency and overall phosphorus balance. Different levels of clover and alfalfa will be investigated, with special emphasis given to the time and intensity of incorporation. In addition, green manures will be harvested and used as vegetal on-farm produced fertiliser. Similar questions will be addressed using an existing DLO-PPO/PRI tillage experiment and on-going studies by WIZ into the effect of different tillage systems (skim plough vs. plough) on nitrogen dynamics and crop yield. WIZ will specifically examine the response of soil C and N to both leguminous and non-leguminous green manures incorporated with different intensity and timing of soil tillage.

Task 5.2 Calibration of NDICEA for nitrogen and carbon
FiBL, ISARA, WIZ, LBI, ILVO, CIRAA (Geert-Jan van der Burgt)
NDICEA will first be calibrated for reduced tillage systems with the incorporation of green manures and off-farm inputs in The Netherlands, Belgium and Germany (data generated in task 5.1). Data from existing mid-term and long-term trials (WP1, 2) will also be used to calibrate the decision support model NDICEA for different pedo-climatic zones across Europe. This will support farmers to make more rational use of green manures and off-farm inputs. The final decision on trials to be included will be based on data quality with regard to NDICEA requirements and with respect to geographical distribution.

Report on results obtained and changes to the original plan/WP aims:

A- results obtained:

Task 5.1: Effect of grass-clover ley, green manure and off-farm inputs on nutrient dynamics and crop performance under reduced tillage
The research was conducted at nine organic farming systems trials across Europe comprising several experimental setups including tillage, green manure treatments and a combination of tillage and green manures. In all cases, experiments consisted of organic farming systems trials.

Conventional tillage consisted of annual ploughing with inversion of the soils to a depth of 20-35 cm. Conventional ploughing was considered as the control treatment and was compared to reduced tillage techniques like non-inversion chisel ploughing.
Green manure treatments were compared to a control treatment without a green manure crop. For trials included in this comparison leguminous green manure crops, or a mixture including a leguminous crop were considered.
The reduced tillage treatments resulted in lower yields at most of the sites with an average of 92% of the yields if compared to the conventionally ploughed treatments (Table 1). Only in the Netherlands, higher yields were found in the minimum tillage treatments with regard to spring wheat (107%) and grass clover (123%), showing the highest yield increases under reduced tillage. Mineral nitrogen levels in spring in the 0-30 cm layer ranged from 8 to 36 kg $N.ha^{-1}$ and were significantly lower under reduced tillage (-15%). Nitrogen use efficiencies for the different crops ranged from about 22% for the chickpea crop in Spain up to 378% for the leek crop at the Belgian site. Nitrogen use efficiency was reduced from an average of 182% to 129% in the reduced tillage conditions. This corresponded with lower yields in the reduced tillage treatments. There seemed to be a trend ($p=0.098$) to increased N-surpluses under reduced tillage.
We found equal or higher yields of the main crops if a green manure crop was grown (+8%), compared to the control treatment without a green manure crop. Barley and oats yields increased by more than 10%. No interaction of tillage×green-manure was found indicating that the green manure crop did not respond in a different way under reduced tillage conditions if compared to conventional tillage.
N-use-efficiencies, as calculated for a single season, went down from an average of 278% to 160% in treatments with green manures (Table 1). Above 100% a considerable proportion of the nitrogen originated from initial soil nitrogen mineralisation and a limited contribution from the preceding green manure crop or other fertiliser inputs. In four out of seven crops, nitrogen use efficiency was somewhat lower when a green manure crop preceded the main crop. Although yields increased in the main crop following a green manure crop, apparently not all of the (calculated) fixed nitrogen available from the preceding green manure crop was taken up by the main crop following it. For these systems, nitrogen surpluses and N-use efficiencies should preferably be discussed in a whole farm perspective and over a whole rotation.
The Estonian and the Spanish trial results indicate that effects of fertilisation on crop performance are larger than those of the green manure crop or type of soil cultivation. The results of the Dutch trial simulations give no reason to assume that soil nitrogen availability is negatively affected by minimum tillage in the organic or conventional systems. The model simulations with NDICEA showed that the effect of green manures on yield of the subsequent crop is dependent on the type of green manure and main crop. However, in the organic and conventional systems, low nitrogen availability in spring may need attention as was the case in most of the sites to prevent nitrogen shortage for the crops in spring.

Table 1: Performance statistics of yield (yield), mineral nitrogen in spring (N-min), nitrogen use efficiency (NUE) and N surplus (N-surplus) in organic farming systems trials across Europe.

	Tillage			Green Manure (GM)		
	plough	RT	*p*	-GM	+GM	*p*
Yield [% of control (RT, -GM)]	100	92	<0.001	100	108	0.001
N_{min} [% of control (RT, -GM)]	100	85	<0.001	100	128	<0.001
NUE [%]	182	129	<0.001	278	169	0.002
N-surplus [kg N ha^{-1}]	10	23	0.098	-4	37	<0.001

Task 5.2 Calibration of NDICEA for nitrogen and carbon

Nitrogen and carbon dynamics were simulated with NDICEA and the model was calibrated to experimental sites in the Netherland, Belgium, Switzerland and Italy. Based on this calibration we designed and adapted the NDICEA model (version 6.2) to cover tillage technique in the model. This newly and adapted version of the NDICEA model was tested on an additional site in Southern France.
From the simulation, no conclusive effects of reduced soil tillage on soil carbon content were found across the set of 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. We introduced tillage as a factor described by means of the overall 'decay factor' in the NDICEA model. This approach means that details like stratification within the topsoil, changes in root pattern, changes in organic matter fraction compositions, soil organisms' composition, detailed soil temperature, moisture and pH effects are described by their net effect on the 'decay', which reflects the level and detail at which processes are described in a field-like-model.
We deducted, based on a calibration procedure, a new set of decay factors for conventional, reduced and no-tillage condition with an increase from coarse sand to clay soils. However, the hypotheses that treatments with stepwise reduction for tillage can best be simulated within NDICEA using a stepwise lower decay factor could not definitely be confirmed from available data.

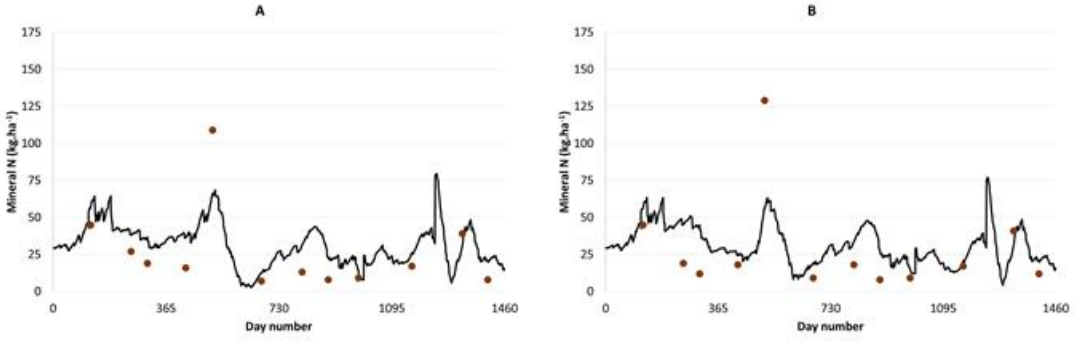

Figure 5: NDICEA-simulated (line) and measured (dots) soil mineral nitrogen in topsoil (0-30 cm) comparing ploughed (left) and reduced tillage (right) for the trial in the Netherlands.

B- comments on deviations from the original plan:
Regarding the subjects to be addressed in this work package there is no deviation from the original plan.

WP 6	**Design of sustainable conservation agriculture systems by use of knowledge-based assessment**

Responsible partner: 1 ISARA Joséphine Peigné (WPM), 6 WUR-APR Wijnand Sukkel (WPCM)

Original description of work:
ISARA, LBI, WUR-APR, CIRAA, SSSA, UB, FiBL AT
There is a need for robust cropping systems which are adapted to pedo-climatic conditions in Europe. The main objective of WP6 is to design new arable systems in organic farming including conservation agricultural techniques to preserve soil fertility and biodiversity and to enhance crop performance. The design is performed in three steps (a) prototyping of new cropping systems by researchers, (b) assessment of obtained prototypes with modelling and (c) discussion and evaluation of the prototypes with farmers and advisors. For this process we will exploit data compiled in the meta-analysis (WP2), and integrate new findings of WPs 3 to 5.

Task 6.1 Modelling and multi-criteria assessment of existing experiments (*Joséphine Peigné*)
ISARA, LBI, WUR-APR, CIRAA, SSSA, UB
Data from existing medium- and long-term experiments (WP1, 2) will be evaluated by multi-criteria methods. Assessment will focus on soil fertility (criteria defined in WP1, 2 and 3), nitrogen management (WP5), carbon sequestration, and energy use efficiency for environmental criteria, machinery, fuel, and labour costs for economic criteria and crop performance for technical criteria.

Task 6.2 Design cropping systems and farmers' assessment (*Joséphine Peigné*)
ISARA, LBI, WUR-APR, CIRAA, SSSA, UB, FiBL AT
From task 6.1, researchers will collectively design new prototypes for organic conservation farming systems. Ranking methods based on multi-criteria assessment will be used to select optimal prototypes according to specific aims and/or agro-environmental conditions (29). In some selected areas, discussion with farmers and advisors will be organized. The aim of the working groups will be to share knowledge

and skills to adapt and implement these selected prototypes for the field.

Report on results obtained and changes to the original plan/WP aims:

A- results obtained:

Task 6.1 Modelling and multi-criteria assessment of existing experiments
Six experiments were evaluated with MASC Model: Frick Tillage (FiBL), Scheyern organic (HMGU), Thil (ISARA), MASCOT (CIRAA+SSSA), Frankenhausen 1 (WIZ) and Broekemahoeve-BASIS (WUR-APR). The selection was based on the duration of the experiments (at least one crop rotation), the available data and the type of agriculture (only organic). First result concerns biodiversity conservation: in all the experiments conservation tillage tend to improve micro-fauna biodiversity compared to conventional tillage. Moreover, in four out of five experiments, macro-fauna is also improved. Biodiversity conservation is also higher in treatment with non-legume green manure in one experiment. In terms of weakness, In four out of five experiments, conservation tillage increase problems of weeds control, pest and diseases. In Broekemahoeve-basis and Thil experiment (with sandy soils), soil structure can also become problematic with conservation tillage. Only two out of five experiments show problems of economic results with conservation tillage; including trial of direct seeding in cover crop in Thil experiment. Thus, even if weeds, pest and disease are difficult to be controlled, no impacts are found in terms of profitability. P and K fertility can be problematic in Thil experiment with conservation tillage (very low level of P and K in soil) and with mixed green manure in MASCOT-experiment.

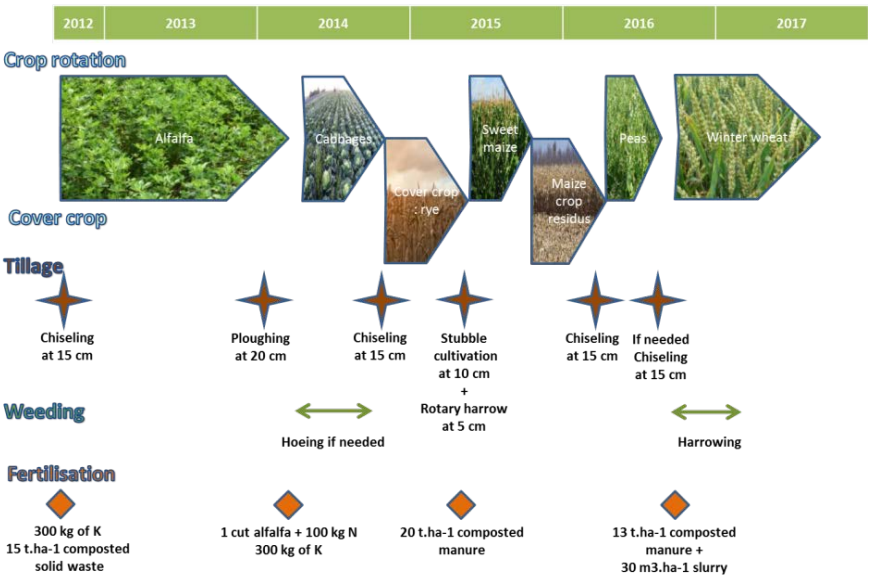

Figure 6: Detailed Western Europe prototypes with crop rotation, green manure, tillage, and weeding and fertilisation operations.

Task 6.2 Design cropping systems and farmers' assessment
During TILMAN-org project, 5 prototypes were designed and assessed. They can be defined according to climatic area where they could be applied: (1) Western, (2) Atlantic, (3) Northern, (4) Nordic and (5) Mediterranean conditions. Prototypes were designed with 19 partners during 2 workshops. Two models were used for assessing the prototypes: MASC and NDICEA. Figure 6 shows the details of Western Europe prototype. Researchers have first defined the objectives of the prototypes: (1) economic results, (2) soil quality, (3) weed control, (4) minimising nutrient losses, (5) efficient natural use and (6) on-farm N fixation. Then, they have chosen the crop rotations according to the defined strategy: competitive crops for economic results (cabbages, maize, winter wheat), and also row crops for weed control (such as maize). On a 6 years crop rotation, 3 years present legumes for maximising on farm N. On the whole rotation, soil is ploughed one time for destroying alfalfa. For all the other crops and green manures, reduced tillage such as chiselling is used. During the first design workshop, compost and crop residues

were added to the soil for improving OM content. Figure 6 shows that researchers also added K fertilisation but in a second step after MASC model evaluation. Indeed, the first prototype was assessed with MASC model, and during the second workshop, they added modifications for improving it. One of the main problems was the P and K fertility of soil (very low). Thus, researches slightly modified the prototype with more mineral fertilisation and also slurry applications. Main strengths of prototype are a good profitability, maintenance of OM content and high biodiversity conservation. Main weaknesses are high N leaching and energy stress.

B- comments on deviations from the original plan:
Regarding the original plan, we decided to organize 2 workshops: one on prototyping and a second one on the evaluation and the re-design of the prototypes. More partners than expected have been involved in WP6. Farmers cropping systems evaluation was done in France but not in all the countries thus we didn't use it. Regarding prototyping method dissemination, Luxemburg partner is interesting in disseminating the method in their country. Prototypes will be discussed with stakeholders in each country thanks to the technical leaflet done at the end of the project (see WP0).

4. Publications and dissemination activities

4.1 List extracted from Organic Eprints

Armengot, Laura; Berner, Alfred; Blanco-Moreno, José Manuel; Mäder, Paul und Sans, F. Xavier (2014) Long-term feasibility of reduced tillage in organic farming. *Agronomy for Sustainable Development*. ONLINE. http://orgprints.org/26861/

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4.2 Additional dissemination activities (Events, chronological)

Date	Title	Location	Description	TILMAN-ORG partner
22.03.2011	Field day	Pétange	Field day organised	Centre Gabriel Lippmann (CRP-GL) and Institute of Organic Agriculture (IBLA)
18.01.2012	Organic Producers' Conference 2012	Birmingham UK	The project was introduced to arable farmers and vegetable growers in a workshop at the conference and initial questionnaires used to gather information and enable follow-up with final questionnaire.	UNEW
10.02.2012	TILMAN-ORG study day[2]	Pisa, Italy	Giornata di studio sul tema TILMAN-ORG/TILMAN-ORG study day February 10, 2012 in Pisa	Centre for Agro-environmental Research "Enrico Avanzi" - University of Pisa (CIRAA) - Scuola Superiore Sant'Anna (SSSA)
28.03.2012	Stakeholder meeting on reduced tillage in organic farming[3]	Beringen, Luxembourg	Stakeholder meeting and presentation of the TILMAN.ORG project	CRP and IBLA - Centre Gabriel Lippmann and Institute of Organic Agriculture
27.06.2012	Bioveldday 2012. Organic field day[4]	Lelystad, prof Broekemahoeve, The Netherlands	Organiser: PPO-agv; with various soil topics including reduced tillage and green manures. Approx. 250 participants.	WUR and LBI - Wageningen University and Research Centre and Louis Bolk Institute
05.07.2012	Organic Arable Event 2012	Blandford, Dorset, UK	Organic Arable Event. Discussion with farmers on stand to encourage engagement with the TILMAN-ORG project, discussion of questionnaires and details of machinery and rotations and green manures used.	UNEW
17.08.2012	Praktijkdag bodem, Farmers field day on soil management[5]	Vredepeel, The Netherlands	Organiser: PPO-agv. Various presentations on reduced tillage and green manures. Field visit to experiments 'soil quality on sandy soils, which are part of the TILMAN-ORG project; approx. 250 visitors	WUR - Wageningen University and Research Centre
29.08.2012	Organic farming research day of the Research Centre of Organic Farming of the EULS	Research Centre of Organic Farming of the Estonian University of Life Sciences	The paper "Organic cropping systems - influence of green manures on crop yields and soil properties in the TILMAN-ORG experiment of EULS" was presented by Anne Luik at the Organic farming research day of the Research Centre of Organic Farming of the EULS, 29.08.2012. The day hat 45 participants.	Estonian University of Life Sciences
02.09.2012	Kennisdag bodem; Knowledge day soil. Symposium for advisors and	Ysselsteyn, The Netherlands	Organiser: PPO-agv. 100 visitors, Several presentations on soil management and workshop on reduced tillage	WUR - Wageningen University and Research Centre

[2] http://projects.fibl.org/tilman-org/Promotional%20material/2012-02-10-tilman-giornata-pisa.pdf
[3] http://projects.fibl.org/tilman-org/Promotional%20material/gabriel-lippmann-2012-invitation.pdf
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	intermediates on soil management[6]			
08.09.2012	Family University of the EULS	Estonian University of Life Sciences	Presentation "Use of green manures for the soil improvement" by Anne Luik at the Family University of the EULS, 08.09.2012, 35 participants.	Estonian University of Life Sciences
21.09.2012	Field day for local farmers	Scheyern, Germany		Helmholtz Zentrum München
20.10.2012	TILMAN-ORG field day in Flanders[7]	Gontrode, Belgium	TILMAN-ORG field day in Flanders ILVO, Belgium	Institute for Agricultural and Fisheries Research (ILVO)
08.11.2012	Estonian organic farming conference "Development of organic farming – from science to organic farming" (Teaduselt mahepõllumajandusele), [8]	Estonian University of Life Sciences	At the event Estonian organic farming conference "Development of organic farming – from science to organic farming" (Teaduselt mahepõllumajandusele), on 08.11.2012, 225 participants, a number of papers on TILMAN-ORG were presented.	Estonian University of Life Sciences
22.01.2013	"Using reduced tillage and green manures in organic systems – what is the research telling us?", Organic Producers' Conference 2013	Birmingham UK	Workshop at the producers' event to report and discuss findings so far.	UNEW
22.02.2013	Organic Producers' Conference [9]	Birmingham UK	Presentation by Julia Cooper about the 12 long-term trials around Europe	Nafferton Ecological Farming Group
26.02.2013	Farm walk	Kirkby Fleetham, North Yorkshire, UK	Farm walk and report and discussion of TILMAN-ORG findings so far with farmers	UNEW
26.02.2013	Farm walk in North Yorkshire[10]	North Yorkshire , UK	Presentation by Julia Cooper about the UK survey and the trials at Newcastle University's Nafferton Farm. Farm walk and report and discussion of TILMAN-ORG findings so far with farmers.	Nafferton Ecological Farming Group
14.03.2013	Data discussion with BIOLAND stakeholders	Scheyern, Germany		Helmholtz Zentrum München
17.04.2013	Field day: innovations in machines for the management of green manures[11]	San Piero a Grado, Pisa, Italy	On April 17, 2013, a field day was held at CIRAA in order to show Italian stakeholders three different techniques for the termination of a green manure crop of barley and vetch. The event was structured in a quick session in the meeting room of CIRAA, where the main issues of the TILMAN-ORG project were presented, followed by the field demonstration of three different machines. The machines compared were: a) disk harrow; b) stone-burier; c) crimper-roller. The main advantages and disadvantages of each machine were highlighted directly in the field and discussed with the stakeholders.	Centro Interdipartimentale di Ricerche Agro-Ambientali (CIRAA) and Scuola Superiore Sant'Anna (SSSA)
29.05.2013	Feldbegehungen Wintergetreide-	Naturhaff der Familie Mathieu	Winter cereal variety trial in organic farming	IBLA

[6] http://www.tuinbouw.nl/sites/default/files/Uitnodiging%20Kennisdag%20Vruchtbare%20zandgronden%209%20feb%202012.pdf
[7] http://www.tilman-org.net/1768.html?&tx_ttnews%5Btt_news%5D=877&cHash=c1e2e4b1782d2530aab75d80f4304277
[8] http://mahekeskus.emu.ee/uudised/mahekonverents-2012
[9] http://www.nefg-organic.org/nefg-researchers-present-tilman-org-results-in-birmingham/
[10] http://www.nefg-organic.org/organic-farm-walks/
[11] http://projects.fibl.org/tilman-org/Promotional%20material/Invito%20Evento%20TILMAN%2017%20apr.pdf

	Sortenversuch im biologischen Anbau	(Derenbach, maison 95)		
04.06.2013	Farm Walk for farmers, 2013	Sinderby, North Yorkshire, UK	Farm walk and discussion with farmers and advisers on the combinations of rotation and reduced tillage options in organic farming.	UNEW
05.06.2013	Feldbegehungen: Wintergetreide-Sortenversuch und Körnerleguminosen-Artenversuch im biologischen Anbau	Karelshaff der Familie Colling-von Roesgen (Colmar-Berg)	Grain legumes species trial	IBLA
26.06.2013	Farm walk for soil researchers and advisers and discussion of TILMAN-ORG findings	Nafferton Farm, Stocksfield, UK	Introduction to Nafferton Farm & some results from the long-term organic versus conventional plots, Northern Soils Network Summer Meeting 2013	UNEW
26.06.2013	TILMAN-ORG field day[12]	Inagro, Rumbeke-Beitem, Belgium	Celeriac crop performance under different tillage practices and with different doses of a cut-and-carry fertilizer was presented during an Open Field Day; trial results of 2012 were discussed as well (Title: Bezoek TILMAN-ORG veldexperiment op Inagro in het kader van een Open Velddag)	ILVO, Inagro
02.07.2013	Organic Arable Event 2013	Shifnal, Shropshire, UK	Organic Arable Event. Discussion with farmers on stand about reduced tillage and weather conditions at crop establishment.	UNEW
05.09.2013	Bioveldday 2013. Organic field day[13]	Lelystad, prof Broekemahoeve, The Netherlands	Organiser: PPO-agv; With various soil topics including reduced tillage and green manures. Approx 300 visitors. Target Group: Farmers	WUR and LBI - Wageningen University and Research Centre and Louis Bolk Institute
09.09.2013 [14]	Excursion to 'Kollumerwaard'	Groningen, Netherlands	The 'Planty Organic'farming system was presented to a group of 30 organic Danish farmers. This farming system is based on cut-and-carry-fertilizers and being tested at experimental farm Kollumerwaard	LBI - Louis Bolk Institute
18.09.2013	Tech and Bio[15]	Valence, France	Tech and Bio is a tradeshow in France with 10 000 visitors (organic farmers, advisors, researchers). We presented the TILMAN-ORG project and experiments during the 2 days (posters and discussion with visitors).	ISARA Lyon
02.10.2013	TILMAN-ORG field day	Inagro, Rumbeke-Beitem, Belgium	Celeriac crop performance under different tillage practices and with different doses of a cut-and-carry fertilizer was presented during an Open Field Day (Title of event: Bezoek TILMAN-ORG veldexperiment op Inagro in het kader van een Open Velddag)	ILVO, Inagro
08.10.2013	TILMAN-ORG field day[16]	ILVO, Melle-Merelbeke, Belgium	Celeriac crop performance under different tillage practices and with different doses of a cut-and-carry fertilizer was presented to organic growers in the frame of a network meeting; trial results were presented and the use of cut-and-carry fertilizers was	ILVO, Inagro

[12] http://www.inagro.be/ophalen_popup.aspx?lijst=Professioneel&ID=283
[13] http://www.biokennis.org/nl/biokennis/showagenda/Biologische-Velddag-1.htm
[14] http://www.inagro.be/ophalen_popup.aspx?lijst=Professioneel&ID=306
[15] http://www.tech-n-bio.com/
[16] http://www.bioforumvlaanderen.be/sites/default/files/BBNgroenten131008bv_0.pdf

			discussed (Title: Bezoek TILMAN-ORG veldexperiment op ILVO in het kader van een Biobedrijfsnetwerk groenten-akkerbouw)	
11.10.2013	Field day for local farmers	Scheyern, Germany		Helmholtz Zentrum München
04.11.2013	Visit to the De Angeli Trial	De Angeli Trial, University of Pisa	On November 4, 2013, CIRAA and SSSA organized a visit to the on-farm experiment included in the TILMAN-ORG (the so called "De Angeli Trial") for the participants of the SMARTSOIL FP7 EU project (http://smartsoil.eu/) at the occasion of the their annual meeting in Florence. The project deals with the improvement of soil fertility in the optics of climate change mitigation. Attenders were scientists (including also Jørgen E. Olesen, the coordinator), policy makers, extensionists, willing to meet Italian farmers applying conservation agriculture techniques in order to have their point of views on bottlenecks, opportunities, etc.	Centro Interdipartimentale di Ricerche Agro-Ambientali (CIRAA) and Scuola Superiore Sant'Anna (SSSA)
22.01.2014	Organic Producers' Conference 2014	Birmingham UK	Discussion with producers on stand and in workshops about the TILMAN-ORG findings and ongoing research.	UNEW
05.02.2014	Annual Meeting of the farmers in the Network on soil and climate friendly arable farming	Western Switzerland	Presentation of the TILMAN-ORG Project at the annual Meeting of the farmers in the Network on soil and climate friendly arable farming (Wintertagung der BKBA-Landwirte der Westschweiz; BKBA = boden- und klimafreundlicher Bioackerbau)	Research Institute of Organic Agriculture (FiBL)
22.03.2014	Field day	Pétange. Luxembourg	Field day with presentation of stubble cleaner and how to measure green house gas emissions organised by CRP Gabriel Lippmann und IBLA Präsentation von Stoppelhobel und Treibhausgasmessungen im Feld organisiert von CRP Gabriel Lippmann und IBLA	CRP and IBLA - Centre Gabriel Lippmann and Institute of Organic Agriculture
27.03.2014	Meeting of farmers participating in the TILMAN-ORG project	Frick, Switzerland		Research Institute of Organic Agriculture (FiBL)
09.04.2014	Farm Walk for Early Stage Researchers	Nafferton Farm, Stocksfield, UK	Farm walk and report and discussion of TILMAN-ORG findings so far with early stage researchers and farm advisers.	UNEW
17.04.2014	Machine demonstration[17]	Choulex, Switzerland	Skimmer plough demonstration (5 ploughs) in collaboration with the TILMAN-ORG project; 70 participants	Research Institute of Organic Agriculture (FiBL)
29.04.2014	Field visit of French organic advisors and researchers	Thil, France	We presented the Thil experiment and TILMAN-ORG to a group of French advisors and researchers (30 people) in the framework of a national project.	ISARA Lyon
01.05.2014	"Effects of reduced tillage in organic farming systems on yield, weeds and soil carbon: a meta-analysis of published and unpublished data"	Oxfordshire, UK	Presentation to the Organic Arable Farmers' Group	UNEW
04.06.2014	TILMAN-ORG stakeholder meeting and field day[18]	CIRAA Centro d'Ateneo di Ricerche Agro-Ambientali	On June 4, 2014, the Italian stakeholders meeting, organized by CIRAA and SSSA, took place (Agricoltura biologica e conservativa: problematiche a confronto). The meeting with stakeholders and the field day was a joint event for the dissemination of	Centro Interdipartimentale di Ricerche Agro-Ambientali (CIRAA) and Scuola Superiore Sant'Anna (SSSA)

[17] http://www.bioactualites.ch/fr/cultures/grandes-cultures-bio/travail-sol/charr-dechaum-avril-2014.html
[18] http://www.avanzi.unipi.it/comunicazione/convegni/incontr_agricoltura_bio_e_conservativa_04_05_2014/giornata_agricoltura_bio_e_conservativa.htm

		"Enrico Avanzi" –, University of Pisa, Italy	the results of several projects dealing with conservation agriculture and organic farming, the organizers are involved in. For TILMAN-ORG, stakeholders were given a picture of the main results of our activities in the project and, at the same time, further developments of the research in this field were discussed (in the same way as done in 2012). Key moments were the presentation of the results of WP4 experiments (Stefano's presentation) and of the farmer survey conducted within WP6 by ISARA (Federica's presentation).	
27.06.2014	Field day of the network of soil and climate friendly arable farming	Kanton of Vaud, Switzerland	Field day of the FiBL network of soil and climate friendly arable farming in collaboration with the cantonal advisory Service of Vaud and the TILMAN-ORG project; 8 participants	Research Institute of Organic Agriculture (FiBL)
01.07.2014	Organic Arable Event 2014	Bletchley, Berkshire, UK	Discussion with groups of organic farmers on their use of reduced tillage and green manures.	UNEW
21.07.2014	Farm Walk for farmers, 2014	Nafferton Farm, Stocksfield, UK	Farm walk, report and discussion of TILMAN-ORG findings with farmers and advisers.	UNEW
12.08.2014	Field day on direct sowing	Flaach , Switzerland	FiBL field day on direct sowing in collaboration with the TILMAN-ORG project; 40 participants	Research Institute of Organic Agriculture (FiBL)
20.08.2014	Field day on reduced tillage	Grosswangen, Switzerland	FiBL field day on reduced tillage in collaboration with the TILMAN-ORG project	Research Institute of Organic Agriculture (FiBL)
18.09.2014	Farm excursion & presentation	Munnikezijl, Groningen, Netherlands & Ens, Flevoland, Netherlands	Farm visit to two organic farms with extensive experience with cut-and-carry-fertilizers & presentation of results of WP5 of TILMAN-ORG for approximately 20 organic Danish and 8 Dutch conventional farmers	LBI - Louis Bolk Institute
10.10.2014	Field day for local farmers	Scheyern, Germany		Helmholtz Zentrum München
06.11.2014	Fachtagung für biologische Landwirtschaft 2014, 06. November 2014, LFZ Raumberg-Gumpenstein[19]	LFZ Raumberg-Gumpenstein	Tagungspunkt: Ergebnisse aus transnationalen Forschungsarbeiten zur biologischen Landwirtschaft Vortrag: ERA-NET CORE Organic II: Reduzierte Bodenbearbeitung und Gründünger für nachhaltige Anbausysteme im biologischen Landbau, Andreas Surböck, FIBL Österreich, Wien.	FiBL Austria

[19] http://www.raumberg-gumpenstein.at/cm4/de/homepage/158-aktuelles/veranstaltungen/4965-fachtagung-fuer-biologische-landwirtschaft-06-11-2014.html

4.3 Planned conference papers:

Title of paper	Authors	Institution and e-mail address of first author	Name of conference	Place/Venue of conference	Date of conference	Poster or oral presentation	Link to presentation (or conference website)	Status (submitted / accepted)
Der kurzfristige Einfluss von drei Zwischenfruchtarten und zwei verschiedenen Bodenbearbeitungen auf Frühjahrs-N_{min} und Hauptfruchtertrag	Grosse, Meike und Heß, Jürgen	Universität Kassel, meike.grosse@uni-kassel.de	13. Wissenschafts-tagung Ökologischer Landbau	Eberswalde	Mar 17-20, 2015	?	http://www.wissenschaftstagung.de/	In preparation
Metagenomic analysis of different forms of tillage management reveals no differences in the diversity of cellulose degrading microbes in soil	De Vries, Maria, Schöler, A; Schloter, M	Helmholtz Zentrum München; maria.devries@helmholtz-muenchen.de	ISME Conference	Seoul /South Korea	Aug 24-29, 2015	Poster	http://www.isme-microbes.org/isme15	
Green manures as winter cover crops improve soil and crops yields (In Estonian)	Liina Talgre, Viacheslav Eremeev, Anne Luik	Estonian University of Life Sciences anne.luik@emu.ee	Estonian organic farming conference	Tartu Estonia	Nov 20, 2014	Oral		
Green manures control weeds in crop rotation (In Estonian)	Helena, Palmeos, Liina Talgre; Vyacheslav Eremeev; Anne Luik	Estonian University of Life Sciences helena.palmeos@emu.ee	Estonian organic farming conference	Tartu Estonia	Nov 20, 2014	Poster		
Green manures impact on product quality (In Estonian)	Darja Matt, Vyacheslav Eremeev; Anne Luik	Estonian University of Life Sciences helena.palmeos@emu.ee	Estonian organic farming conference	Tartu Estonia	Nov 20, 2014	Oral		
Green manures influence on arbuscular myccorrhiza development in potato (In Estonian)	Eve Runno-Paurson	Estonian University of Life Sciences eve.runno-paurson@emu.ee	Estonian organic farming conference	Tartu Estonia	Nov 20, 2014	Poster		
Impact of green manures as winter cover crops on winter wheat yield and quality (In Estonian)	Viacheslav Eremeev, Anne Luik	Estonian University of Life Sciences anne.luik@emu.ee	Estonian organic farming conference	Tartu Estonia	Nov 20, 2014	Poster		

4.3 Further possible actions for dissemination

- List publications/deliverables arising from your project that Funding Bodies should consider disseminating (e.g. to reach a broader audience)

  We consider the technical notes that were produced during the project – one on reduced tillage and one on earthworms (http://orgprints.org/26331/) - worth dissemination.
  We feel that we have already disseminated the project findings via various channels.

- Indicate publications/deliverables that could usefully be translated (if this has not been done, and indicate target language)

  See above.
  The leaflet on earthworms could be translated to French and Spanish.
  Pfiffner, Lukas (2014). Earthworms – Architects of fertile soils. Technical guide. Research Institute of Organic Agriculture, CH-Frick.

4.4 Specific questions regarding dissemination and publications

- Is the project website up-to-date?

  The project website has been continually updated for partner information, news and publications (via Organic Eprints). Videos were continually uploaded. Now that the project is finished, a note will be made that the page will not be updated anymore and further necessary adaptations will be made.

- List the categories of end-users/main users of the research results and how they have been addressed/will be addressed by dissemination activities

  A wide range of end users were reached with the dissemination activities. The technical notes, videos, articles the farmers' press, numerous field days, and the stakeholder events, which were organised by the project partners, targeted farmers, advisors, the machinery industry as well as scientists. Dialogue with scientist took place for instance at the TILMAN-ORG session and poster presentations at the Scientific Conference at the 18th Organic Word Congress in Istanbul. Furthermore, the TILMAN-ORG partners presented their results at scientific conferences. Policy makers were addressed with the article on the project in the magazine "International Innovation.

  Researchers: Peer review publications and Conference Proceedings have been published and further articles will be published.
  The knowledge generated in TILMAN-ORG has been communicated in various conferences in Europe. Moreover TILMAN-ORG results were also presented in US at the occasion of an international conference "Innovations in Organic Food Systems" in Long Beach, California. The TILMAN-ORG coordinator was also invited for an oral presentation at the Annual Meeting of the Soil Science Society of America in Long Beach.
  A positive impact of TILMAN-ORG is also the fact that members were invited to be partner in Horizon 2020 consortia, e.g. in the call SFS 4 "Soil quality and functions" (project selected and contract negotiations started), and in the SFS 2B call "Soil improving cropping systems" (submission pre-proposal in 2015). Moreover TILMAN-ORG members elaborated a proposal in the frame of the COII+ call, and the proposal was selected for funding after evaluation by an expert panel. The two new projects

clearly show that TILMAN-ORG has been well received by the scientific community, in particular also in the non-organic farming research domain.

Farmers and advisors: Articles in farmers press, videos, commented slide shows were produced. Moreover field days and workshops with farmers were organised. In technical leaflets, information was condensed. Results were also presented at farmers conferences.
Based on the number of clicks on TILMAN-ORG videos there is a huge interest in the outcomes of the project. The very well visited farmers' field days (up to 1000 visitors) show that farmers have been reached to a high degree.

Policy makers: An article in International innovations has been published. For instance in Switzerland, TILMAN-ORG members were invited to elaborate subsidy schemes to support farmers who apply reduced tillage under organic farming conditions.
TILMAN-ORG members were invited to elaborate subsidy schemes to support farmers who apply reduced tillage under organic farming conditions. This shows that TILMAN-ORG has become influential at the policy level.

Machine industry: Prototypes of new machines like the "Roller Crimper" were jointly developed with the machine industry. Machine industry was invited at several occasions to present the latest developments of new and innovative machines for tillage and weed control in various countries.
There were strong interactions with the machine industry, and in Europe, a series of new equipment for basic soil tillage, seed bed preparation and weed control has been developed and marketed.

Society: Newspaper articles informed the public on new developments in conservation agriculture
We experienced that the interest of the public in aspects of soil conservation and climate mitigation as well as in aspects of the maintenance of biodiversity is astonishingly high. This was for instance the case at the open days of FiBL Switzerland in 2013, where 4000 visitors were informed on pros and challenges of reduced tillage in organic farming. The TILMAN-ORG web page was constantly up-dated during the projects life span, and will be maintained in the next years.

- Impact of the project in relation to main beneficiaries of the project results
(Note: for the different categories of end-users/main users of the research results, explain how well the project has been able to reach these target groups, and any known impact)

Through the numerous events, publications and videos the project results have been made available in an easily accessible way to the target groups, and the project results related to the feasibility of reduced tillage have thus already found their way into agricultural practice.

5. Added value of the transnational cooperation in relation to the subject

- The TILMAN-ORG project pushed forward the idea of joining two ways of more sustainable agriculture: organic farming and conservation agriculture.
- The TILMAN-ORG project was the only project at the ISOFAR/IFOAM conference in Istanbul 2014, with a special session, offering visibility in the scientific community, and attracting a large audience.
- The scatted knowledge on reduced tillage and green manures in Europe was assembled and has been disseminated by various channels.
- The critical mass in various research disciplines was reached thanks to TILMAN-ORG.

- PhD students and young scientists experienced the fruitful collaboration in a European network project, which was both trans- and interdisciplinary.
- The project allowed working at various levels: on-farm, applied, and basic research thanks to its competences present in the team.
- TILMAN-ORG made use of a series of long-term and mid-term experiments in Europe, which manifests clearly an added value for the consortia, but also for all contributing partners.
- Methods were standardised across Europe and new field experiments were established in a coordinated way. Following this approach, results achieved are comparable and data can be integrated and analysed in a meaningful way.
- Published and unpublished data on reduced tillage across Europe was analysed by meta-analysis software and more specific insight was gained on potentials and challenges of conservation strategies in various pedo-climatic zones of Europe. Findings were targeting key topics such as yield, weeds and carbon stocks as related to climate mitigation. This was only possible due to the European Network project.
- A new, research gap filling COII+ project (FertilCrop) was funded, focussing on interactions of biological and physical soil properties, and on the rhizosphere. This demonstrates that the outcomes of TILMAN-ORG are relevant at EU level.
- Other new co-operations were established at EU level (e.g. the Horizon 2020 project SFS 4 iSQAPER), but also national grants were obtained with TILMAN-ORG as a reference (e.g. project on soil and climate friendly agriculture in Switzerland, funded by Coop Switzerland).

ANNEX 1: CHANGES IN WORK PLAN AND PROBLEMS ENCOUNTERED

Changes in consortium and work plan

- Thorsten Haase left for a new position and his role in TILMAN-ORG as a WP-co-coordinator of WP5 was taken over by Koen Willekens. His role as a contact point at WIZ has been taken over by Meike Grosse.
- Geert-Jan van der Burgt decided to leave LBI for a new job in a late phase of the project and Chris Koopmans did the final part of WP5.
- Andreas Gattinger resigned on coordination activities in TILMAN-ORG, but was still responsible for the part related to greenhouse gas emissions. Andreas Fliessbach became the co-coordinator of WP3.

Problems encountered, delays and corrective actions planned or taken, if any:

No major problems were encountered. The postponement of some activities (e.g. experimental activity on N dynamics for WP5) to the second part of the lifetime of the project, has led to reduced time and human resource availability, limiting the exploitability of the results.

ANNEX 2: COST OVERVIEW AND DEVIATIONS FROM BUDGET

Project budget and costs in € (if in National currencies, please indicate):

Partner no.	1	2	3	4	5	6	7	8
TOTAL BUDGET	87000	166270	123842	145371	75000	75000	70000	400001
Spent at Mid term	43295	102000	50661	78339	31043	37875	31570	118654
Spent in 2nd period	50500	64444	83517	72497	91115	37125	43630	303785
TOTAL SPENT	93795	166444	134177	150836	122158	75000	75200	422439
DEVIATION	6795	174	10335	5465	47158	0	5200	22438

Partner no.	9	10	11	12	13	14	15	
TOTAL BUDGET	189000	49899	93000	75090	75090	65456	99720	
Spent at Mid term	71552	26016	48173	49281	50010	23093	44481	
Spent in 2nd period	157297	27770	44827	26594	25080	42363	54205	
TOTAL SPENT	228849	53786	93000	75875	75090	65456	98686	
DEVIATION	39849	3887	0	785	0	0	-1034	

Person months (PM) spent on the project:

Partner no.	1	2	3	4	5	6	7	8
TOTAL PM budgeted	50	28	36	36	4	6	15	37
Spent at Mid term	25	15	18	16	2	3	7	9
PM spent in 2nd period	27	16	17	20	5	4	10	30
TOTAL PM SPENT	52	31	35	36	7	7	17	39
DEVIATION	2	2	-1	0	3	1	2	2

Partner no.	9	10	11	12	13	14	15	
TOTAL PM budgeted	28	9	36	40	40	27	14	
Spent at Mid term	10	7	18	24	24	12	7	
PM spent in 2nd period	22	6	18	16	16	15	8	
TOTAL PM SPENT	32	13	36	40	40	27	15	
DEVIATION	4	4	0	0	0	0	1	

Reasons for major deviations in spending compared to original budget:

Additional synthesis activities including an overall statistical analysis, a full synthesis report and synthesis paper led to an additional workload and time spending of WP5 coordinator LBI.
Partner 2: we don't have all the invoices of ISOFAR Istanbul meeting. Our final costs could be modified.

ANNEX 3: Recommendations to the CORE Organic consortium in relation to launching and monitoring of future transnationally funded research projects

- In our understanding, the calls are relatively broad. This bears a certain risk that too many topics are integrated in one project. This is in a way positive, since it favours the more holistic view of organic farming rather than concentrating in topic research. On the other hand it bears the risk of too much dilution of funds and manpower to the variety of subjects addressed in a project. Moreover too many research groups may apply for a certain call, questioning the total work load for proposal development as related to the available funds.
- The funds for some partner countries are small. If only little own funds can contribute, some partners may not perform according their potential and capacities.
- Three years projects are short for field research, since we need at least two experimental years. We suggest having the opportunity to submit projects with duration of 4 years.
- There should also be a pot for the coordination costs, in the range of 5 to 7 percent of the requested amount from the CORE Organic.
- Although we feel that the CORE Organic funding scheme has some potential to be improved, we very much appreciate the research program.