SNOWMAN NETWORK

Knowledge for sustainable soils

Project number SN03 – 14

SUSTAIN

Soil Functional Biodiversity and Ecosystem Services, a Transdisciplinary Approach

Midterm Research Report

Start date of project: 01/10/2011

Project duration:
36 months (year1)

End date of project: 30/09/2014

Date of report: 07/10/2012

Project coordinator:

Daniel Cluzeau

Name of coordinator organisation: University of Rennes 1 (UR1)

Revision:

Abstract

SUSTAIN project aims to understand how reduced tillage systems impact on soil functional biodiversity and soil functions (e.g. soil structure, water regulation, filtering and pest regulation), to quantify the consequences on the soil ecosystem services, to investigate the socio-economic sustainability of these systems and to develop and disseminate tools to stakeholders. It involved 6 teams, 3 from France and 3 from the Netherlands. This midterm research report reflects the tasks realized during the first year (2011-2012), the first results obtained and SUSTAIN management. It also presents the plan for the second year.

During this first year, two main tasks were planified in supplement to the coordination, i.e. field campaign and dissemination. Concerning the coordination, 6 meetings were done in order (i) to meet each other and to meet ECOSOM project partners, (ii) to organize the sampling campaign, and (iii) to supervise students. Sampling campaign were realized in the Netherlands and in France in order to characterize the biological and physical states and also to compare the different methods used by each partners. Results obtained in France showed that in trends reduced tillage systems (reduced tillage or direct seeding) could impact positively on biological (earthworm community) and physical (soil porosity, soil aggregate stability, water conductivity, macroporosity) states. However, the high variability of the results combines with many contradictory results, prevent us to conclude on the impact of reduce tillage system on soil biological and functional state. Moreover, results from this year are not in accordance with previous results obtained on the same trials. These contradictory results could be explained by i) the dryness conditions before and during sampling time, ii) the previous crop (crop rotation) which could strongly impact on soil and perhaps could interfere with the tillage effect. Under Dutch site, biological data are still under treatment; physical data show that water conductivity is improved under conventional ploughing. In order to confirm or infirm the results obtained this first year, we propose to realize another field campaign next year (2013). Dissemination was done towards scientists (6 colloquium or workshops), stakeholders e.g. farmers, agricultural adviser and large public (more than 40 trame shows).

For the next year, another field campaign will be conducted, ecosystem service will be analyzed and the economical and sociological approaches will be done. Moreover the modelling analysis will start. In fine, the dissemination task will be pursued.

Short project summary

The main objectives of SUSTAIN are (i) to understand how reduced tillage systems, as compared to conventional tillage systems, impact soil functional biodiversity and soil functions such as soil structural maintenance, organic matter and nutrient cycling, water regulation, filtering and pest regulation; (ii) to quantify the consequences of reduced tillage systems on the soil ecosystem services of food production and GHG mitigation, (iii) to investigate the socio-economic sustainability of reduced tillage systems, (iv) to develop and disseminate tools as soil disturbance indicators, system sustainability evaluation.
The study is conducted in France and the Netherlands in order i) to compare data from two European countries strongly interested in the development and evaluation of reduced-tillage systems, ii) to exchange and enhance the skills of the respective research groups. The complementarity of the experimental sites allows the assessment of many soil services under contrasting conditions and help to derive generic soil quality indicators.
SUSTAIN is based on the analysis of new data recorded during the project, combined with assessment of existing datasets already recorded by each team (since 10 years for France, 3 years for the Netherlands). Tasks are carried out at different experimental field sites and through regional farm networks, which allows for the integration of studies carried out under controlled experimental conditions versus on-farm conditions, different geographical levels such as site, regional, national (France, Netherlands) and cross-national scales. This set-up also facilitates the dissemination of knowledge and best practices among relevant stakeholders, from farmers to policy makers at national and European levels.

Detailed objectives (figure 1):

(1) To assess keystone soil fauna groups (earthworms and nematodes) in experimental sites to determine the response of functional soil biodiversity to reduced tillage systems (WP2).

(2) To assess chemical and physical parameters reflecting soil functions such as maintenance of soil structure (distribution of bioturbations i.e. biopores and aggregates, morphological structure, soil structural stability), organic matter (soil C content, organic matter characterization) and nitrogen (N) cycling, water regulation (infiltration, conductivity, runoff and soil erosion, water retention) and filtering (pesticide losses, pesticide content and leaching) (WP3),

(3) To quantify the soil ecosystem services of i) food production, in terms of quantity (yield) and quality (proteins, mycotoxins) and ii) GHG mitigation (WP4)

(4) To evaluate the socio-economic aspects through the quantification of economical balance sheets at the crop system level and the rotation (quantification of economic budget at farm scale, but without breeding aspect), and sociological surveys of farmers' motivation and willingness to change their practices (WP5). This socio-economic evaluation will be done through representative regional farm networks, focusing on monetary aspect (costs-benefits).

All data from WP2, WP3, WP4, WP5 will be integrated through different modelling approaches (WP6) to:

(5) Detect and develop soil indicators (WP6). Multivariate statistical approaches will be applied to analyze the relationships between soil biodiversity (WP2), soil functions (WP3) and soil ecosystem services (WP4) in order to identify indicators of sustainable soil management, accounting for multiple ecosystem functions and services.

(6) Evaluate the environmental impact of tillage systems through the improvement of Life Cycle Analysis (WP6 using data from WP2, WP3, WP4, WP5)

(7) Evaluate the socio-economic sustainability of tillage systems by using modelling tools (e.g. MASK) applied at the Cultural Systems scale (WP6 using data from WP5).

The dissemination of knowledge (WP7) will be ensured through scientific publication, however a strong effort will also be made to distribute information to end-users. This will be achieved through the production of brochures or booklets specifically targeted at different stakeholders (farmers, technicians and policy makers). Moreover, summer schools, events (field days, week of sciences) at local and national scales and meetings addressing different stakeholder groups will also aid in information transfer. The website and involvement of the European Learning Network on Functional Agrobiodiversity (FAB), a multi-stakeholder network for sharing of knowledge and FAB-based best practices (www.eln-fab.eu) will ensure European wide dissemination.

(8) Interact with stakeholders such as farmers to i) raise awareness on soil biodiversity and soil functions related to agricultural practices, ii) provide guidelines for good practices (WP7 using data from WP2, WP3, WP4)

(9) Interact with policy makers to provide recommendations on implementation strategies for improving soil biodiversity levels and associated services for the long-term sustainable management of soils (WP5 and WP6).

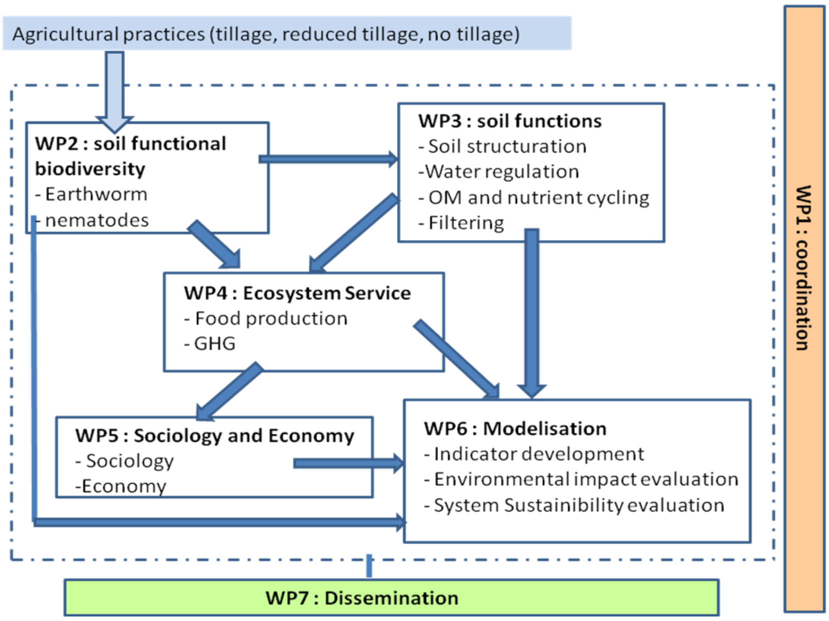

Figure 1: global framework of SUSTAIN project

Project Gantt Chart

	2011-S2	2012-S1	2012-S2	2013-S1	2013-S2	2014-S1	2014-S2
WP1	X	X	X	X	X	X	X
WP2		X	X	X			
WP3		X	X	X			
WP4				X	X	X	
WP5				X	X	X	
WP6					X	X	X
WP7	X	X	X	X	X	X	X

Acknowledgements

SUSTAIN partners acknowledge the SNOWMAN NETWORK partners for their funding, i.e. Ministère de l'Ecologie, du développement durable des transports et du logement from France (MEDDTL) which gave 165 750.00 euros and Stichting Kennisontwikkeling en Kennisoverdracht Bodem from the Netherlands (SKB) which gave 50 000.00 euros.

SUSTAIN partners also aknowledge all the students involved in this first year of study, for their enthusiasm and their performance during the field and the laboratory phases, and also during the data analysis and report writing.Their energy is part of the success of this first campaign.

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1. Use of grant

During this first year grant was used as presented in table 1, details will be proved by the respective administrative structures to the funder.

Table 1: Use of grant by the different partners during the first year of SUSTAIN project.

Partner N°	1	2	3	4	5	6
Name	University Rennes UR1	INRA	CRAB	University Wageningen	PPO	ECNC
Grant from SNOWMAN (euros)	82 500.00	36 150.00	47 100.00	37 500.00	12 500.00	0.00
Depenses (euros)	22 851.39	11 253.77	14 400.00	12 517.00	5 200.00	0.00

2. Background / need / adequateness of the work made

Soils have many functions and deliver ecosystem services such as production of agricultural goods. The EU Thematic Strategy for Soil Protection (2006) includes a strong focus on soil biodiversity, because soil organisms are fundamental in delivering the key ecosystem goods and services mentioned above, with benefits to farmers and society as a whole. However, as stated by the European Commission, our understanding of how soil biodiversity is linked to soil functions and environmental services is still very limited.

In response to soil degradation problems associated with conventional agriculture, alternative production systems such as no-tillage or reduced tillage systems have been developed. Farmer's interest in exploring the benefits of these systems is noticeably increasing as observed in France (ADEME report 2007). Similarly, in the Netherlands interest from farmers, researchers and policy makers has gained momentum over the last three years. It has often been claimed that reduced tillage systems are more sustainable from an environmental point of view (Holland, 2004), however results are sometimes complex as report by ADEME (2007), du especially to local conditions (soil, climate). In the same way, concerning the crop production, studies showed contrasted results (Labreuche et al., 2001; Chervet et al., 2004 ; Chervet et Sturny, 2007). Until now no study has proposed to give an overview of the impact of these reduced tillage systems from soil parameters such as biodiversity and chemical and physical properties to soil ecosystem services, while integrating socio-economic sustainability (ADEME, 2007). This type of information, as well as indicators for monitoring, is crucial to guide practical implementation and policies.

Therefore, a transdisplinary study is needed. The SUSTAIN project proposes a novel transdisciplinary approach by assessing the impact of different tillage systems on soil functional biodiversity, soil functions, and on two soil-related ecosystem services (i.e. food production and impact on GHG emissions). This approach will be complemented by social and economic approaches. Moreover, the aims of SUSTAIN also are to develop an indicator of soil quality, to assess the environmental impact of these tillage systems and their sustainability. In addition, results will be formulated for dissemination to end users, policy makers and the general public.

In order to archives these goals, SUSTAIN brings together a broad spectrum of expertise in soil biology, soil physic, soil chemistry and agronomy as well as tools for integrated soil ecosystem analysis. This expertise is combined with the economic and social evaluation of services provided by soil biodiversity (table 2).

Table 2: list of partners and their skill

Partner N°	1	2	3	4	5	6
Name	University Rennes UR1	INRA	CRAB	University Wageningen	PPO	ECNC
Persons	D. Cluzeau G. Pérès	V. Hallaire, S. Menassery T. Morvan, M. Corson	D. Heddadj, P. Cotinet	M. Pulleman, S. Crittenden, L. Brussaard,	W. Sukkel	B. Delbaere, V. Mikos
Skills	Soil biology, soil physic	Soil physic, soil chemistry, agronomy, ecosystem assessment	Agronomy, Ecosystem assessment (socio-economy)	Soil biology, soil physic	Soil biology, Agronomy	Dissemination

3. Aims and comparison with predetermined objectives

Within the global framework of SUSTAIN (figure 1), the aims of this first year were focusing on WP2, WP3 and WP7, and detailed as follow:

- **WP2:** To assess how soil biodiversity (specific, functional, community) is impacted by reduced tillage systems. This will be carried out in experimental field sites. Soil biodiversity will be assessed through 2 main groups i.e. earthworms and nematodes.
- **WP3:** To assess the contribution of biological processes to (1) soil structure (soil aggregation) (2) soil water dynamics (infiltration, water storage, runoff, erosion) (3) soil organic matter (quantity, quality, availability), (4) nutrient cycling (nitrogen dynamics), (5) the filtering role of soil against pesticides (Glyphosate) and NO3 leaching, and (6) pest regulation.

  The objectives were to sample both in French and Dutch sites.
- **WP7:** To disseminate the experimental results to project partners, Commission Officials, the scientific community, stakeholders and the general public.

The coordination goals were to optimise the internal communication between partners, through the organization of meetings and a database implementation.

4. Results

4.1 Coordination (WP1)

4.1.1 Meetings

4.2.1.1 University of Rennes

- **<u>Common meeting ECOSOM-SUSTAIN</u>**

As requested by SNOWMAN, SUSTAIN project made some bridges with ECOSOM project. Therefore, University of Rennes organized a join meeting in January 2012, during 3 days in France (at the Biological Station of Paimpont, University of Rennes 1), in order (i) to present the two programmes, (ii) to manage the sampling campaign. Minutes are detailed in annexe 1.

The meeting was organized as follow:

Tuesday 10/01/2012:

13 talks were given in order to present ECOSOM and SUSTAIN projects, their study sites and to detail their WPs (discussion were mainly focusing on impact of reduced tillage).

The main conclusions were:

- **Concerning Sites**: base on the PPT presented on SUSTAIN sites, informations about ECOSOM sites will be gave (Swedish and Dutch sites); details about agricultural practices will be gave (as requested during SNOWMAN kick-off meeting, November 2011); list of parameters recorded in each site will be done;

- Concerning the Harmonization of protocols: Each expert will keep his methodology BUT for common parameters, the different methodologies will be done in limited situations in order to make the link between all results; Necessity to fix the depths for some measurements.

-Concerning Ecosystem services: Parameters will be related to Ecosystem services; Identification of common ES, but keep in mind that functions could be regarded as ecosystem services (water regulation, soil conservation).

- **Sampling campaign:** Necessity to fix the number of sampling campaigns; several dates for physical parameters, less for biodiversity under reduced tillage systems; all parameters will be measured at the same moment for at least 1 date -> France (March), NL (May), S (to fix).

- **Schedule of common meetings:**

  - First meeting, Paimpont, January 2012;
  - Second SNOWMAN meeting, Wageningen, end of 2012 (beginning of 2013) which will be organized in thematic meetings: Reduced tillage meeting (presentation of results obtained the first year), OM meeting (presentation of results obtained the first year), LCA meeting, Dissemination meeting (preparation of 1rst stakeholder meeting, discussion of brochure structure), General Stakeholder committees (necessity to fix the location),
  - Third meeting, in Paimpont, beginning of 2014 with the aims: presentation of result, preparation of restitution meeting,
  - Restitution meeting to stakeholders, Paris, May-June 2014.

- **LCA**: necessity to identify indicators and relevant methodology associated (easy, fast, …), LCA will be the main topic of second meeting

- Concerning the common dissemination: technical guide should be produced in common on impacts of i) reduced tillage and ii) organic inputs, the structure of this guide will be discussed in 2012-2013 and content will be written in 2013-2014; website -> different websites will be produced (one for each programme) interconnected and connected with SNOWMAN website; Newsletter of ECNC will be used to diffuse informations from both projects; Database is still under reflexion.

Wednesday 11/01/2012:

5 talks were given in order to discuss more in details points concerning SUSTAIN project. SUSTAIN's partners benefited from the presence of S. Schrader, a german colleague[1], expert in the impact of reduced tillage on soil functioning. The main conclusions were:

- **Concerning Data management**: a common database should be proposed in order to facilitate the data exchanges and uses -> University of Rennes will produce the conceptual model and the characteristics table to all partners; reflexions on data management will be developed during 2012

- **Concerning the sampling campaign (planning):** Common sampling campaigns will be managed: 5/03/012 (France), 30/04/2012 (NL) with interactions between sampling teams (French partners will visit the Netherlands, and vice versa).

- Concerning the Evaluation of economical sustainability of reduced tillage systems (method MASC): will be discussed in 2013 and 2014 in interactions with dutch partners.

- Concerning the Sociological and economical approaches: this aspect will be assessed in 2013 and discussed during the next common meeting.

Thursday 12/01/2012:

This day was used to visit the French field site.

- **Progress meetings**

Three progress meetings were organized with researchers and students from University of Rennes 1, INRA and CRAB to organize the field campaign, to discuss about the results and train the defense of the students (Paimpont March 2012, Paimpont May 2012 and June 2012).

4.2.1.2 INRA

INRA partners took place at the kick-off meeting at Paimpont (January) and at the 3 progress meetings (March, May and June).

4.2.1.3 CRAB

INRA partners took place at the kick-off meeting at Paimpont (January) and the at 3 progress meetings (March, May and June).

4.2.1.4 University of Wageningen

Partners from University of Wageningen took place at the kick-off meeting at Paimpont (January).

Two progress meetings were organized with researchers and students from WU and PPO that work at the Lelystad site (Lelystad, February 2012 and June 2012).

[1] SNOWMAN consortium had asked SUSTAIN partners to involve a German expert in SUSTAIN project.

4.2.1.5 PPO

Partner from PPO took place at the kick-off meeting at Paimpont (January) and at the two progress meetings (Lelystad, February 2012 and June 2012).

4.2.1.6 ECNC

Partner from PPO took place at the kick-off meeting at Paimpont (January).

4.2 Sampling campaigns

Sampling campaign was discussed during the kick-off meeting in January Paimpont: it was decided that sampling will be done the week 5/03/012 in France, and the week 30/04/2012 in the Netherland with interactions between sampling teams (French partners will visit the Netherlands, and vice versa).

4.2.1 In France

Field work was done on Kerguéhennec site, an experimental site supervised by Chamber of Agriculture (CRAB partner). Sampling was mainly carried out from 5 march to 16 march.

Three trials were assessed (they are all arranged in block designs which allows for appropriate sampling scheme), (figure 2).

<u>Description of the different trials:</u>

- "Agronomic" trial (code FKA), implanted in 2000, combines 3 tillage systems (standard tillage i.e. conventional ploughing at 25 cm depth, reduced tillage i.e. superficial tillage at 8 cm depth, direct drilling) and 4 four fertilizer sources (mineral fertilization, poultry manure, pig slurry and cattle manure);

- "Transfer" trial (code FKT), implanted in 2000, assesses the impact of 3 tillage systems (standard tillage i.e. conventional ploughing at 25 cm depth, reduced tillage i.e. superficial tillage at 8 cm depth, direct drilling) on pesticide transfer.

FKA and FKT are managed under conventional management

- "Organic farming" trial (code FKO), implanted in 2003, assesses 4 tillage systems (conventional tillage i.e. conventional ploughing at 25 cm depth, agronomic ploughing i.e. ploughing at 15 cm depth, reduced tillage i.e. superficial tillage at 15 cm depth, much superficial tillage in 8cm).

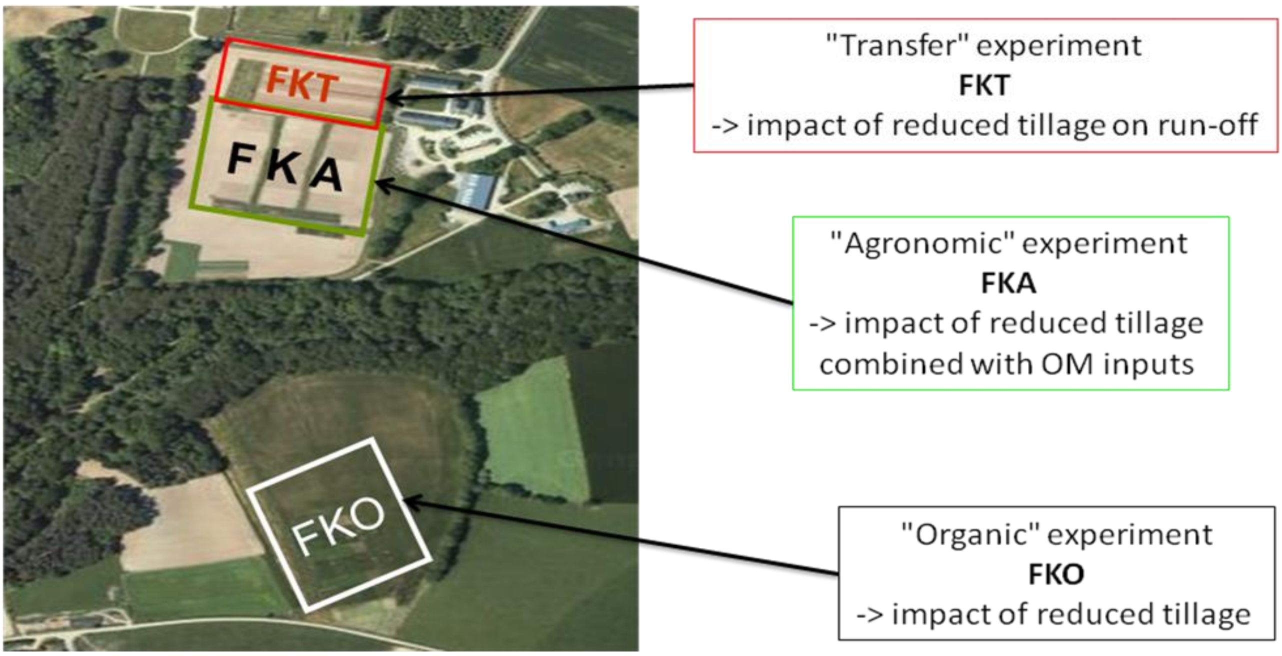


Figure 2: location of the 3 trials from Kerguehennec site

<u>Parameters assessed were</u>:

- Biological parameters: Earthworm sampling and soil sampling for nematodes analysis,
- Chemical parameters: soil sampling for chemical analysis
- Physical parameters: Hydraulic conductivity by saturated (double ring, realized by Dutch and French teams) and unsaturated methods (decagon method, realized French team); bulk density; aggregate stability, including methods comparison (French vs Dutch methods); macroporosity analysis (image analysis method); distribution of biological structure on soil profile; run-off; pesticide transfer.

Depending on the specificity of the trials, parameters were assessed or not (details in table 3)

Table 3: Details of the soil parameters assessed in the different trials during the first campaign (2012)

	Earthworm	nematodes	Hydraulic conductivity	bulk density	aggregate stability	macroporosity analysis	biological structure	run-off	pesticide transfer
FKA	X	X	X	X	X				
FKB	X	X	X	X	X	X	X		
FKT	X	X	X		X			X	X

Twelve french persons were involved in the sampling campaign (5 students, 5 technicians and 2 supervisors) and four dutch persons took part (2 students and 2 supervisors).

4.2.2 in The Netherlands

Field work was done on Lelystad site (in the Flevopolder), which has been implemented and managed by Applied Plant Research (PPO partner). Sampling was mainly carried out 30 April to 11 May.

The Lelystad experiment consists of a randomized complete block design with 4 replicates and was implemented in 2008 both for organic farming and for conventional farming. It compares conventional vs reduced tillage.

PPO's actions on Lelystad site are:

- Maintenance of field trial Non-inversion Tillage
- On-going testing and improving of various techniques to improve the technical manage ability for practice
- Determination of crop yields, soil mineral nitrogen contents, weed pressure, soil physical characteristics (infiltration rate aggregate stability, penetration resistance etc).

Soil parameters assessed were:

- Earthworm sampling, including methods comparison (French vs Dutch methods)
- Hydraulic conductivity estimation by saturated (double ring method, realized by Dutch team) and unsaturated methods (decagon method, realized French team), and aggregate stability including methods comparison (French vs Dutch methods).

Nine dutch persons were involved in the sampling campaign (6 students and 3 supervisors) and six french persons took part (2 students, 3 technicians and 1 supervisor).

4. 3 Research results on Biodiversity (WP2) and Physical functions (WP3)

Because the results were obtained due to the collaboration of all partners (University of Wageningen, PPO, University of Rennes 1, INRA, CRAB), we proposed to present the results trials by trails instead of partner team by partner team. Some results, such as nematodes are still under analysis.

4.3.1 Results on French site (Kerguéhennec site)

4.3.1.1 FKA trial - Study realised by french team (Robin Guilhou, 2012, annexe 1)

This study shows that reducing tillage significantly modified its physical properties, confirming the results of other authors (Kribaa et al, 2001; Abid and Lal, 2008; Bottinelli et al., 2011). The positive correlations between the physical parameters measured (aggregate stability, porosity, hydraulic conductivity) allow us to distinguish between worked and unworked layers:

- Under direct seeding, aggregate stability was higher than under conventional ploughing which is in accordance with literature (Tebrügge et Düring, 1999; Rhoton et *al.*, 2002; Martinez et al., 2008; Bottinelli et *al.*, 2009; Menassery-Aubry et *al.*, 2011), soil was significantly more compacted related to a low porosity which induced a low infiltration potential (figure 3).
- Superficial tillage increased soil aggregate stability within the upper worked layer; soil is less compacted than under direct seeding related to a higher porosity which induced a higher conductivity.

Further informations are needed to describe this structural changes resulting from reducing tillage; a morphological approach using image analysis on undisturbed soil blocks will allow us to characterize the pore changes between treatments, and their seasonal dynamics.

On the contrary, there was no effect of fertilisation on these parameters: results were not statistically different between organic and mineral treatments.

However, due to a strong variability of the results, most of the results were observed in trends but without any statistical difference (p>0.05).

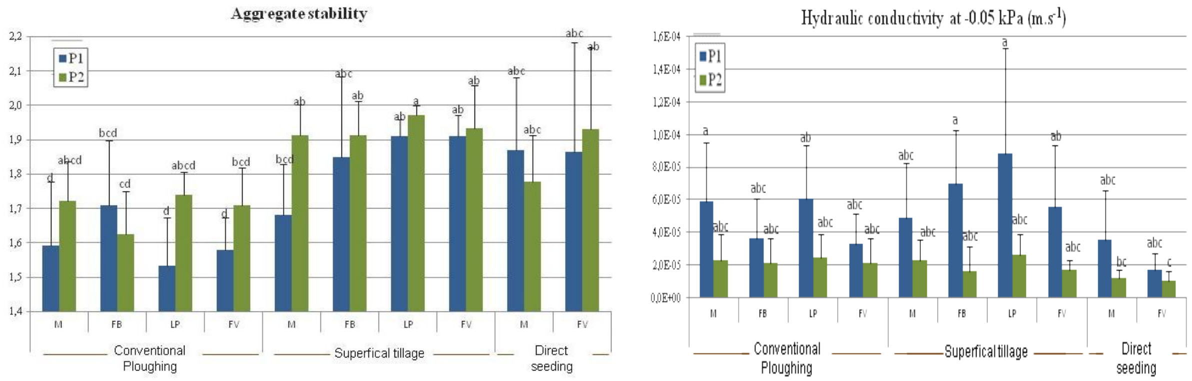


Figure 3: aggregate stability (left) and hydraulic conductivity (right) measured under different systems and different fertilization (M: mineral, FB: Cow manure, LP: pig slurry, FV: Poultry manure) at two depth: P1 for 2 cm, P2 for 12 cm. Different letter show significant differences between treatments (p>0.05).

Earthworms are more abundant under conventional tillage in comparison with surface tillage and under direct seeding (p>0.05) (figure 4, table 4). This result is not in accordance with most of the literature which shows that reduced tillage systems improve earthworm abundance (Chan 2001; Kladivko 2001, Rosas-Medina et *al.*, 2010), but support some results obtained (Ernst and Emmerling 2009, Capowiez 2009). The highest biomass is observed under direct seeding (table 4) which supports literature.
In accordance to literature (Johnson-Maynard et *al.*, 2007; Chan, 2001; Piron et al., 2011), the reduced tillage systems (SD and DS) impact on earthworm functional structure by increasing the relative anecic abundance.
However, once again, due to a strong variability of the results, biological results were observed in trends but without any statistic differences (p>0.05).
Concerning nematodes, results are still under analysis.

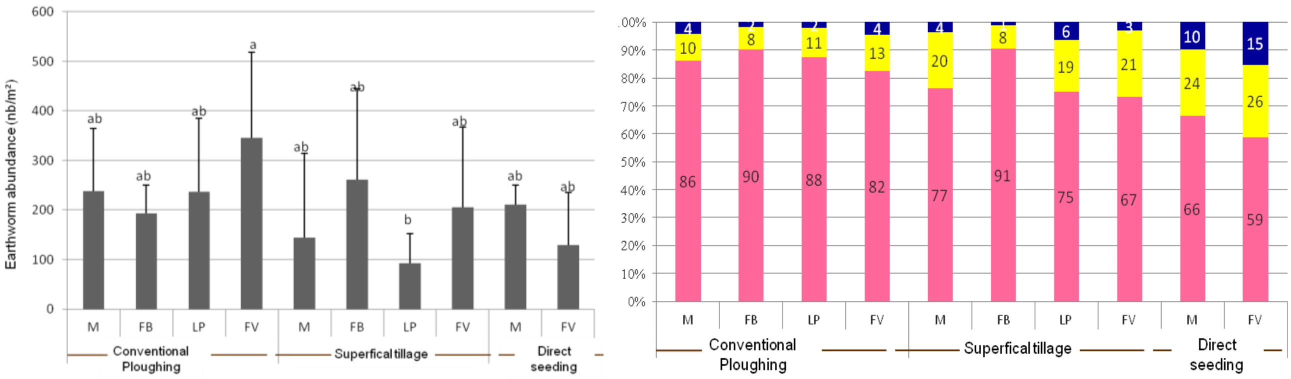


Figure 4: earthworm abundance (ind./m²) (left) and relative abundance of the ecological earthworm groups (right; pink: endogeic, blue: epigeic, yellow: anecic) measured under different systems and different fertilization (M: mineral, FB: Cow manure, LP: pig slurry, FV: Poultry manure) Different letters show significant differences between treatments (p>0.05).

Table 4: abundance (Ab, nb. ind./m²) and biomass (Bm, g/m²) of earthworm community and for the different ecological groups (Epigeic: Epi, Anecic: Ane, Endogeic: End) measured under different tillage systems (L: tillage, TS: reduced tillage, SD: direct seeding) and different fertilization (M: mineral, FB: Cow manure, LP: pig slurry, FV: Poultry manure.)Different letters show significant differences between treatments (p>0.05).

	Ab (nb ind/m²)	Bm (g/m²)	Ab Epi	Ab Ane	Ab End
L	253 [a]	71 [ab]	8 [b]	27 [b]	218 [a]
TS	171 [b]	61 [b]	5 [b]	28 [b]	138 [b]
SD	171 [ab]	92 [a]	20 [a]	42 [a]	108 [b]
M	198 [a]	71 [ab]	12 [ab]	34 [ab]	152 [a]
FB	227 [a]	66 [ab]	3 [b]	18 [b]	205 [a]
LP	164 [a]	52 [b]	5 [ab]	21 [ab]	138 [a]
FV	221 [a]	88 [a]	14 [a]	41 [a]	166 [a]
L M	239 [ab]	56 [a]	10 [ab]	23 [ab]	206 [a]
L FB	194 [ab]	61 [a]	4 [b]	16 [b]	175 [a]
L LP	236 [ab]	65 [a]	5 [ab]	25 [ab]	207 [a]
L FV	345 [a]	103 [a]	15 [ab]	45 [ab]	284 [a]
TS M	144 [ab]	57 [a]	5 [b]	29 [ab]	110 [a]
TS FB	261 [ab]	71 [a]	3 [ab]	21 [ab]	236 [a]
TS LP	92 [b]	39 [a]	6 [ab]	17 [b]	69 [a]
TS FV	205 [ab]	77 [a]	6 [ab]	44 [ab]	137 [a]
SD M	211 [ab]	100 [a]	21 [a]	50 [a]	140 [a]
SD FV	130 [ab]	84 [a]	20 [ab]	34 [ab]	76 [a]

The study of correlations reveals numerous interactions between physical and biological parameters; some negative correlations between abundance and porosity however remind the absence of a simple causal relationship between those parameters (table 5).

There is a positive correlation between earthworm abundance and soil humidity, especially due to the abundance of endogeic. This is in accordance with literature which showed that earthworm abundance positively impact on soil water retention (Ehlers, 1975) and also supports the definition of endogeic group which creates an aggregative structure that should act as a sponge (Bouché, 1972).

Table 5: matrix of Spearman's correlation (R) between biological and physical parameters (P1= 2 cm depth, P2 = 12 cm depth)

	Humidity		Porosity		Stability		Conductivity K5		% MO	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
Abundance (AB)	0,23	0,19	-0,27	-0,06	-0,11	-0,28	-0,18	-0,12	-0,42	-0,10
Biomass (BM)	0,19	0,00	-0,34	-0,25	0,06	-0,09	-0,22	-0,24	-0,11	0,07
Epigeic AB	-0,03	-	-0,36	-	0,14	-	-0,19	-	-0,06	-
Anecic AB	0,06	-0,18	-0,25	-0,26	0,16	-0,04	-0,21	-0,13	-0,07	0,06
Endogeic AB	0,24	0,25	-0,20	0,02	-0,16	-0,34	-0,13	-0,11	-0,49	-0,17
Abond. Epi Ad	-0,01	-	-0,34	-	0,13	-	-0,20	-	0,03	-
Abond. Ané Ad	0,01	-0,15	-0,25	-0,26	0,02	-0,02	-0,16	-0,26	0,14	0,04
Abond. End Ad	0,30	0,21	-0,19	0,04	-0,08	-0,16	-0,08	-0,09	-0,25	0,04
Abond. Adultes	0,30	0,17	-0,27	-0,07	-0,03	-0,09	-0,15	-0,16	-0,12	0,10
% MO	0,01	0,71	1,00	0,68	0,00	0,28	0,28	0,73	1	1

P-value :
< 0,001
< 0,01
< 0,05

Surprising, there is a negative correlations between soil porosity and earthworm community (abundance, biomass) especially epigeic abundance and anecic abundance. There is also a negative correlation between soil water conductivity (K5) and earthworm biomass and anecic abundance. This is not in accordance with literature which showed that earthworm abundance increase soil porosity (Pérès et al., 1998) and positively impact soil infiltration (Ehlers, 1975; Kladivko, 2001) especially due to the tubular porosity created by anecic species. This difference with literature could be explained by the study scales assessed by the methods (detailed in annexe 1): biological method assessed 1 m² while physical method assessed a smaller scale (less than 50 cm²).

Another surprising result is that there is a negative correlation between soil stability and earthworm abundance, especially with endogeic abundance. This is not in accordance with previous study which showed that earthworm dejections (aggregates) presented a higher stability than the soil matrix (Bottinelli 2011; Johnson-Maynard et al. 2007).

Another surprising result is that soil organic matter is negatively correlated with earthworm abundance and especially endogeic abundance.

Considering all these contradictions with literature, we propose to carry another field campaign in order to confirm or infirm the results obtained in 2012 and better understand how cultural practices force their earthworm populations and dictate their biological activity.

4.3.1.2 FKO trial (study realised by french and dutch teams, Ado Maman Nasser, 2012 & Mart Moss, 2012; annexes 2 & 3)

This study shows (figure 5), but only in trends, that superficial tillage at 15cm (C15) and agronomic ploughing (AP) seem to increase the earthworm abundance and biomass; however the positive effect of the reduction tillage systems on these characteristics cannot be confirmed or affirmed due to the high variability of the data, especially data obtained in block 3 which are totally inverses of the rest of data obtained in the trial.

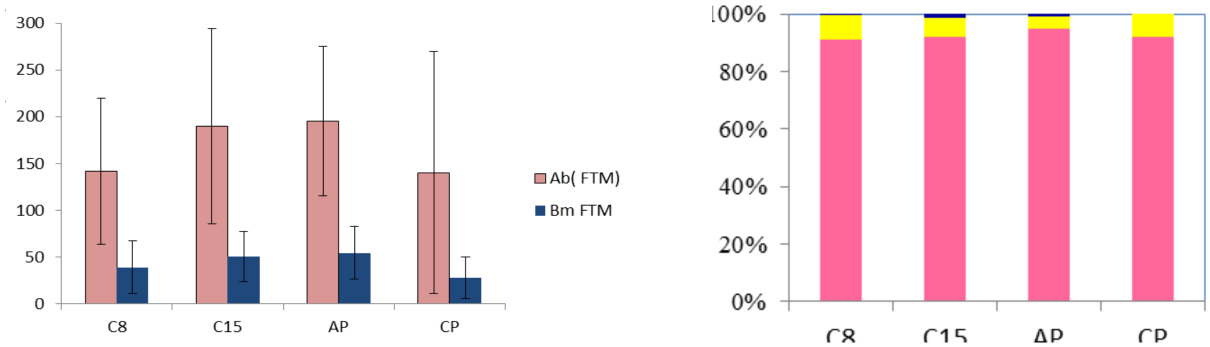


Figure 5: earthworm abundance (Ab, ind./m²) and biomass (Bm, g/m²) (left) and relative abundance of the ecological earthworm groups (right; pink: endogeic, blue: epigeic, yellow: anecic) measured under different systems (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p>0.05).

The analysis of the earthworm dynamic requires a comparison of data issued from the same sampling method; therefore, the dynamic is analysis from 2010 to 2012 (table 6). Data shows that since 2010, earthworm abundance increases under all systems, however, the smallest increase is observed under superficial tillage at 8 cm (+ 141%) while the highest is observed under agronomic ploughing (+ 195%).

Table 6: Dynamic of abundance and biomass of earthworms (from 2004 to 2012) under different systems (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing).

Année	Méthode	Date prélèvement	Abondance lombricienne (ind/m2)				Auteurs
			C8	C15	AP	CP	
2004	Formol	***	100*	90	135	120	S. Coulomb
2006	Formol	Début mars	160*	145	110	55	R. Grimaud
2007	Formol	27-mars	61	60	77	92	L. Anthony
2010	Formol +tri manuel	16-avr	63	80	48	48	N. Armal
2011	Formol + tri manuel	10-mars	126	80	73	50	E. Bordon
2012	Formol +tri manuel	05 mars	142	190	195	140	
			Biomasse (g/m2)				
2004	Formol	***	60*	30	30	22	S. Coulomb
2006	Formol	Début mars	90*	60	35	20	R. Grimaud
2007	Formol	27-mars	39,6	39,5	27,6	18,9	L. Anthony
2010	Formol+tri manuel	16-avr	41	41,3	19,4	16,9	N. Armal
2011	Tri manuel(7cm)+ formol	10-mars	61	33,1	22,7	16,1	E. Bordon
2012	Formol +tri manuel	05 mars	38,86	50,70	54,58	27,64	

**** données manquantes ; * données issues du semis direct*

Looking at the individual weight of earthworms (Table 7), we observed that it strongly decreased from 2010 to 2012, which could be explained by the community structure (more small earthworms in 2012 e.g. more juveniles, or more endogeic ?). This should have to be studied by a more detailed analysis of the former data, which will be done in 2014.

Table 7: Individual earthworm weight (g/individu) in 2010 and 2012 under the different systems (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing)

		C8	C15	AP	CP
2010	Abundance	63,00	80,00	48,00	48,00
	Biomass	41,00	41,30	19,40	16,90
	Individual weight	0,65	0,52	0,40	0,35
2012	Abundance	142,00	190,00	195,00	140,00
	Biomass	39,00	50,70	54,60	27,60
	Individual weight	0,27	0,27	0,28	0,20

Comparing the effect of the different reduced tillage systems year per year (Table 7), we observed that the biological responses never follow the same schema: in 2004 and 2007, the highest abundances were observed under ploughed systems, while in 2006, 2010 and 2011, the highest values were observed under reduced tillage systems, and in 2012 they were observed under C15 and AP. Therefore, the hypothesis is that the previous crops could have a strong impact on biological response.

Concerning the physical parameters, superficial tillage at 8cm (C8) increases aggregate soil stability ($p<0.05$, figure 6 left), and seems to impact positively on earthworms bioturbation and total macroporosity in surface. Furthermore, superficial tillage at 8cm (C8) also seems to increase the soil hydraulic conductivity in surface (figure 6 right), in contradiction with superficial tillage in 15cm (C15). Further informations are needed to explain these values, which can be due to the difference of the surface structure in C8; therefore, a description of the soil surface (roughness, crusts) will be performed in the next stage, in 2014.

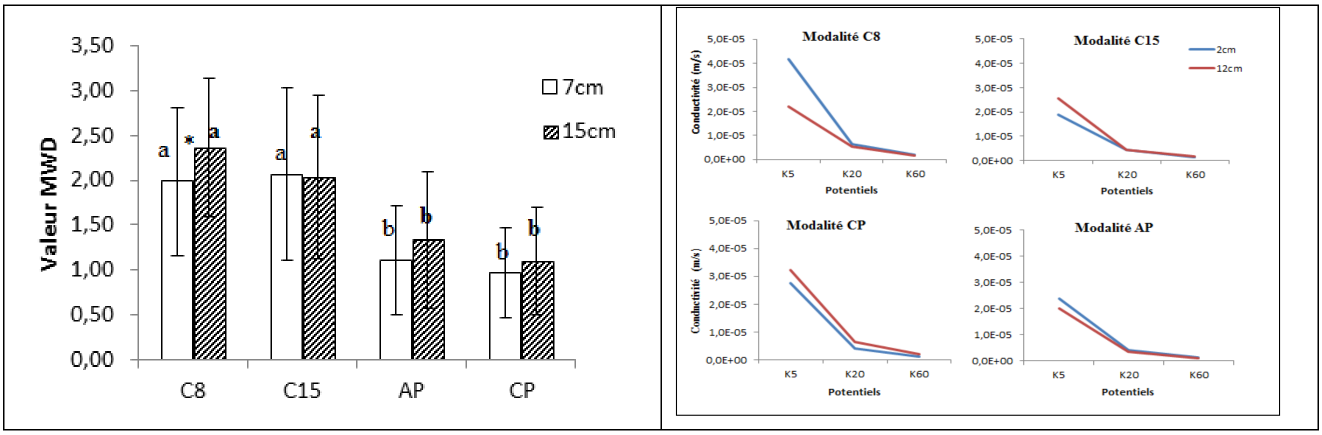


Figure 6: aggregate stability (left) at two depths (7 and 15 cm) and hydraulic conductivity (right) measured under different systems (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p>0.05).

Comparing the hydraulic conductivity assessed by two different approaches, we observed that results differ depending on the method: by infiltrometer method (decagon) (figure 7, left), hydraulic conductivity follows this order C8>CP>AP>C15, while using double ring method (figure 7, right) the order is CP>AP>C8>C15. These differences could be explained by the scale investigated by each method: i) double ring method measures saturated hydraulic conductivity (K_{sat}) involving the whole macropores, whereas decagon method measures unsaturated hydraulic conductivity (K(h)) involving only the pores implicated at a given water potential, ii) double ring assessed a larger soil volume than decagon. In order to really compare these methods and define their complementarities more data are requested, and will be obtained in the other trials.

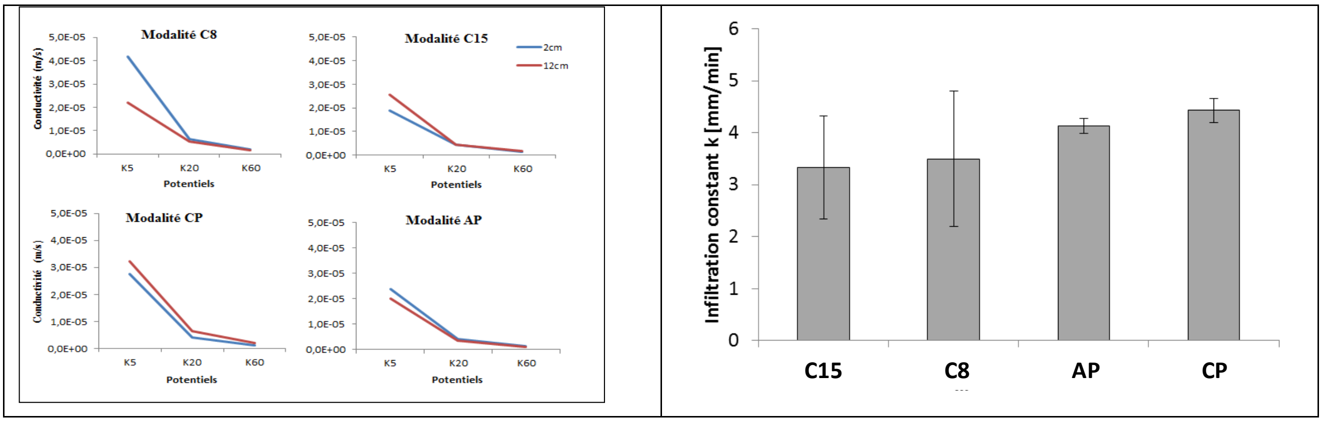


Figure 7: hydraulic conductivity measured by two methods: by infiltrometer (decagon – left) and double ring (right) under different systems (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing).

However, the high heterogeneity of the results could not permit to conclude on the impact of reduced tillage systems neither on soil biology nor on sol physical state. Moreover, the soil dryness during soil sampling could have interfered on the quality of the measurements. Another campaign seems to be necessary.

4.3.1.3 Water conductivity at saturation at FKA and FKO (study realised by Wageningen University team)

The results presented below show a preliminary overview of water conductivity measured under FKO and FKA trials. The ability of the soil to conduct water at saturation was tested using the double ring infiltrometer in March 2012. Initial data indicate that reduced tillage systems do not, in general, incur a penalty in terms of saturated hydraulic conductivity (Kfs) (Table 8). One exception is CP at FKO, which appears to have higher Kfs than the other treatments in the same fields. But note that these data have not yet been analysed for statistical significance. Moreover more data over multiple years will be available later in the project to see if these results are consistent in time. Quite some variation is visible between the fertilization treatments in FKA, suggesting an interaction between fertilization and tillage effects (figure 8).

Table 8: Water conductivity (Kfs) measured under FKO and FKA. Data collected in spring 2012.

Location	Field	Treatment	Kfs(average)
Kerguehennec	FKO	AP (agronomic ploughing)	0.42
		CP (conventional ploughing)	0.57
		C15 (reduced tillage 15 cm depth)	0.35
		C8 (reduced tillage 8 cm)	0.43
	FKA	LFV (conventional ploughing, poultry manure)	0.57
		LM (conventional ploughing, mineral fertilisation)	0.62
		SDM (direct seeding, mineral fertilisation)	0.42
		SDFV (direct seeding, poultry manure)	0.63
		TSFV (reduce tillage, poultry manure)	0.48
		TSM (reduce tillage, mineral fertilisation)	0.67

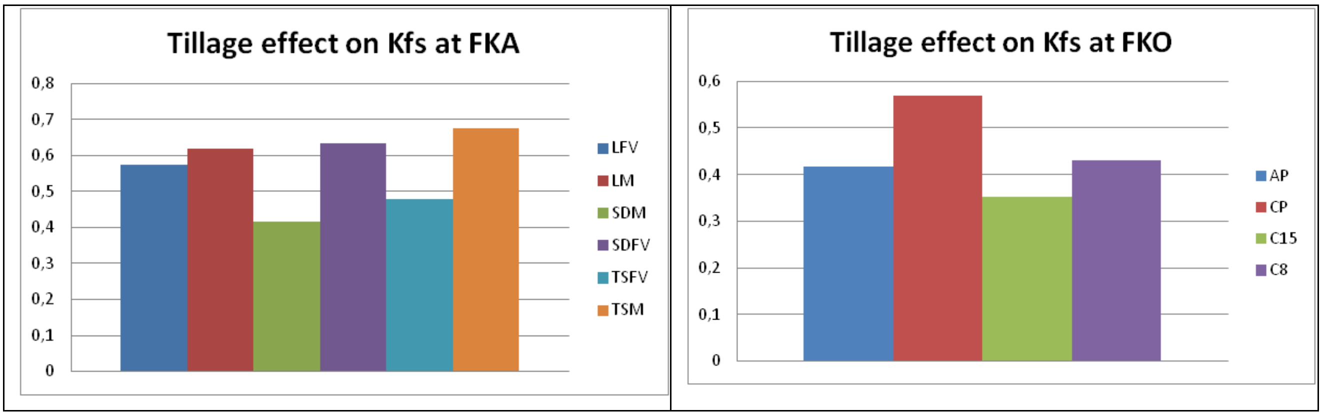
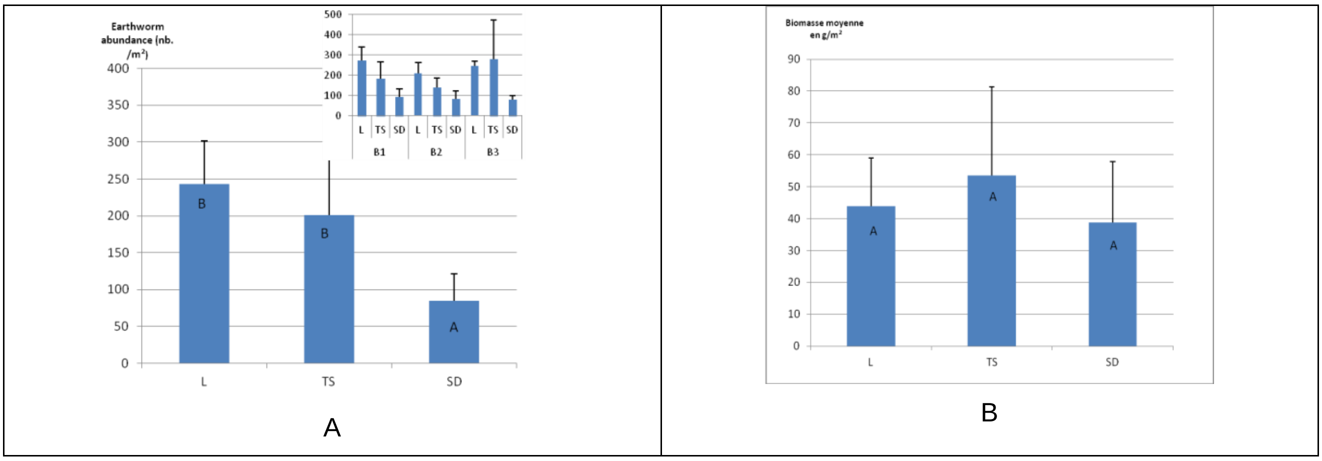


Figure 8: Water conductivity (Kfs) at FKA trial (L: conventional ploughing, SD: direct seeding, TS: superficial tillage; M: mineral, FB: Cow manure, LP: pig slurry, FV: Poultry manure) and fKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing).

4.3.1.4 FKT trial (study realised by french team)

Note: at this state only the earthworm results are analysed for FKT trial.

This study shows that (figure 9), compared to conventional tillage (L), reduce tillage systems (i.e. superficial tillage TS, direct seeding SD) decrease earthworm abundance (respectively p>0.05, p<0.05), while earthworm biomass is higher under superficial tillage (TS) (P>0.05). In the other hand, direct seeding impacts on earthworm functional structure by increasing anecic rate, in accordance with literature.



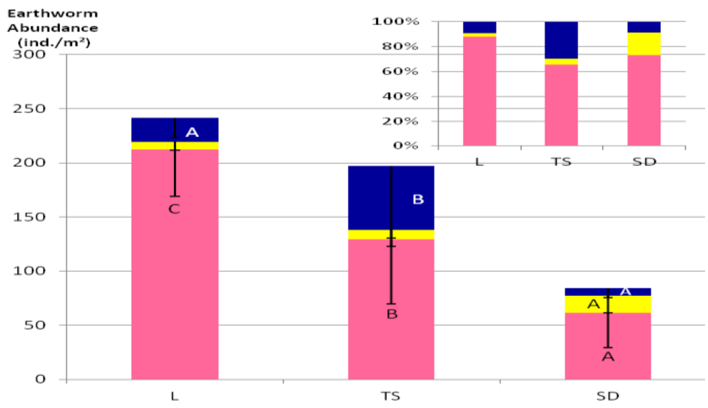


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Figure 9: earthworm abundance (ind./m²) (figure 9a), earthworm biomass g/m² (figure 9b) and relative abundance of the ecological earthworm groups (figure 9c, pink: endogeic, blue: epigeic, yellow: anecic) measured under different systems (L: conventional ploughing, TS: reduced tillage, SD: direct seeding). Different letters show significant differences between treatments (p>0.05).

The study of earthworm dynamic (figure 10) shows that earthworm abundance increases from 2009 to 2012 under conventional tillage, while it decreases under direct seeding. Concerning the biomass, this parameter decreases under the three systems but more strongly under direct seeding. This decrease under direct seeding in 2012 is related to the quasi absence of epigeic, and the strong decrease of anecic number as well as endogeic number. This decrease is not easy to explain because under direct seeding, environmental conditions are known to be favourable to epigeic (due to the maintenance of mulch on soil surface and no inverse tillage) and also favour anecic. One reason could be the use of pesticides under direct seeding. This should be confirmed or infirmed by the knowledge of pesticides applications and also transfers (which will be analysed on this trial).

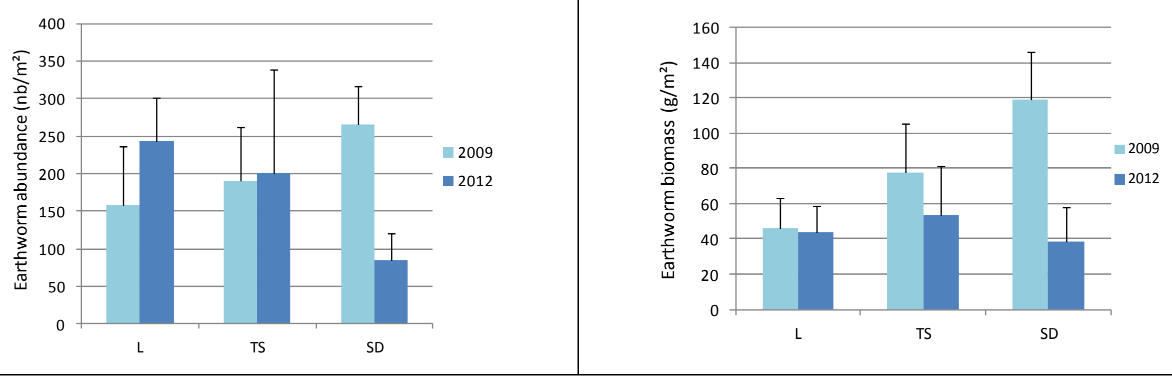

Figure 10: dynamic of earthworm abundance (ind./m²) (left) and earthworm biomass (g/m²) between 2009 and 2012 under different systems (L: conventional ploughing, TS: reduced tillage, SD: direct seeding).

4.3.1.5 Synthesis of results obtained on French site

We were very surprised by the results obtained in 2012 (especially concerning the biological response which showed that reduce tillage affected earthworm community in terms of abundance and biomass) which were not in concordance with i) results observed in the literature, ii) previous results we obtained before on this experimental site.

Therefore, this first year ended with more questions than answers, and suggested some hypotheses especially concerning the strong impact of i) technical actions related to previous crop, ii) surface state. In order to test these hypotheses, we propose to carry on another field campaign in 2013 (field campaign which was not previously planned) by which we will take into account the crop and also the surface state.

4.3.2. Results on Dutch site (Lelystad site)

The results presented below show a preliminary overview of water conductivity measured at PPO Lelystad site. The ability of the soil to conduct water at saturation was tested using the double ring infiltrometer in May 2012 (Table 9). Initial data indicate that reduced tillage systems do not, in general, incur a penalty in terms of saturated hydraulic conductivity (Kfs). One exception is the ploughed treatment (P) at J10-3 PPO Lelystad which appears to have higher Kfs than the other treatments in the same fields. But note that these data have not yet been analysed for statistical significance. Moreover more data over multiple years will be available later in the project to see if these results are consistent in time.

Table 9: Water conductivity (Kfs) measured under Dutch sites. Data collected in spring 2012.

Location	Field	Treatment	Kfs(average)
PPO Lelystad	J9-2b	P (conventional ploughing)	0.93
		NIT (no inverse tillage)	0.91
	J10-3	P (conventional ploughing)	1.1
		NIT (no inverse tillage)	0.81

At Lelystad site, the following long-term data for earthworm populations have been found (Tables 10 and 11) for the conventional and the organic farming system, respectively. In both farming systems the earthworm community was strongly dominated by the endogeic earthworm *Aporrectodea caliginosa*. Total earthworm numbers were not significantly different between reduced tillage (M and/or NIT) and mouldbourd ploughing (MP) in the conventional farming system. However the epigeic earthworm *Lumbricus Rubellus* tended to be favoured by reduced tillage in out of 6 seasons.

Table 10: Earthworm numbers and biomass as a function of tillage treatment in the Conventional farming system.

Sampling date	Tillage system	*Aporrectodea caliginosa* (m^{-2})	*Aporrectodea rosea* (m^{-2})	*Lumbricus rubellus* (m^{-2})	Total abundance (m^{-2})	Biomass ($g\,m^{-2}$)	Adult/juvenile ratio
Spring 2009	M	50	7	1	68	-	1.01 b
	NIT	26	2	2	38	-	2.37 a
	MP	40	1	0	41	-	0.30 b
Fall 2009	M	101	4	0	110	15 ab	0.41
	NIT	153	7	2	169	26 a[2]	0.14
	MP	87	4	0	95	11 b	0.14
Fall 2010	M	170 b	7	17 a	208	56	0.79
	NIT	277 a	38	22 a	358	77	0.37
	MP	240 ab	30	0 b	279	79	0.89
Spring 2011	M	49	3	2	60	12 a[3]	0.63
	NIT	52	2	0	61	8 ab	0.50
	MP	23	3	0	29	3 b	0.25
Fall 2011	M	218 a	2	12 a	245	44 a[4]	0.48
	NIT	113 b	3	0 b	127	25 b	0.49
	MP	181 ab	10	0 b	192	26 ab	0.16
Spring 2012	M	154	2	29 a	188	24 ab	0.24
	NIT	176	7	17 a	204	35 a[5]	0.19
	MP	136	1	1 b	143	18 b	0.36

[1] Species abundances, total abundance and total biomass are back-transformed means. Tillage systems: minimum (M), mouldboard plough (MP) and non-inversion tillage (NIT). Species with > 1 % of overall abundance are included, other species present were *Lumbricus terrestris*, *Lumbricus castaneus* and *Eiseniella tetraedra*. Species abundance columns are ordered from left to right by decreasing overall abundance. Letters indicate significant differences between tillage systems within sampling date ($P<0.05$).

In the organic farming system, ploughing (MP) significantly increased total earthworm abundance in 3 out of seasons, mainly explained by higher numbers of *Aporrectodea Caliginosa* (significant in all seasons; Table 7). The different response of *A. caliginosa* to tillage in conventional vs organic farming system is probably explained by a higher organic matter input in the organic system, which is easily accessible to endogeic earthworms after ploughing. Endogeic species are well adapted to arable systems with frequent ploughing as they feed on organic matter incorporated into the mineral soil, do not use permanent burrows and have short regeneration times. Negligible numbers of anecic individuals were found at the Lelystad site, irrespective of tillage.

Table 11: Earthworm numbers and biomass as a function of tillage treatment in the Organic farming system.

Sampling date	Tillage system	*Aporrectodea caliginosa* (m^{-2})	*Lumbricus rubellus* (m^{-2})	*Eiseniella tetraedra* (m^{-2})	*Aporrectodea rosea* (m^{-2})	Total abundance (m^{-2})	Biomass ($g\,m^{-2}$)	Adult/juvenile ratio
Spring 2009	M	125 b	45	6	8	195 b	-	0.41
	NIT	147 b	31	15	17	236 ab	-	0.26
	MP	273 a	45	21	5	375 a	-	0.42
Fall 2009	M	227 b [2]	168	0	9	415	129 a	0.46
	NIT	151 b	116	1	5	289	82 b	0.36
	MP	271 a	80	2	16	389	78 b	0.24
Fall 2010	M	89 b	52	1	10	159 b	40 b	0.61
	NIT	64 b	15	1	5	104 b	34 b	0.57
	MP	271 a	44	7	23	357 a	75 a	0.35
Spring 2011	M	18 ab	4	1	1	28	11	2.00
	NIT	8 b	5	1	1	21	6	0.25
	MP	58 a	2	1	2	75	16	1.22
Fall 2011	M	365 b	50	21	10	560 b	97	0.38
	NIT	293 b	51	85	6	555 b	84	0.42
	MP	566 a	44	88	31	841 a	93	0.19
Spring 2012	M	309 ab	84	20	12	557	74 a	0.50
	NIT	230 b	80	11	9	446	58 ab	0.51
	MP	383 a	38	8	5	543	35 b	0.26

[1] Species abundances, total abundance and total biomass are back-transformed means. Tillage systems: minimum (M), mouldboard plough (MP) and non-inversion tillage (NIT). Species with > 1% of overall abundance are included, other species present were *Lumbricus terrestris*, *Lumbricus castaneus*, *Aporrectodea longa*, *Allolobophora chlorotica* and *Murchieona minuscula*. Species abundance columns are ordered from left to right by decreasing overall abundance. Letters indicate significant differences between tillage systems within sampling date (P<0.05).

The analysis of the relation between infiltration capacity and earthworm biomass (figure 11) shows significant correlations especially under conventional ploughing (P) and in a less extend under non-inverse-tillage. The link with earthworm community structure has to be analysed to find some explanations (Crittenden et al., 2012-Eurosoil).

Values are high relative to literature, but we have found consistent levels throughout our sampling campaigns, so we would say within our methodology the values are ‘normal’. Also we believe the site has higher earthworm numbers than average, even if no anecics are present, and this may have an effect.

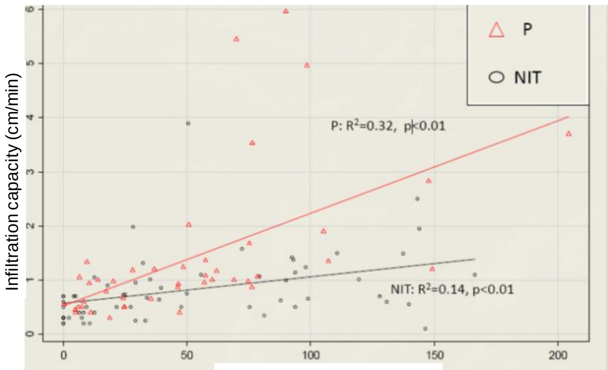

Figure 11: relation between infiltration capacity and earthworm biomass in Lelystad site (P: conventional ploughing, NIT: non-inverse-tillage)

4.4 Dissemination

4.4.1. University of Rennes

4.4.1.1 Presentations at scientific conferences

- G. Pérès, L. Brussaard, D. Cluzeau, M. Corson, S. Crittenden, B. Delbaere, V. Hallaire, J. Heddadj, G. Korthals, S. Menasseri, T. Morvan, M. ,Potthoff, M. Pulleman, S. Schrader, W. Sukkel. 2012. How does reduced tillage influence soil biodiversity, soil functions and ecosystem services? The example of the SUSTAIN project. Oral presentation - EUROSOIL 2012, 2-6 July 2012, Bari, Italy.

4.4.1. 2 Dissemination for multi-stakeholders, farmers, large public (presentation, training)

Dissemination for multi-stakeholders, farmers and large public aims to i) aware about soil and especially soil biodiversity and how agricultural practices impact on soil functioning or dysfonctioning, ii) propose tools to sample earthworms in order to characterize the biological state of soil.

Dissemination could be animation (posters, observation with microscops, games), conference, training (during all the day). The list of these different actions is detailed in tables 12 and 13.

During the first year of SUSTAIN programme, 43 presentations have been given to multi-stakeholders, i.e. 21 in 2011 (from 01/10/2011 to 31/12/2011) and 22 in 2012 (from 01/01/2012 to 31/10/2012).

Table 12: list of dissemination actions towards multi-stakeholders, farmers and large public in 2011.

Date	Framwork	Actors	Location	Type of dissemination	Public type
10et11/09/2011	"Art & Nature" Festival	DC, GP, MG, LR, CB, HH, KH, AD	Paimpont Station(35)	Animation	Large public
7, 8 et 9/10/2011	Trade show "Ille et Bio"	DC, GP, MG,CB, HH, AD, ND	Guichen (35)	Animation - Conference	Large public, teachers, farmers
19/10/2011	Training for farmers	DC, ND	Besançon (25)	Training	Technicians from agricultural chamber
08/11/2011	"Sols de Bretagne 56" Colloquium	MG	Bignan (56)	Conference	Stakeholders (policy, farmers)
17/11/2011	Training for farmers "OPVT"	HH, ND	Mazières en Gatine	Training (OPVT)	Farmers
18/11/2011	Training for farmers	ND, HH, AD	Maure de Bretagne (35)	Training	Farmers, technicians, agricultural advisers
24/11/2011	Training for farmers	GP,ND, HH	Le Faouet (56)	Training	Farmers, technicians, agricultural advisers
30/11/2011	"Eau & Rivière de Bretagne" Colloquium	DC	Pontivy (56)	Conference	Farmers, technicians
01/12/2011	"Educagri Ecophyto" days	DC, ND	Dijon (21)	Training (OPVT)	Teachchers from agricultural school
02/12/2011	"TCS" days	ND	Vendôme (41)	Conference	Farmers, technicians, agricultural advisers
05 et 06/12/2011	Training for farmers "OBMA"	ND	Haute-Marne (52)	Training (OPVT)	Farmers, technicians
09/12/2011	Training for farmers "OBMA"	ND	Vaucluse (84)	Training (OPVT)	Farmers, technicians
12 et 13/12/2011	Training for farmers "OBMA"	ND	Vendée (85)	Training (OPVT)	Farmers, technicians
14/12/2011	Training for farmers	DC	Pont-scroff (56)	Training	Farmers, technicians
13/12/2011	School (primary school)	MG, AD	Paimpont (35)	Animation	Pupil
14/12/2011	Training for farmers "OPVT"	DC, ND	Angers (49)	Training (OPVT)	Farmers, technicians

Table 13: list of dissemination actions towards multi-stakeholders, farmers and large public in 2012.

Date	Framwork	Actors	Location	Type of dissemination	Public type
15 et 16/02/2012	Training for farmers "OPVT"	DC, ND	Sergonzac (16)	Training (OPVT)	Winegrower
24/02/2012	Training for farmers "OPVT"	DC, ND	Beaulieu sur Layon (49)	Training (OPVT)	Technicians, agricultural advisers
28/02/2012	Training for farmers	GP, ND	Angers (49)	Training	Farmers
01/03/2012	Training for farmers "OPVT"	ND, HH, DC	Paimpont (35)	Training (OPVT)	Techniciens
07/03/2012	Training for farmers "OPVT"	ND	Auxerre (89)	Training (OPVT)	Technicians, farmers, agricultural advisers
09/03/2012	Training for farmers	DC	Ploermel (56)	Training	Farmers
13/03/2012	Training for farmers	GP	Pontivy (56)	Training	Farmers
13/03/2012	Training for farmers "OPVT"	ND	Châlons-en-Champagne	Training (OPVT)	Technicians, farmers, agricultural advisers
16/03/2012	Training for farmers "OPVT"	ND	Thouars (79)	Training (OPVT)	Technicians, farmers, agricultural advisers
27/03/2012	Training for farmers "OPVT"	ND	Milly la Forêt (91)	Training (OPVT)	Technicians
29/03/2012	Training for farmers "OPVT"	HH	Plémet	Sampling demonstration (OPVT)	Technicians, farmers
13/06/2012	"Terrenales" days	DC,HH,ND	St-Rémy en Mauges (49)	Conférence et stand	Technicians, faremrs
04/06/2012	"FNE" days	ND	Rambouillet	Training (OPVT)	Agricultural advisers
11, 12, 13 et 17/09/2012	Training for farmers "OPVT"	DC, ND, HH	Bazas, Lyon, Reims, Rennes	Training (OPVT)	Agricultural advisers
21/09/2012	"OAB" technical days	ND	Paris	Short presentation (15')	Agricultural Network coordinators
26/09/2012	Training for farmers "OPVT"	ND	Chambray (27)	Conference	Farmers, technicians, students
19/10/2012	Training for farmers	GP	Besançon (25)	Training	Farmers
25/10/2012	Training for farmers	GP	Hennebont (56)	Training	Farmers

4.4.1.3 Publications (scientific report)

- Ado Maman Nasser. 2012. Impact des Techniques Culturales Simplifiées sur la qualité des sols en Agriculture Biologique dans le contexte breton. Approche biologique et Physique. Master 2 student report. Agrocampus Ouest school (Rennes). September 2012 (Annexe 2).

- Pauline Lenancker. 2012. Impact du non-travail du sol sur la qualité des sols en contexte agricole breton. Approche physique et biologique. Licence 3 student report University Rennes 1 (still under writting).

4.4.1.4. Publications (scientific, article in peer-reviewed journal)

- Pulleman, M., Creamer, R., Hamer, U., Helder, J., Pelosi, C., Pérès, G., & Rutgers, M., 2012. Soil biodiversity, biological indicators and soil ecosystem services-an overview of European approaches. Current Opinion in Environmental Sustainability, 4(5), 529–538.

4.4.2 INRA

4.4.2.1 Presentations at scientific conferences

- G. Pérès, L. Brussaard, D. Cluzeau, M. Corson, S. Crittenden, B. Delbaere, V. Hallaire, J. Heddadj, G. Korthals, S. Menasseri, T. Morvan, M. ,Potthoff, M. Pulleman, S. Schrader, W. Sukkel. 2012. How does reduced tillage influence soil biodiversity, soil functions and ecosystem services? The example of the SUSTAIN project. Oral presentation - EUROSOIL 2012, 2-6 July 2012, Bari, Italy.

- S. Busnot, S. Menasseri-Aubry, M. Pulleman, S. Crittenden, J. Faber, G. Peres. 2012. Etude comparative de méthodes de mesure de la stabilité structurale des sols cultivés. Poster Journée de la mesure (J2M) INRA, France, 8-11 October 2012

- Y. Bénard, V. Hallaire. 2012. Mesure d'infiltrométrie des sols par la méthode DECAGON. Poster Journée de la mesure (J2M) INRA, France, 8-11 October 2012

4.4.2.2 Publications (scientific report)

- Robin Guihlou. Impact du non labour sur la qualite des sols en contexte agricole breton : approche physique et biologique. Master 2 student report. Univesity of Rennes 1, Agrocampus Ouest school (Rennes). September 2012 (Annexe 1).

4.4.3 CRAB

4.4.3.1 Presentations at scientific conferences

- G. Pérès, L. Brussaard, D. Cluzeau, M. Corson, S. Crittenden, B. Delbaere, V. Hallaire, J. Heddadj, G. Korthals, S. Menasseri, T. Morvan, M. ,Potthoff, M. Pulleman, S. Schrader, W. Sukkel. 2012. How does reduced tillage influence soil biodiversity, soil functions and ecosystem services? The example of the SUSTAIN project. Oral presentation - EUROSOIL 2012, 2-6 July 2012, Bari, Italy.

4.4.3.2 Dissemination for multi-stakeholders, farmers, large public (presentation, training)

- Heddadj, D. 2012. Les techniques culturales sans labour. Kerguéhennec, 7 mars 2012. Presentations at students from IUT Quimper

4.4.3.3 Publications (scientific report)

- Younna Jiquel. Impact des techniques culturales sans labour sur l'état structural du sol et le comportement du maïs dans le contexte Breton. Master 2 student report. Agrocampus Ouest school (Rennes). September 2012 (Annexe 4).

4.4.3.4 Publications (technical review)

- Heddadj, D. 2012. 10 ans de recherche sur le travail du sol. Communication à la revue TCS, n°69, sept/oct, 2012. *(article rédigé par Matthieu Archambeaud)*

4.4.4 Wageningen University

4.4.4.1 Presentations at Scientific conferences

- G. Pérès, L. Brussaard, D. Cluzeau, M. Corson, S. Crittenden, B. Delbaere, V. Hallaire, J. Heddadj, G. Korthals, S. Menasseri, T. Morvan, M. ,Potthoff, M. Pulleman, S. Schrader, W. Sukkel. 2012. How does reduced tillage influence soil biodiversity, soil functions and ecosystem services? The example of the SUSTAIN project. Oral presentation - EUROSOIL 2012, 2-6 July 2012, Bari, Italy.
- Pulleman, M., Crittenden, S., Eswaramurthy, T., De Goede, R. 2012. Soil tillage effects on earthworm populations and species diversity in arable farming systems; understanding the temporal and spatial dimensions. Oral presentation. XVI ICSZ – International Colloquium on Soil Zoology. Coimbra, Portugal, 06-10 August 2012
- Crittenden et al. 2012. Can reduced disturbance improve soil physical quality through earthworms?" FAO/IAEA International Symposium on Managing Soils for Food Security and Climate Change Adaptation and Mitigation. Poster presentation. 23 – 27 July 2012, Vienna, Austria.
- Crittenden et al. 2012. "Can reduced disturbance improve soil physical quality through earthworms?". Poster presentation. EUROSOIL 2012, 2-6 July 2012, Bari, Italy.

4.4.4.2 Presentations for multi-stakeholder event, farmer, technicians, large public

- Pulleman, M. 2011. Klimaatverandering en ecosysteemdiensten. Presentatie voor stakeholders (begeleidingscommissie). Lelystad, 15 september 2011
- Pulleman, M. Relatie tussen grondbewerking, bodemleven & bodemstructuur. Stakeholder meeting praktijknetwerk niet-kerende grondbewerking. Lelystad, 19 december 2011
- Crittenden et al. 2012. "SUSTAIN project, a SNOWMAN network collaboration". Oral presentation. ELN-FAB European Seminar: Applying functional agrobiodiversity in the Mediterranean 14 & 15 June 2012, Avignon, France
- Pulleman, M. 2011. Relatie tussen grondbewerking, bodemleven & bodemstructuur. Oral presentation at a meeting of the Dutch Network of Practice for Non-inversion tillage systems. Lelystad, 19 December 2011.

4.4.4.3 Publications (scientific report and professional)

<u>Scientific report</u>

- Ros, M. 2012. Internship at INRA Lousignan & Biological Research Station Paimpont. **MSc Internship Report**. Wageningen University. Department of Soil Quality. August 2012 (Annexe 3).
- Guan, Y and Li, T. Non-inversion tillage system promotes soil physical factors and earthworm community. **Bsc thesis**. Van Hall Larenstein. July 2012.

- Poot, N. 2012. Effect of non-inversion tillage on soil structural and hydraulic properties in a marine loam soil in the Netherlands. Department of Soil Quality, Wageningen University. **MSc thesis.** March 2012

- Eswaramuthy, T. 2012. Effects of inversion and non-inversion tillage on earthworm population dynamics and species diversity in organic and conventional arable farming systems. **MSc thesis.** March 2012

Popular article

- Berg, G.A. van den; Rozen, K. van; Pulleman, M.M. (2012). Worm blij met natte zomer : Interview met Klaas van Rozen en Mirjam Pulleman. Boerderij 97 (49). - p. 40

4.4.4.4. Publications (scientific, article in peer-reviewed journal)

- Pulleman, M., Creamer, R., Hamer, U., Helder, J., Pelosi, C., Pérès, G., & Rutgers, M., 2012. Soil biodiversity, biological indicators and soil ecosystem services-an overview of European approaches. Current Opinion in Environmental Sustainability, 4(5), 529–538.

4.4.5 PPO

4.4.5.1 Presentations at Scientific conferences

- G. Pérès, L. Brussaard, D. Cluzeau, M. Corson, S. Crittenden, B. Delbaere, V. Hallaire, J. Heddadj, G. Korthals, S. Menasseri, T. Morvan, M. ,Potthoff, M. Pulleman, S. Schrader, W. Sukkel. 2012. How does reduced tillage influence soil biodiversity, soil functions and ecosystem services? The example of the SUSTAIN project. Oral presentation - EUROSOIL 2012, 2-6 July 2012, Bari, Italy.

4.4.5.2 Presentations for farmers and technicians

- Meeting of the Dutch Network of Practice for Non-inversion tillage systems. Lelystad, 19 December 2011.

- Seminar on Soil management for intermediates, advisors and policy. Venray, 9th February 1012

- Farmers field day. Akkervelddag. With specific attention to the BASIS experiment en various aspects of non inversion tillage, soil biodiversity and soil management. Lelystad, 27 June 2012. http://www.akkerbouwvelddag.nl/ . 300 visitors to the BASIS experiment (farmers, researchers, student, advisors)

- Farmers field day at Vredepeel. With specific attention to soil management, soil quality indicators, organic matter management and minimum soil tillage.Vredepeel 17th August 2012. 200 visitors.

- W. Sukkel and D. van Balen, 30 Januari 2012. Presentation, BASIS, non inversion tillage on clay soil. Meeting for researchers, 25 persons present

- W. Sukkel, Vredepeel 9 februari 2012. Presentation 'Soil in Sight' at a meeting for advisors and intermediates. 100 persons present.

4.4.5.2 Publications (scientific report and professional)

- W. Sukkel October 2012: Submitted: Article on Reduced tillage and shallow ploughing in professional magazine for organic agriculture

- Newsletter results 2012 from the Basis experiment

4.4.6. ENCN

ECNC provided that the ELN-FAB network (www.eln-fab.eu) to distribute information and the results of the project to the wide range of stakeholders all over Europe.

Presentation about the Sustain project at the ELN-FAB European Seminar

Some 40 experts met in Avignon, France, to exchange information on functional agrobiodiversity (FAB) and its application in the Mediterranean region. In the framework of the European Learning Network on Functional AgroBiodiversity (ELN-FAB) a European Seminar was held on Thursday 14 and Friday 15 June 2012. The meeting aimed to stimulate the uptake of functional agrobiodiversity throughout the Mediterranean region as a contribution to sustainable agriculture.

Representatives from science, policy, business and practice from 10 European countries participated in the seminar. In the mornings there were two sessions with presentations and discussion on functional agrobiodiversity, and on Thursday afternoon there was an excursion to an agroforestry test site. A marketplace was held on Friday morning, giving participants the opportunity to give a brief presentation on their work or various initiatives, to enable the participants to establish contacts. These snapshot presentations were followed by a lively exchange.

During the closing session the chairman of the seminar, ECNC's Ben Delbaere, presented the conclusions of the seminar. Some of the points raised were that functional agrobiodiversity is much more than just pest control and covers many facets, such as pollination, erosion control and increased soil organic matter. To apply FAB in different cases requires tailor-made approaches that take regional differences into account. It is important that the scientific community convince farmers and society at large of the usefulness of FAB, while constantly keeping an eye on and influencing developments in national and international agricultural policy.

The European Seminar was organized by ECNC in cooperation with DIVERSITAS and the Groupe de Recherche en Agriculture Biologique (GRAB), and hosted by INRA in Avignon, France.

<u>News items</u>

The ELN-FAB newsletters and the regularly updated website made sure that the information about Sustain project is properly disseminated to the relevant target groups.

4.5 Others

4.5.1 Students involved

In France

- Robin Guihou (Master 2), master of INRA
- Ado Maman Nasser (Master2), master of University of Rennes
- Youna Jiquel (Master 2), master of CRAB
- Justine Zech (Master 2), master of CRAB
- Pauline Lenancker (Licence 3), master of University of Rennes

In the Netherlands

- Peter Guan, Tian Li (BSc)
- Mart Ros (Msc)
- Joanna Frazão (PhD)
- Tamila Eswaramuthy (MSc)
- Natasja Poot (MSc)
- PPO: 5 other students involved from higher from university and professional agricultural education in various topics in the BASIS experiment

4.5.2 Collaborations

Prof. Lijbert Brussaard stayed at University of Rennes (Biological Research Station Paimpont) for a sabattical time, from May to June 2012.

5. Anticipated use and especially application of results

At this stage of SUSTAIN project, i.e. one year after the begining, there is no special advice for anticipated use or application of the results

6. Conclusion / recommendations

Regarding the results obtained this first year, a new sampling campaign is needed and therefore will be conducted, especially to test the effect of crop rotation which seems to be very important on biological and physical responses (prevalent driver) and to test the effect of surface state. Moreover, in order to coordinate actions from ECOSOM and SUSTAIN, a join meeting is planned in January 2013 in The Netherlands.

Actions planned for next year: another field campaign will be conducted, ecosystem service will be analyzed and the economical and sociological approaches will be done; moreover the modelling analysis will start and the dissemination tasks will be pursued.

7. References

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Menasseri-Aubry S., Piron D., Cluzeau D., Hallaire V., 2011. Evaluer et modéliser la gestion des matières organiques associées à une réduction du travail du sol en vue d'une agriculture durable, rapport du Programme de Recherche d'Intérêt régional (région de Bratagne), 215p.

Piron, D., M. Moussay, G. Pérès, A. Bellido, M. Guernion, and D. Cluzeau. 2011. Caractéristiques et évolutions des communautés lombriciennes sous l'influence du travail du sol et de la fertilisation organique. Tiré du rapport final du Programme de Recherche d'Intérêt Régional (Région Bretagne) intitulé "Évaluer et modéliser la gestion des matières organiques associée à une réduction du travail du sol en vue d'une agriculture durable". 215p.

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8. Annexes

Annexe 1 : Robin Guilou's report

Robin Guihlou. Impact du non labour sur la qualite des sols en contexte agricole breton : approche physique et biologique. Master 2 student report. University of Rennes 1, Agrocampus Ouest school (Rennes). Juin 2012.

Annexe 1 - Robin
Guilhou 2012 - memoi

Annexe 2 : Ado Maman Nasser's report

Ado Maman Nasser. 2012. Impact des Techniques Culturales Simplifiées sur la qualité des sols en Agriculture Biologique dans le contexte breton. Approche biologique et Physique. Master 2 student report. Agrocampus Ouest school (Rennes). September 2012 (Annexe 2).

Annexe 2 - Ado
maman Nasser 2012 -

Annexe 3 : Mart Moss's report

Ros, M. 2012. Internship at INRA Lousignan & Biological Research Station Paimpont. MSc Internship Report. Wageningen University. Department of Soil Quality. August 2012.

Internship
Report_Mart Ros_Sci

Annexe 4 : Younna Jiquel's report

Younna Jiquel. Impact des techniques culturales sans labour sur l'état structural du sol et le comportement du maïs dans le contexte Breton. Master 2 student report. Agrocampus Ouest school (Rennes). September 2012.

Annexe 4 - Younna
Jiquel 2012 - Memoire