SNOWMAN NETWORK

Knowledge for sustainable soils

Project number SN03 – 14

SUSTAIN

Soil Functional Biodiversity and Ecosystem Services, a Transdisciplinary Approach

Second Annual Report

October 2012-September 2013

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Project coordinators:

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

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Abstract

The 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. The project involves 6 teams, 3 from France and 3 from the Netherlands. This second annual report describes the major tasks realized during the second year of the project (October 2012-September 2013) and the results that have been obtained as well as the SUSTAIN coordination activities. It also presents the planning for the third and final year of the project.

Results obtained in France and in the Netherlands in 2011-2012 had already shown that reduced tillage systems (reduced tillage or direct seeding) can impact positively on biological (earthworm community) and physical (soil porosity, soil aggregate stability, water conductivity, macroporosity) states. However results were not always consistent with what had been found in previous years, indicating that variability in the results between years can be very high. This prevented us from making general conclusions about tillage effects on biological and physical soil properties at that stage. We decided to carry out another field campaign in the fall 2012 (the Netherlands) and spring of 2013 (France).

Therefore, during this second year (October 2012- September 2013), three main tasks have been performed, in addition to the coordination, i.e. field campaign, social approach and dissemination. In preparation for the last year of the project, we had extensive discussions of the approaches to be used or the data integration, ecosystem services evaluation and socio-economic evaluation of the systems.

Concerning the coordination, a total of six national and international meetings were organized in order to: (i) discuss progress among each other and with the ECOSOM project, (ii) organize the sampling campaign, and (iii) discuss the supervision of students.

Field campaigns were realized in the Netherlands and in France in order to characterize biological and physical soil properties and functions. Results obtained in France gave the following results:

- Under organic management (FKO), the measurement realised in March 2013 showed that the agronomical ploughing (15 cm depth) was favourable to earthworm abundance and biomass, however it affected anecic species. In contrast, the reduced tillage systems (superficial tillage at 8 or 15 cm depth) were not favourable to earthworm abundance but they improved the development of anecic species (e.g. *Aporrectodea giardi*). The monitoring of earthworm community since the beginning of the trial (2003) demonstrated that reduced tillage systems are significantly positive for earthworm biomass and anecic abundance, while no constant results are observed concerning abundance and endogeic community. Moreover, this study also showed that some earthworm species such as *Aporrectodea caliginosa* and *Allolobophora chlorotica* seemed to take benefit from ploughing actions. Monitoring approach (2003-2013) showed that reduced tillage systems, especially very superficial tillage (8 cm depth) always improved microbial biomass (also observed in 2013), while no significant impact on nematofauna was observed. Reduced tillage systems also appeared favourable to chemical properties (C, N, P, organic matter content), aggregate stability, hydraulic conductivity at soil surface, but few impact on soil bulk density. The relationships between biological and physical parameters suggested that endogeic community reduced the hydraulic conductivity while the presence of anecic species, especially *L. r. rubellus* increased the hydraulic soil functioning. In fine, this study showed that in most years, reduced tillage systems increased the weed pressure and in consequence reduced the yield. This result was especially observed Triticale crop, while it was not observed under wheat and maize crops reinforced by the dried conditions.

- The analysis of the runoff, erosion and pesticides transfer (FKT), showed an evolution of the results since the beginning of the trial: in 2003, the runoff was higher under reduced tillage systems (direct seeding and superficial tillage), then it was the inverse (higher under conventional ploughing), but in 2013, the runoff was higher under direct seeding. Therefore, we could not conclude on the positive impact of reduced tillage systems on runoff; however results concerning erosion were more constant: reduced tillage systems reduced the erosion, which is in accordance with literature. Concerning the pesticide transfer (analysed in 2013), the transfers were strongly related to the properties of the different molecules (KoC, solubility) and did not allow us to conclude on the impact of reduced tillage systems. Concerning the phosphorus transfer, it was lower under reduced tillage systems for the total phosphorus and particular phosphorus while it was higher for soluble phosphorus. New data will be done next year (2014).
- At Lelystad site, earthworms were collected from spring 2009 to spring 2012 for the conventional and the organic farming system. Community were strongly dominated by the endogeic earthworm *Aporrectodea caliginosa*. Under *conventional system*, abundances were very heterogeneous depending on the seasons (higher in autumn than in spring). Reduced tillage systems (minimum or non-inversion tillage) seemed to be favourable to earthworm abundance, but only in trends (it was only significant once in autumn 2012). However, this result was supported by other results obtained at the farmers fields Hoeksche Waard, where earthworms were assessed over 4 seasons: earthworm abundance was significantly higher under reduced tillage than under moldboard ploughing in farmers fields. Under *organic system*, the abundances were also heterogeneous depending on the seasons but without any clear difference between autumn and spring; total abundance of earthworms was significantly affected by tillage treatment in 3 out of 6 samplings: the ploughed system showed higher earthworm numbers than the reduced tillage systems, except in the autumn of 2012 (no difference between treatments). Under both management systems (organic and conventional) *Lumbricus rubellus* was positively impacted by reduced tillage systems. The assessment of an extra parcel in autumn 2012, which presented another crop within *organic crop rotation*, showed contrasted results: reduced systems improved earthworm abundances due to the increase of *A. caliginosa*. In complement to biological parameters, data on soil structure (aggregate stability) and soil organic matter contents were collected in fall 2012 in different fields of the BASIS experiment, after four years after the start of the trial. The analysis showed that: i) aggregate stability was significantly higher under reduced tillage in both farming systems, but only at 10-20 cm depth; ii) soil organic matter contents were significantly higher in the reduced tillage system compared to the ploughed system, but only at 0-10 cm depth.

All of these results underline the complexity of the system and the necessity to integrate all the parameters of the system (crop rotation, climate conditions, spatial and temporal variability) in order to really understand the biological response as well as physical responses and to identify the relevant drivers of soil biodiversity, soil functioning, and therefore the ecosystem services linked. This meta-analysis of all these data, will be facilitated by the SUSTAIN database which has started to be build and which will be implemented during February and March 2014.

For the <u>sociological analysis</u> (applied on the farm network in Brittany), twenty six farmers involved in reduced tillage systems were interviewed. This study led to the definition of three agronomical coherence classes based on the depth tillage and the number of changes of the cropping system level. This study also showed that the main reason for farmer to change their systems refers to economic and social improvements, such as savings on working time and costs; however it is in evolution, integrating environmental consideration. Progressively, farmers gain a systemic view of soils and enter in an adaptation process. Their information sources are diversified (partnerships of an association, magazine, but few from internet) and many of them have in common the fact that they enhance the exchanges between farmers. In conclusion, the farmers have underlined the necessity to leave the top-down approaches (from researchers to farmers through advisors) in order to develop an interactive network and therefore co-construct the evolution of the production system thanks to the sharing of knowledge between advisors, farmer and searchers.

Dissemination was done towards scientists (1 colloquium, 4 publications) and stakeholders e.g. farmers, agricultural adviser and large public (more than 30 trame shows).

For the next year, (i) another field campaign will be conducted on the farm network in Brittany order to assess the spatial variability at regional scale of the biological and physical responses, (ii) ecosystem service will be analyzed and (iii) the economical and sociological approaches will be done. Moreover the modelling analysis will start, with a strong effort for the Life Cycle Analysis and the meta-data analysis. In fine, the dissemination task will be pursued with a common meeting with ECOSOM project addressed to stakeholders, national meetings addressed to farmers, and a technical brochure and a handbook.

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).

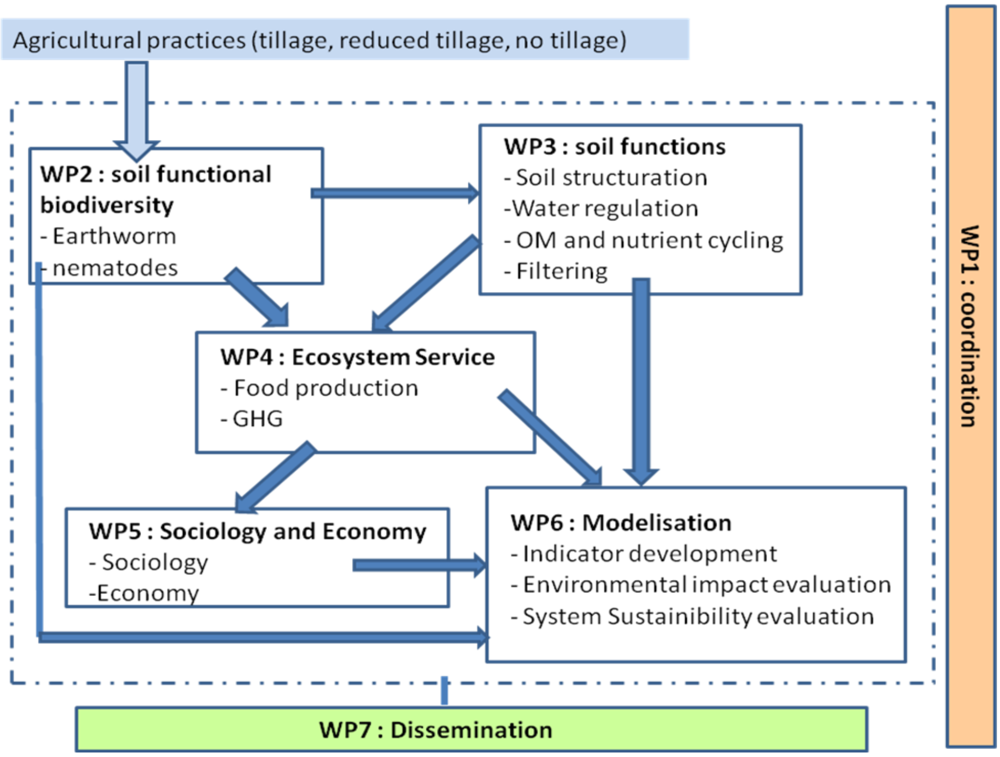

Figure 1: Global framework of SUSTAIN project

Table 1: 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

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

Acknowledgements

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SUSTAIN partners also acknowledge all the students involved in this second 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 second campaign.

SUSTAIN partners also thank Marie-Anne Saint-James from "Ouest Valorisation" for her administrative support in the management of the consortium agreement. This task was time consuming and requiered a huge effort to succeed.

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1. Use of grant

During this second year our grant was used as presented in table 1, details were provided in July 2013 by the respective administrative structures to the funder.

Table 3: 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	Wageningen University	PPO	ECNC
Grant from SNOWMAN (euros)	82,500.00	36,150.00	47,100.00	37,500.00	12,500.00	0.00
Expenses Year 1 (euros)	22,851.39	11,253.77	14,400.00	2,262.00	5,200.00	0.00
Expenses Year 2 (euros)	44,876.27	9,553.48	26,400.00**	18,386.00	3,500.00**	0.00

* Wageningen University charged the total amount for Oct 2011- September 2013 to SKB in December 2013

** Amount, based on previous budget, will be confirmed by partners

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), due 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 (see table 2).

3. Aims and comparison for year 2 according to predetermined objectives

Within the global framework of SUSTAIN (figure 1), the aims of this SECOND year were focusing on WP2, WP3, WP4, WP5 and WP7, and detailed as follow:

- **WP2:** To assess how soil biodiversity (specific, functional, community) is impacted by reduced tillage systems. This was carried out in experimental field sites in France and in The Netherlands and also on farm network in The Netherlands. Soil biodiversity was 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, (4) nutrient cycling (nitrogen, carbon and phosphorus), (5) the filtering role of soil against pesticides, and (6) pest regulation (via nematode community structure).
  The objectives were to sample both in French and Dutch sites.
- **WP4:** To assess the impact on ecosystem services such as food production
- **WP5:** To develop a sociological approach through questionnaires addressed to farmer network.
- **WP7:** To disseminate the experimental results to project partners, Commission Officials, the scientific community, stakeholders and the general public.

The coordination goals **(WP1)** were to optimise the internal communication between partners, through the organization of meetings and a database implementation.

4. Results

4.1 Coordination (WP1)

This chapter details, partners by partners, the different meetings which were organized during the second year of the project.

4.1.1 University of Rennes

4.1.1.1 Annual meetings

During this second year, one annual meeting was organised in common with ECOSOM and SUSTAIN (February 2013).

As requested by SNOWMAN, SUSTAIN project made some bridges with ECOSOM project. Therefore, **Wageningen University** (Mirjam Pulleman) and **University of Rennes 1** (Guénola Pérès) organized a joint SUSTAIN-ECOSOM meeting in February 2013, during 2 days in The Netherlands (at the Kasteel Hoekelum). Objectives were: (i) to present and discuss the results obtained the first year for the two topics that are common to both projects (reduced tillage and organic matter management), (ii) to discuss the future dissemination actions (technical guide, stakeholders meeting), (iii) to present the future actions for the social and economical approach, and the ecosystem services approach, (iv) to present the LCA modelling action which will be done in 2014.

The detailed programme and presentations (pdf) are produced in annexe 1.

The meeting was organized as follow:

Tuesday 26/02/2013:

Twelve talks were given in three sessions and presented in the following order:

i) results from ECOSOM and SUSTAIN projects for two specific themes i.e. reduced tillage and organic matter management,
ii) result on methodological approaches and method comparison for infiltration and aggregate stability measurements.
iii) past and future dissemination actions

The main conclusions were

- **Concerning the results from reduced tillage and organic matter management:** Results were presented and showed that variation in biological and some of the physical properties was high when comparing different years and seasons. It was decided that a new field campaign would be done in 2013 for some of the French sites (sure: French one for SUSTAIN, and perhaps some other). We will also produce a list of potential drivers which can act on biological and physical properties and appropriate statistical techniques will be used to check if these factors can explain the variability found.

- Concerning the methodological approaches: With respect to the hydraulic conductivity measurements, it clearly appeared that the Decagon and double ring methods do not measure the same parameters and these two methods cannot be compared directly. They can however be used as complementary approaches. For aggregate stability it appeared that results obtained from SUSTAIN and ECOSOM should be combined to further analyse the commonalities and the added value of each approach. Results so far look promising enough to produce a paper.

- Concerning the dissemination actions, different points were discussed and decisions were taken regarding:

- ✓ **<u>Meetings</u>**: Dissemination meetings will be organized for addressing different stakeholders:
    - for farmers at national level (based on existing network, e.g. CRAB, PPO) and separate meetings will be organized to deal with reduced tillage and OM management;
    - for other stakeholders (policy makers, advisors …), with several options:
        - 1 by country
        - 1 common in one country:
            - 1 day but separated topics : ½ day OM + ½ day RT; theory and field trip (however, this field trip seems to be very difficult to organize)
            - 1 day with mix of topics: Ecosystem services = common hat
            - 2 different meetings with separated topics (OM and RT)

    ⇨ Simon proposed a phone meeting with SNOWMAN dissemination board to take part to the discussion
- ✓ **<u>Brochure</u>:** It was decided that the brochure will not be a technical guide, and that the topics i.e. reduced tillage and organic matter management will be separated.
    - for Reduced Tillage
        - it will be included in a reduced tillage Handbook (NL), led by PPO.

        - the technical brochure which was produced few years ago by CRAB, will be updated by SUSTAIN results and other knowledge (F)
    - for OM
        - the technical brochure will be similar to French technical brochure on Reduced tillage.

- ✓ **Webcommunication.** The communication via internet tool will be different depending on programmes
    - 1 webpage on INRA for ECOSOM
    - 1 webpage on University of Rennes for SUSTAIN
    - 1 website for SUSTAIN

  There will be a strong relation between SUSTAIN and ECNC activities around the European Learning Network for Functional Agrobiodiversity. t (and ECOSOM should also take benefit from ECNC)
  There will also be a strong relation with SNOWMAN website

- ✓ **Dissemination to Scientists.** The dissemination to scientist will be done via i) the participation in scientist congress (e.g RAMIRAN at Versailles, World congress of soils sciences in Korea, International Symposium on Earthworm Ecology at USA), ii) peer-reviewed papers

- ✓ **Dissemination to large public.** The dissemination to large public will be done through the participation at different social events (France only), training to farmers and technical papers to farmers (France and The Netherlands).

Wednesday 27/02/2013:
sEight talks were given in different sessions in order to:

i) present the sociological and economical approaches which will be developed in 2013.
ii) discuss about 3 ecosystem services such as carbon sequestration, soil structure, water flux, yield production.
iii) discus about the Life Cycling Analysis which will be developed in 2014.

The main conclusions were
- Concerning the social and economical approach: the work will be done in France (Kerguéhennec); Djilali will send the questionnary to benefits from comments. If a student is available, the investigation could be done in NL as part of MSc thesis research (SUSTAIN).

- Concerning the Ecosystem Services: two types of Ecosystem Services were identified, classified as “soft” Ecosystem services which are easily measured (e.g. food production) and “hard” Ecosystem services which not directly measured (e.g. carbon sequestration, GHG).
For the "soft" ES, the relation between soil properties and ES will be done in France (SUSTAIN - Kerguéhennec), and perhaps in Lelystad. It is still necessary to think about the parameters which have to be included in the analysis.
For the "hard" ES, it will be done in France for carbon sequestration (ECOSOM-Qualiagro). At Lelystad it has been done already in one of the fields of the field experiment, other fields may follow in the near future. Data for other GHG (N2O emissions, SUSTAIN-Lelystad) are available but still under evaluation for their quality. Discussions will continue based on the scheme proposed by INRA France.

4.1.1.2 Progress meetings

Field campaign and results: three progress meetings were organized with researchers and students from University of Rennes 1, INRA and CRAB to organize the student recruitment and the field campaign, to discuss about the results and train the defense of the students:

- Paimpont 8th January
- Paimpont 17th June
- Kerguéhennec 9th September

Brochure and social events for farmers: during the meeting at Kerguéhennec, half a day was dedicated to the discussion of the French brochure and social events for famers. It was decided that a working group will work on the brochure and that a first meeting will be done at the beginning of 2014. Dutch colleagues will be invited to take part of the discussion. Concerning the social event, it has been planned for June 2014. Another working group involving also researchers on different topics such as biodiversity, physical properties and chemicals properties, ecosystem services, will work on that.

Social sciences aspect: in June (18th), Guénola Pérès attempted to the STRASS meeting at Paris (SNOWMAN project), in order to share her experience with this social sciences SNOWMAN project.

Dissemination aspect: in September (10th), Guénola Pérès took part at the phone meeting, with the presence of Ingrid van Reijsen (SKB), Agathe Revallier (Veolia-ECOSOM), in order to discuss about the dissemination actions. SUSTAIN and ECOSOM partners received many advices concerning the organisation of the stakeholders meeting. All these informations will be discussed with all the partners of each programme.

4.1.1.3 SUSTAIN Database

The work concerning the SUSTAIN database has started. This work is led by University of Rennes. At this stage, the conceptual model has been proposed (annexe 2) and will be finalized in January 2014. There will be intense relationships between the different SUSTAIN partners and University of Rennes in order to implement this data base during February and March 2014. Therefore all data will be accessible to all SUSTAIN partners for the rest of the project and for the meta-data analysis which was planned in the third year of the project.

It have been decided that this database will not contain all initial data collected during SUSTAIN project, but it will contain what we call “aggregative” data i.e. data which have been more or less analyzed. This choice was motivated by the fact that all partners have their own database which contain the initial data; however these data in their original form are not suitable for the all partners, aggregative data will be more relevant. Data will be at “replicate” scale which will allow statistical analysis. The development of the database will be done on Access software.

4.1.2 INRA

INRA partners took place at the kick-off meeting at Wageningen (February) and at the 3 progress meetings (January, June, September, December).

4.1.3 CRAB

INRA partners took place at the kick-off meeting at Wageningen (February) and at the 3 progress meetings (January, June, September, December). Moreover, the last meeting in September, was organised by Djilali Heddadj (CRAB).

4.1.4 Wageningen University and PPO

Annual meeting and progress meetings

Mirjam Pullman organized the annual meeting at Wageningen (February), at which others partners from University of Wageningen and PPO took place.

Several progress meetings were organized with researchers and students from WU and PPO that work at the Lelystad site.

4.1.5 ECNC

Partner from ECNC (Veronika Mikos) took place at the annual meeting at Wageningen (February).

4.2 Biological and Physical properties (WP2, WP3)

4.2.1 Sampling campaigns

The sampling campaign was discussed during a progress meeting at Paimpont in January 2013 and also during the annual meeting at Wageningen in February 2013. It was decided that due to the contradicting results obtained in France in 2012 compared to previous years (see chapter on “Results”) another sampling campaign would be done in France the week of 25/03/2013 in France.

Moreover, a final field campaign was done in the Netherlands in the autumn of 2012.

4.2.1.1 In France

Field work was done on Kerguéhennec site, an experimental site supervised by the Chamber of Agriculture (CRAB partner). Sampling was mainly carried out from 25th of march to 28th of march.

All the three trials were assessed (figure 2).

Description of the different trials:

- “Organic farming” trial (code FKO), implanted in 2003, assesses 4 tillage systems (CP= conventional tillage i.e. conventional ploughing at 25 cm depth; AP= agronomic ploughing i.e. ploughing at 15 cm depth; C15= reduced tillage i.e. superficial tillage at 15 cm depth; C8= very superficial tillage at 8cm depth); number of plots: 12.
- “Transfer” trial (code FKT), implanted in 2000, assesses the impact of 3 tillage systems (standard tillage i.e. CP= conventional ploughing at 25 cm depth; ST= reduced tillage i.e. superficial tillage at 8 cm depth; DS= direct seeding) on pesticide transfer; number of plots: 9.
- “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);number of plots : 30.

FKA and FKT are managed under conventional management

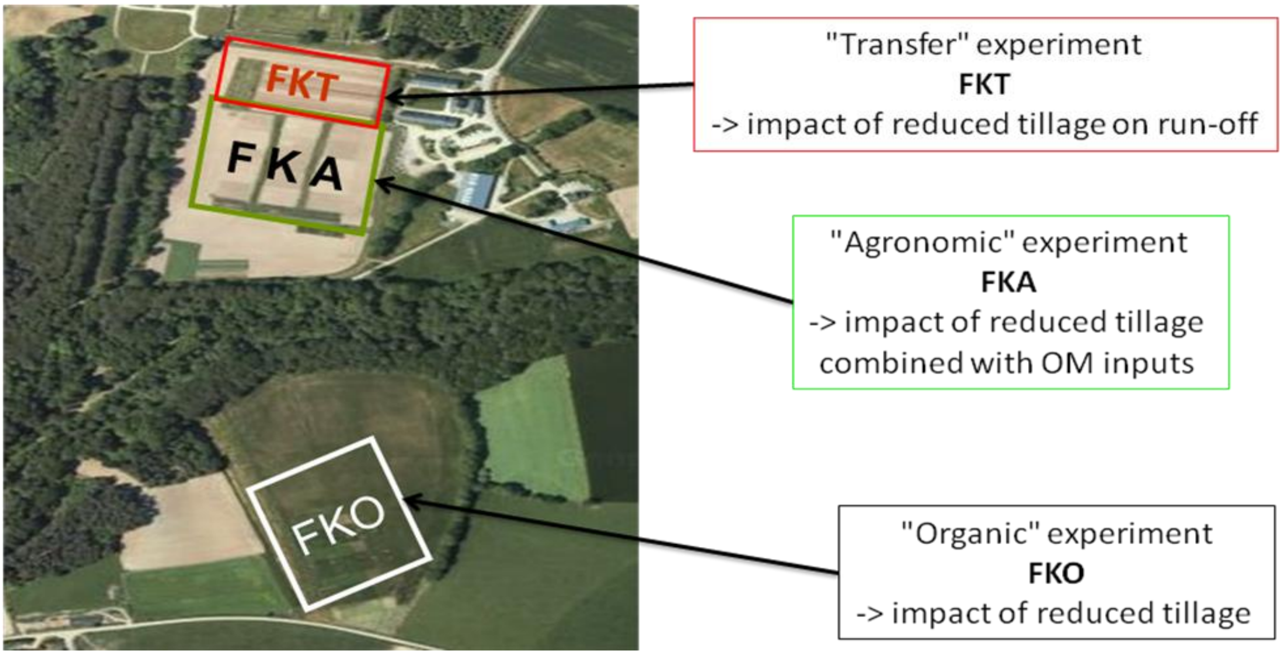

Figure 2: location of the 3 trials from Kerguehennec site

Parameters assessed:

Compared to 2012, less parameters were measured in 2013, because i) result of some parameters (e.g. aggregate stability) were constant since several years, ii) cost and human time consuming. However some parameters which seemed to be very interesting were added such as microbial biomass, chemical parameters (Table 4).

Table 4: comparison of the parameters measured in 2012 and 2013

	2012	2013
Biological parameters:	Earthworm, Nematodes,	Earthworm, Nematodes Microbial biomass
Chemical parameters		C, N, MO, P
Physical parameters	Hydraulic conductivity (double ring and decagon methods) bulk density; aggregate stability (French and Dutch methods); macroporosity analysis (image analysis method); distribution of biological structure on soil profile; run-off; pesticide transfer.	Hydraulic conductivity (Bearkam and decagon methods) Structural organization (spade method) run-off; pesticide transfer.

Depending on the specificity of the trials, parameters were assessed or not (details in table 5). Do to the fact that the trial FKO will be destroyed soon, we put a lot of energy on this trial.

Table 5: Details of the soil parameters assessed in the different trials during the second campaign (2013). Under brackets, the number of replicates.

	earthworm	nematode	microbial biomass	chemical analysis	hydraulic conductivity	structural organization	run-off pesticide transfer
Nb replicates/ plot	3	1	1	1	1 (* 3 depths)	1	Different dates
FKA	X (→90)		X(→30)	X(→30)	X(→30 * 3 depths)	X(→30)	
FKO	X (→36)	X (→12)	X(→12)	X(→12)	X(→12 * 3 depths)	X(→12)	
FKT	X (→27)				X(→9 * 3 depths)	X(→9)	X(3* different dates)

Twelve french persons were involved in the sampling campaign (5 students, 5 technicians and 2 supervisors). Moreover, Bastien Dannevoye (a PhD. student from STRASS programme) joined us during the field campaign, in order to take part to the sampling and also to exchange with Teatske Bakker (a master student) on sociological aspect.

4.2.1.2 in The Netherlands

The Lelystad field experiment, named BASIS is maintained by PPO and was implemented in 2008. The trial compares a ploughed system with 2 forms of reduced tillage (non-inversion tillage and minimum tillage). These tillage systems are implemented in an organic cropping system and in a conventional cropping system that are located next to each other.

The study area (52°31'N, 5°29'E) is located in a polder that was reclaimed from the Ijsselmeer lake in 1957. The daily mean temperature ranges from 2°C in winter to 17°C in summer, and mean annual rainfall was 794 mm during the study (Royal Netherlands Meteorological Institute, 2012). The soil is a calcareous marine clay loam with 23% clay and 12% silt. Soil pH is 7.9 (Crittenden et al. 2012a, submitted).

Description of the different trials

The BASIS field experiment consists of two randomized complete block designs with 4 replicates. The organic farming system and the conventional farming system are separated by a ditch (Fig. XX). Different parcels within one farming system (e.g. A and B) represent different crops in the rotation. The organic system has a 6 year crop rotation and the conventional system has a 4 year crop rotation. Each parcel is divided into 4 blocks and each block is divided into 3 tillage systems.

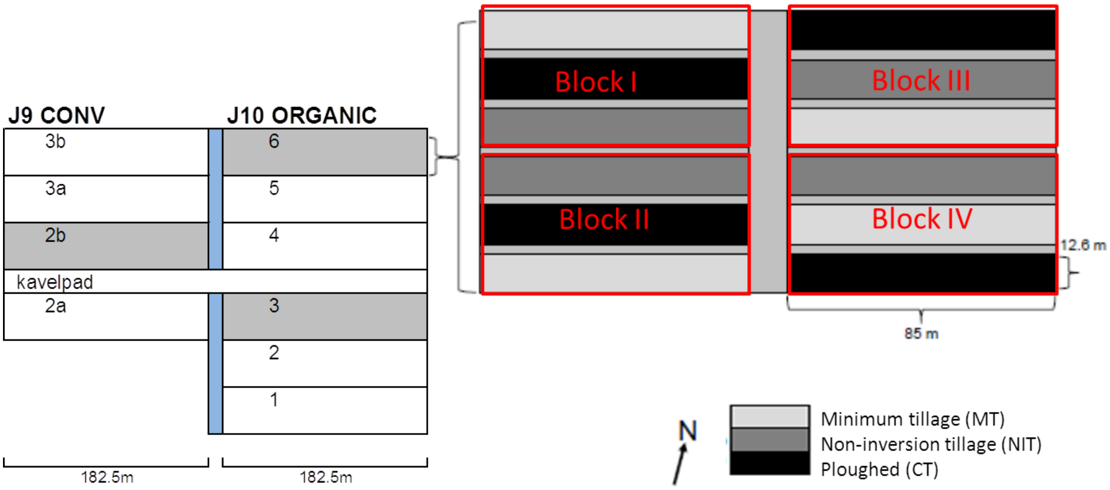

Figure 3: Layout of the BASIS field trials. Conv: conventional farming system; Org: organic farming system.

The three tillage systems are:
- Ploughed system: Mouldboard ploughing to 25 cm depth in autumn and cultivation to 8 cm for seedbed preparation
- Non-inversion tillage: Reduced tillage system with yearly subsoiling to 20 cm deep in autumn and cultivation to 8 cm for seedbed preparation.
- Minimum tillage: Reduced tillage system with optional subsoiling to 20 cm deep in autumn only if soil compaction was high and cultivation to 8 cm for seedbed preparation.

Subsoiling was done using a Kongskilde Paragrubber Eco 3000.

Description of the farmers fields

A limited number of soil parameters was measured in farmers fields in the hoeksche Waard. This is a 325 km2 area in the southwest of the Netherlands consisting of polders that were gradually reclaimed from the sea starting in the 15th century. The Hoeksche Waard is mainly under agricultural land use with crop rotations that include potato, sugar beet, and winter wheat (Steingrover et al., 2010; Rutgers et al., 2012).

Soils are calcareous marine sandy loam to clay (de Bakker et al., 1989). Daily mean temperature is 10 C and annual precipitation is 900 mm (Royal Netherlands Meteorological Institute, 2012). Earthworms were sampled on 3 private farms in the eastern part of Hoeksche Waard as well as at PPO Westmaas research farm 10 km to the north west. On each farm a tillage experiment was set up in 2008 consisting of a non-inversion tillage (NIT) plot beside a mouldboard ploughed (MP) plot at each farm.

Parameters assessed

A final set of data on the long term trial in Lelystad was collected on various dates before fall ploughing. Earthworms, soil organic matter (LOI method), aggregate stability (wet sieving method), infiltration capacity and penetrometer resistance was measured by Bas Oudshoorn, an MSc thesis student at Wageningen University. In addition, samples were taken by PPO for assessment of nematode feeding group diversity. As in other years, PPO measured crop yields, mineral nitrogen concentrations in the soil at different points in time and N_2O emissions at around key events.

In farmers fields in the Hoeksche Waard earthworm numbers and species were determined in parallel plots with and without ploughing on each farm. Sampling was done during spring 2010, fall 2010, fall 2011 and spring 2012. Additionally, soil samples taken during the fall 2010 earthworm sampling were used to measure soil pH, texture, total nitrogen and soil organic matter content.

4.2.2 Results on french site - FKO trial – reduced tillage under organic farming

(study realised by french teams, led by UR1, Florent Lelu, annexe 3)

Data from FKO site were assessed through two approaches: (i) a synchronic analysis applied to the 2013 data, (ii) a dynamic analysis applied to all data from the different field campaigns from the start of the trial. Due to the fact that sampling methods and sampling strategy were not consistent every years, the dynamic approach was conducted in two phases: (i) for the first one, data were analysed year per year separately (approach called “year per year”) and the result of the statistical approach was discussed, (ii) for the second one, only the data presenting consistent method were analysed together and years are used as co-variable (approach called “all years”).

In this report, both approaches will be presented.

4.2.2.1 Earthworm community

In 2013, abundances were comprised between 258 i/m² (very superficial tillage C8) and 502 i/m² (Agronomical Polughing AP) and biomasses were comprised between 66 g/m² (conventional tillage CT) and 88 i/m² (AP) (figure 4). These abundance values are higher compared to those usually obtained under cultivated sites in Brittany (ranging from 86 to 320 i/m²; Cluzeau et al., 2012) and also under organic farming management in France (ranging from 52 to 161 i/m²; Peigné et al., 2009). However, the biomass values are in accordance with values observed under organic farming systems (ranging from 12 to 86 g/m²; Peigné et al., 2009). These high abundances could be explained by the high Organic carbon of the site combined to the favourable texture (Pérès, 2003).

Result showed that agronomic ploughing (AP) increased the earthworm biomass ($p<0.05$) and abundance (in trends, $p>0.05$); in contrast, no positive impact on abundance was observed for reduced tillage system (i.e. superficial tillage or very superficial tillage), however in trends these systems compared to conventional ploughing seemed to be more favourable for the earthworm biomass.

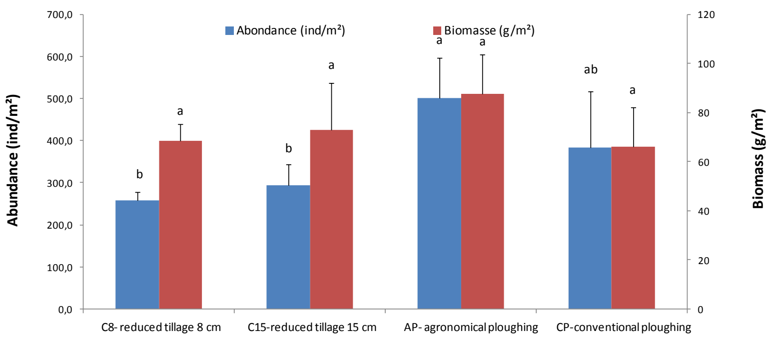

Figure 4: earthworm abundance (Ab, ind./m²) and biomass (Bm, g/m²) measured under different treatments in FKO trial in 2013 (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p<0.05).

Concerning the ecological structure (Figure 5), epigeic were very rare, which is commonly observed under cultivated field (Cluzeau et al, 2009) and is explained by the fact that epigeic are the most exposed to the agricultural constraints (Chan, 2001). Endogeic were dominant whatever the tillage system; their dominance in cultivated field is commonly observed and is explained by their tolerance to cultivated actions (Cluzeau et al., 2009; Chan, 2001). Moreover, in our study they seemed to be positively impacted by the ploughing action, especially by the agronomical one at 15 cm depth ($p<0.01$); this could be explained by the food availability which could be increased by the ploughing action (Bouché, 1972; Piron, 2008).

Anecic were significantly more important under high reduced tillage (C8) than under conventional tillage ($p<0.012$), and in trends, this study showed that reduced tillage systems (C8, C15) seemed to be more favourable to anecic than ploughing system. This is explained by the destruction of the burrow network caused by the ploughing action, combined to the deleterious action on the earthworm body and also the removed of the food supplied into the soil (Chan 2001; Ernst & Emmerling 2009; Pérès, 2003).

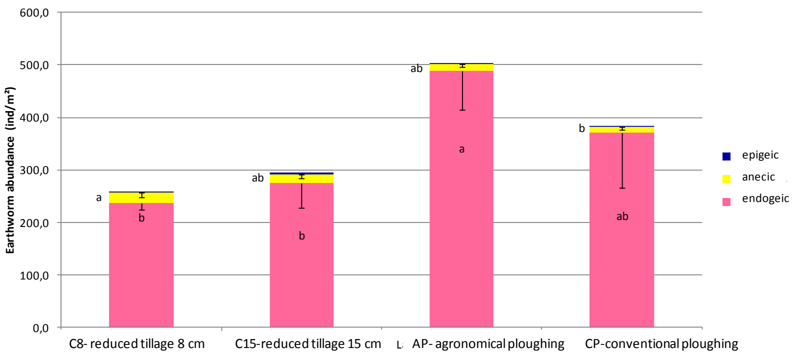

Figure 5: Relative abundance of the ecological earthworm groups (right; pink: endogeic, blue: epigeic, yellow: anecic) measured under different treatments in FKO trial in 2013 (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p<0.05).

Concerning the specific structure (Table 6), the values of species richness was comprised between 8 to 10 species, which is higher compared to cultivated system usually observed in Brittany (Cluzeau et al., 2012) and to organic farming systems in France (ranging from 6 to 7 species; Peigné, 2009). This high species richness was due to the presence of some rare species (*Octalasium cyaneum* and *Allolobophora icterica*). The endogeic community was dominated by *A. caliginosa* (NCCT) and *A. chlorotica* (ACCT) which is commonly observed in the literature; the anecic community was dominated by *N. giardi* (NG).

There was no clear impact of reduced tillage system on the species richness neither on the eveness; however, four species seemed to be impacted by the agricultural systems: *A. caliginosa* (NCCT) and *A. chlorotica* (ACCT) were positively impacted by ploughing systems (p<0.05), which could be explained by the increase of the food availability due to ploughing impact; *A. rosea* (ARR) seemed to be positively impacted by a cultivated action at 15 cm depth. In contrast, anecic species, such as *N. giardi* (NG) was strongly altered by ploughing action.

Table 6: Abundance of earthworm species, species richness and eveness, measured under different treatments in FKO trial in 2013 (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)

		C8	C15	LA	LC
epigeic	L. Castaneus (LC)	0,0	0,6	0,0	0,2
	L. rub. Castaneus (LRC)	0,7	2,3	0,7	0,1
endogeic	A. Chlorotica (ACCT)	99,3 **b**	118,7 **b**	216,4 **a**	153,7 **ab**
	A. Icterica (AI)	0,1	0,1	30,3	2,6
	A. Rosea (ARR)	12,0 **b**	18,7 **ab**	34,9 **a**	13,3 **b**
	N. Caliginosa (NCCT)	125,3 **c**	137,4 **bc**	206,8 **ab**	201,1 **a**
	O. Cyaneum (OC)	0,0	0,1	0,0	0,0
anecic	L. Rubellus (LRR)	3,0	4,6	2,4	2,8
	L. Terrestris (LT)	3,1	0,3	2,0	2,2
	N. Giardi (NG)	14,6 **a**	11,6 **ab**	8,4 **b**	6,7 **b**
species richness		8	10	8	9
eveness		0,60	0,56	0,60	0,56

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Earthworm dynamic.

The analysis of the earthworm dynamic was performed from 2004 to 2013 (7 dates: 2004, 2006, 2007, 2010, 2011, 2012, 2013).

The analysis of the results obtained year per year (Figure 6) showed that the abundance values as well as endogeic values were very heterogeneous: some years, abundance seemed to be positively impacted by reduced tillage and some years it was the opposite. In contrast, in most of the years (except 2012 and 2013), the biomass as well as the anecic abundance were more important under reduced tillage systems (C8, C15) than under ploughing systems (AP, CP) (Lelu, 2013).

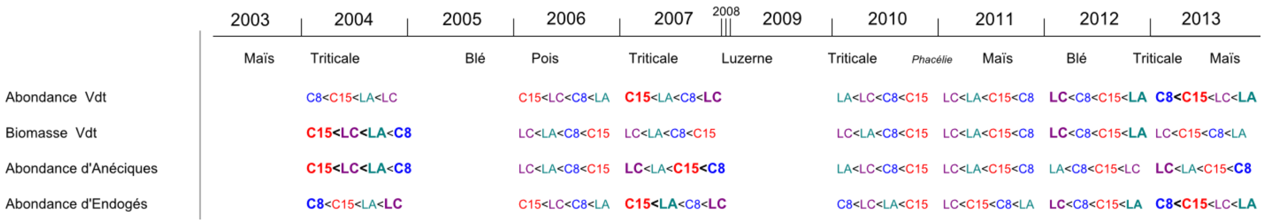

Figure 6: Results of the "year per year" approach presenting the impact of different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) on earthworm abundance, biomass, anecic and endogeic abundance. In bold, the treatments which are significantly different from the other (p<0.05).

This result was reinforced by the "all year" statistical analysis, where years are co-variable: biomass was positively impacted by reduced tillage systems (C8, C15, AP), especially C8, while it was altered by deep ploughing (CP); anecic were altered by both ploughing systems, and especially deep ploughing action (C8) (Table 7).

Table 7: Mean of earthworm abundances, biomasses, anecic and endogeic abundances under different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) on. Different letters show significant differences between treatments (p<0.05)

. Parameter	C8	C15	AP	CP	P value
Earthworm abundance	218.2	223.1	304.4	266.1	0.090
Earthworm biomass	76.3 ^{a}	64.8 ^{ab}	67.6 ^{ab}	46.4 ^{b}	0.024
Anecic abundance	23.6 ^{a}	20.5 ^{ab}	15.1 ^{bc}	12.8 ^{c}	0.006
Endogeic abundance	191.3	196.8	283.3	250.5	0.144

4.2.2.2 Nematofauna

Nematofauna was only studied in 2013.

The study showed that the abundance of nématofaune ranged from 1.8 to 3.5 i/g of soil (Figure 7). These values are very low compared to the mean abundance observed cultivated sites in Brittany, i.e. 13.2 i/g of soil. It could be related to the absence of fertilisation in 2012. Very superficial tillage system seemed to have a bad impact on nématofaune while superficial actions (ploughing or non-inverse tillage) seemed to increase the density of nématofaune.

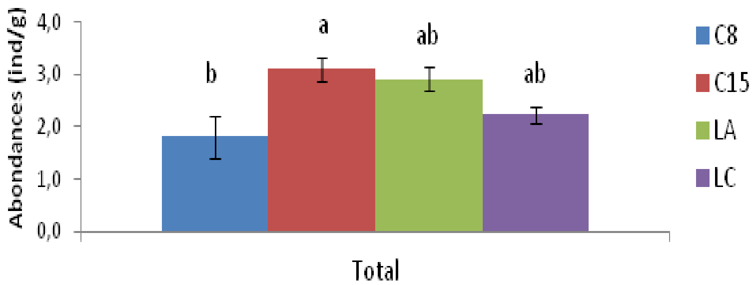

Figure 7: Nematofauna abundance (i/g of soil) measured under different treatments in FKO trial in 2013 (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p<0.05).

4.2.2.3 Microbial biomass

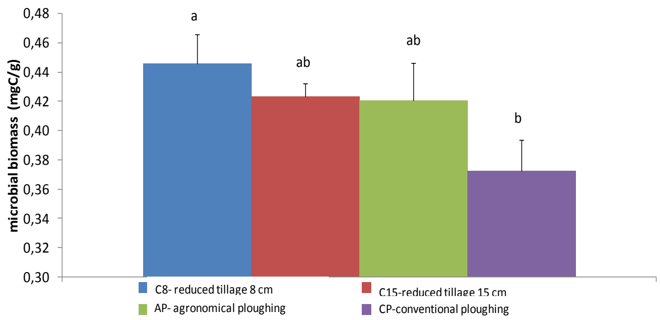

Figure 8: Microbial biomasses (mgC/g of soil) measured under different treatments in FKO trial in 2013 (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments ($p<0.05$).

In 2013, The values observed in our study, ranging from 0.37 mgC/g of soil (CP) to 0.44 mgC/g of soil (C8) are higher than those observed under cultivated soils in Brittany (i.e. average 0.248 mgC/g of soil; Cluzeau et al., 2012); however, they are conformed to values observed under crop system under organic management (i.e. ranging from 0.2 to 0.6 mgC/g of soil; Vian et al., 2009). Our study showed that the reduction of tillage systems (C8, C15, AP) were favourable to microbial biomass ($p<0.1$), and it was explained by the fact that microbial biomass is strongly impacted by the location of organic matter (Andrade *et al.*, 2003).
The analysis of the dynamic of the microbial response during 3 years (Lelu, 2013) confirmed that reduced tillage systems are favourable to microbial biomass (Figure 9) and supported the fact that this microbial biomass follows the organic matter burying (Vian et al., 2009).

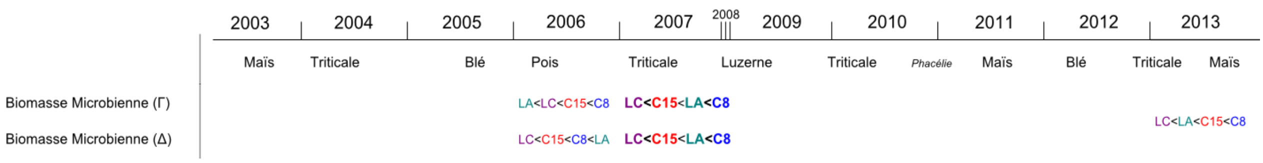

Figure 9: Results of the "year per year" approach presenting the impact of different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) on microbial biomass. In bold, the treatments which are significantly different from the other ($p<0.05$).

4.2.2.4 Chemical analysis

In 2013, the carbon and nitrogen values measured in FKO trial were higher than those measured at national scale (BDAT), which is related to the local pedological characteristics of the trial (Peigné, 2009). In contrast, the phosphorus values are closed to values observed in similar pedological and climatic conditions (Huang, 2012) (Figure 10).
In trends, the conventional ploughing system (CP) presented the lowest values of Carbone, Nitrogen and Phosphorus, compared to reduced tillage system (C8, C15, AP), however this difference was significant only for carbon parameter ($p=0.05$). The positive effect of reduced tillage systems, such as C8 and C15, is commonly observed in the literature and is explained by i) the localisation of organic matter on soil surface for the non-inverse tillage (C8 and C15) (Vyn et al, 2007) and ii) the highest root network density and the best distribution of this root network at the first centimetre depth (Gregory, 2006; Vyn et al, 2007) which allows an increase of the rhizodeposition produced by roots under these systems (Gale et al., 2000; Nguyen, 2003). The high values observed under agronomical ploughing (AP) is explained by the ploughing action

which dilutes the organic matter concentration, and therefore carbon, nitrogen and phosphorus in the first 15 cm.

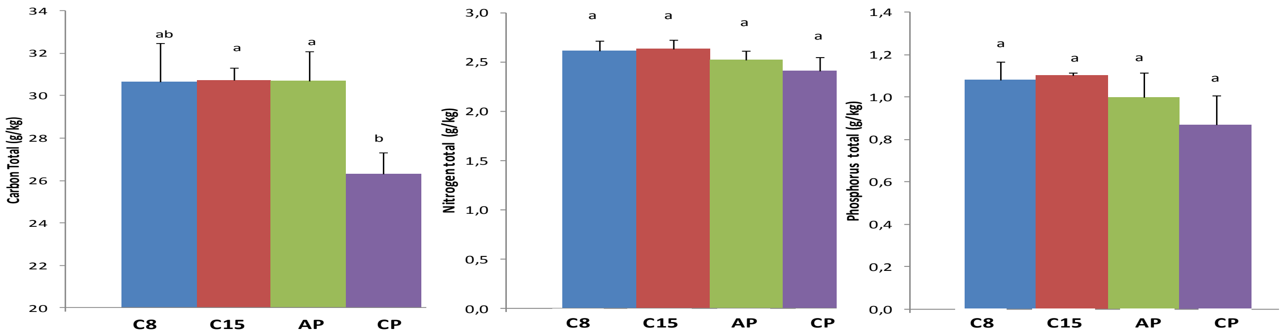

Figure 10: Values of total Carbon (g/kg), total Nitrogen (g/kg) and total Phosphorus –g/kg) measured at 0-15 cm depth under different systems of FKO trial in 2013(C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments (p<0.05).

Dynamic of the organic matter.

Concerning the organic matter in soil, the analysis of 4 years data shows that (Table 8):

- reduced tillage systems (C8, C15 and AP) significantly increased the organic matter in the first centimetres (0-5 cm), with a higher value for C8. However, this positive impact was not observed for the deeper layers (5-15 cm and 15-25 cm).
- for reduced non-inverse tillage systems (C8, C15), there was a decrease of the OM values correlated to the depth, while under ploughing systems (AP and CP), the OM values were homogeneous according to the ploughing depth.

Therefore, our study showed that there is a high stratification of OM depending on practices.

These results are commonly observed in the literature (Franzluebbers et al. 1995; Baker et al. 2007) , which demonstrate that the vertical stratification of OM content is observed after few years under reduced tillage systems (Guérif 1994). This stratification is due to the restitution of crop residue on soil surface and incorporation at low depth of organic matter (Andrade et al. 2003).

Table 8: Mean of organic matter content at different depths under different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) on. Different letters show significant differences between treatments (p<0.05)

. Parameters	C8	C15	AP	CP	p-value	N
Organic matter (0-5 cm)	5,4^{a}	4,8^{ab}	4,8^{ab}	4,2^{b}	0,043	4
Organic matter (5-15 cm)	4,6^{ab}	4,3^{b}	4,8^{a}	4,3^{b}	0,005	4
Organic matter (15-25 cm)	4,2^{a}	3,9^{b}	4,1^{a}	4,3^{a}	0,003	4

4.2.2.5 Physical parameters – hydraulic conductivity

In 2013, the results obtained (Figure 11) showed that at soil surface (0 cm) depth, the conductivity values reflected a medium conductivity (AFNOR, 2005). The differences between treatments were not very important and differences were only observed for the potential 5 cm (K_5) which reflects the conductivity due to macropores. At this potential, in trends, the absence of ploughing (C8, C15 vs AP, CP) and the diminution of the depth tillage action (C8 vs C15 and AP vs CP) increased the conductivity at soil surface (p>0.05).

These results are also observed in the literature and are explained by the presence under no-ploughing systems (C8, C15) of crop residue on soil surface which decreases the risk of soil sealing (Vian, 2009) and the presence of a dense root network which improves the porosity (Carof et al., 2007). Moreover, the presence of anecic earthworm should increase the conductivity due to the creation of burrow network opened at soil surface (Capowiez et al., 2009). Under ploughing systems, the conductivity should be lower due to the destruction of anecic burrow network (Capowiez et al., 2009) and the low stability of the porosity against the raining event (Bastardie et al., 2005).

At 5 cm depth, the values were lower than at soil surface, but kept in the same range, moreover, the difference between treatments were less important.

At 15 cm depth, the highest conductivity was observed under conventional ploughing (CP) while the lowest was observed under agronomical ploughing (AP). Even if these results were not significant, they are observed in the literature and could be explained by the creation of a plough pan at 15 cm under AP, while the macropores due to mechanical action could decrease the bulk density (Carof et al., 2007) and improve hydraulic conductivity under CP. The difference between AP and C15, could be explained by the fact that ploughing action creates a plough pan, while chisel action does not.

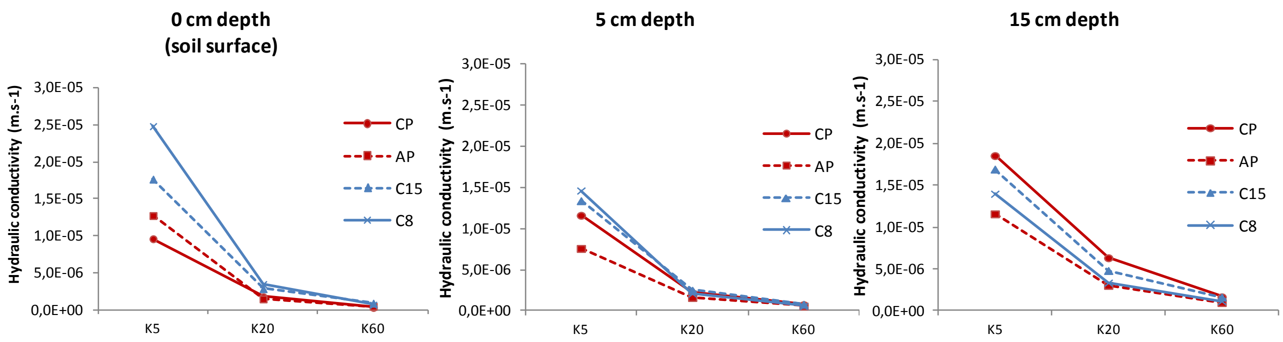

Figure 11: Hydraulic conductivity (m/s, method: decagon) measured in 2013 in FKO trial under different treatments (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) and at 3 depths (0 cm, 5 cm, 15 cm).

Dynamic of hydraulic conductivity

The study of hydraulic conductivity obtained during at least 4 years, showed that under this trial, there is no significant effect of reduced tillage systems on hydraulic conductivity ($p>0.05$), even if in trends the non-inverse tillage systems (C8, C15) seem to increase the conductivity at low depth, and that conventional tillage seems to increase the conductivity at deeper depth (Table 9).

According to the bulk density measured during several years, the reduced tillage systems C8 tends to decrease the bulk density ($p>0.05$), however, the values observed under the different treatment are very closed.

Table 9: Mean of hydraulic conductivity at different depths and mean of bulk density measured under different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing). Different letters show significant differences between treatments ($p<0.05$)

Parameters	C8	C15	LA	LC	p-value	N
Hydraulic conductivity (1-5 cm)	2,66 E-05	1,93 E-05	1,50 E-05	1,44 E-05	0,577	5
Hydraulic conductivity (15-17 cm)	1,70 E-05	2,02 E-05	1,63 E-05	2,23 E-05	0,724	4
Bulk density	1,057[a]	1,127[ab]	1,144[b]	1,174[b]	0,019	26

4.2.3 Results on the french study FKT trial - Impact of reduced tillage on runoff, erosion and transfers of associated pollutants

(study realised by french team, led by CRAB, Valentin Dauguet, 2013 annexe 4)

4.2.3.1 Runoff

During this study **in 2013**, height runoff events were measured.

Direct seeding (DS) was the tillage system which generated the highest average runoff (0.34 mm per event) compared to the conventional ploughing (CP) and the superficial tillage (ST) (respectively 0.13 mm and 0.07 mm) (Figure 12). A high variability was observed between replicates for the same treatment, especially under direct seeding. Runoff decreased during the study period, until March 20, and then increased on 9 and 12 April.

This year 2013 was characterized by a higher runoff in DS, ST had the lowest runoff, while CP occupied an intermediate position. The parameters that may explain these differences are the porosity, the hydraulic conductivity and the surface conditions (surface roughness).

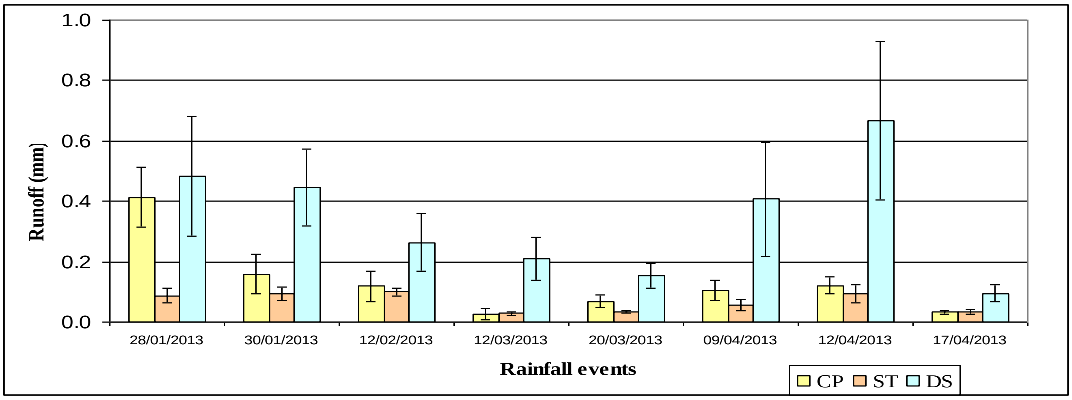

Figure 12: Average runoff per rainfall event at different dates, measured in 2013 in FKT trial under different treatments (CP: conventional ploughing; ST: superficial tillage; DS: direct seeding)

Concerning the porosity: measurements between 0 and 5 cm showed no differences between treatments. However, the penetrometry indicated greater compaction in the DS mode, so that CP and ST were nearby and had lower values.

Concerning the infiltrability: ST was the modality that had the highest infiltrability, while the DS had the lowest and CP had intermediate values. These results can be explained by a lower porosity in DS and a higher macroporosity for ST and CP.

Concerning the surface roughness: the highest surface roughness was observed under ST and the lowest under DS. The surface roughness was less under CT than under ST.

Therefore, our study showed that the combination of roughness state and porosity, explains the differences in runoff between treatments.

4.2.3.2 Erosion

Sediment concentrations in runoff samples collected were higher under ploughing system (CT) compared to the other systems. On the follow-up period, the average concentration was 1.03 g/l for ploughing treatment 'CP', 0.38 g/l for Surface Tillage and 0.87 g/l for Direct Seeding. During the season the sediment concentration, although variable, oscillated from 0.16 g/l to 1 g/l for all treatments, with an important event on April 9 when the sediment concentrations were very higher than 1 g/l under direct seeding.

Regarding the sediment dynamic, we can underline a decrease in the concentration for all treatments, from the first run until the fifth (20/03), then an increased for the rain event of April 9, followed by a decrease in the last two events.

Regarding the erosion flux (Figure 13), direct seeding treatment (DS) always presented the highest value, except for the first event. In contrast, the surface tillage treatment (ST) was the treatment which generated the lowest soil losses. The fluxes decreased during the season except for the date of April 9 where there was a sharp increase; however, cumulative fluxes were relatively low: CP (1.35 g/m²), ST (0.22 g/m²) and DS (2.75 g/m²).

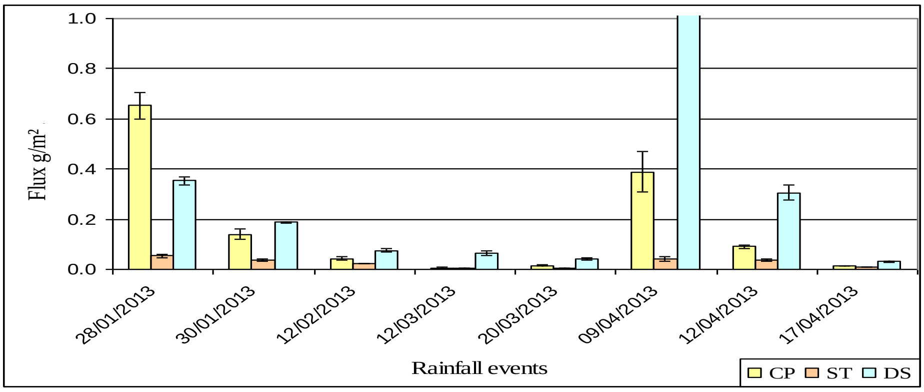

Figure 13: Average erosion flux in runoff per rainfall event at different dates, measured in 2013 in FKT trial under different treatments (CP: conventional ploughing; ST: superficial tillage; DS: direct seeding)

4.2.3.3 Herbicides

Herbicides analyzes were performed on five runoff events (Figure 14).

The concentrations of ***metsulfuron methyl*** in runoff were always below the detection limit (0.1 µg/l).

For the ***isoproturon*** concentrations, they presented higher averages under reduced tillage systems (ST and DS) respectively 8.78 µg/l and 8.08 µg/l against 3.88 µg/L under CP. For this molecule, a decrease in concentration during rainfall events was visible for all treatments; however, the means flux of isoproturon were higher under DS (1.86 mg/m²) than in ST (0.32 µg/m²) and in CP (0.24 µg/m²).

This year, *pendimethalin* concentrations were different depending on the treatment: the DS had the highest concentration with 0.46 µg/l against 0.30 µg/l in CP and 0.13 µg/l in TS. For the fluxes, it was also the DS which has the highest value (0.11 µg/m²) followed by CP (0.02 µg/m²) and ST (0.01 µg/m²).

Regarding the concentrations, the concentrations of isoproturon (IPU) were much higher than those of pendimethalin, although the latter had been given at a twice dose. Concentrations of *pendimethalin* were very low during the season. Indeed, *pendimethalin* is highly adsorbable by organic matter (KoC = 15744 ml/g); moreover, it is slightly soluble (0.33 mg/l) that limits its infiltration and percolation. Therefore, this molecule is mainly transferred by erosion. Concerning the isoproturon, the concentrations were much higher in DS and ST compared to CP. Indeed, this molecule is by its high solubility (70.2 mg/l) and low adsorption capacity (KoC = 122 ml/g), mainly conveyed in soluble form. IPU concentration decreases faster in ST and DS during the first rainfall events. This can be explained partly by the fact that the residuals capture the molecule which is then "washed" by the first rains, and secondly by the percolation, reducing this stock at the soil surface.

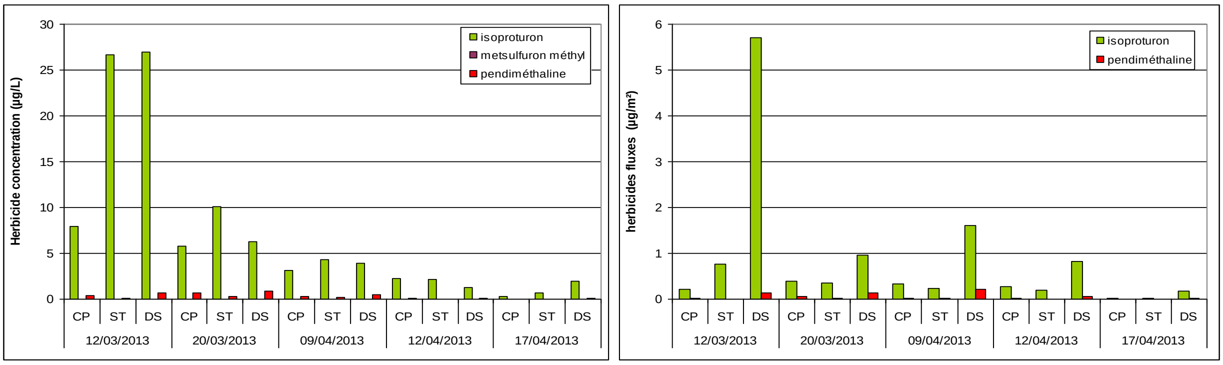

Figure 14: Average herbicide concentrations and flux in runoff per rainfall event at different dates, measured in 2013 in FKT trial under different treatments (CP: conventional ploughing; ST: superficial tillage; DS: direct seeding)

4.2.3.4 Phosphorus

Total P concentrations were higher on average in runoff under CP (1.99 mg/l) than those under DS (1.55 mg/l) and under ST (1.18 mg/l).

For particular Phosphorus (PP), the highest concentrations were quantified under CP with 1.73 mg/l against 1.24 mg/l under DS and 0.64 mg/l in ST.

The opposite effect was observed for the average concentrations of soluble Phosphorus (PS): the highest values were under ST (0.54 mg/l), while the lowest values were under CP (0.16 mg/l), DS presenting intermediate situation (0.27 mg/l).

P concentrations are correlated with sediments concentrations. The P soluble presented in runoff probably came from the phosphorus concentration in the topsoil layer in the minimum tillage systems.

Concerning the phosphorus flux (Figure 15), P total flux was the most important under Direst Seeding (DS). For all the events, the total flux was 1.45 mg/m² under conventional ploughing (CP), 0.38 mg/m² under superficial tillage (ST) and 2.85 mg/m² under Direct Seeding (DS).

Particular P flux was much more important under DS (0.48 mg/m²) and lower under ST (0.03 mg/m²) and under CP (0.02 mg/m²).

P soluble (PS) fluxes were higher under DS (0.09 mg/m²), while they were more or less the same under ST (0.03 mg/m²) and under CP (0.02 mg/m²).

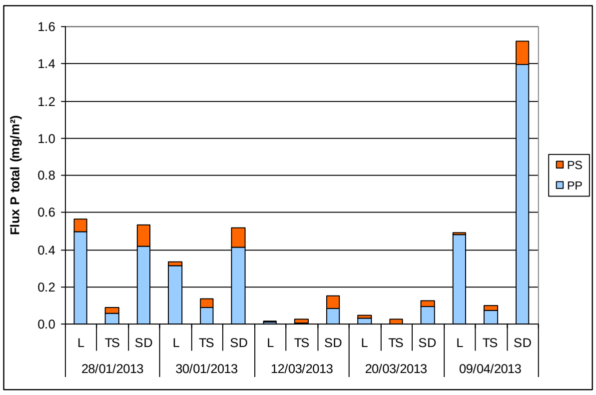

Figure 15: Average phosphorus fluxes (soluble phosphorus PS, particular phosphorus PP) in runoff per rainfall event at different dates, measured in 2013 in FKT trial under different treatments (L: conventional ploughing; TS: superficial tillage; SD: direct seeding)

4.2.4 Results on the French study FKA trial – Impact of reduced tillage and organic management

(Study realised by french teams, led by UR1, Martin Desplat, annexe 5)

Martin Desplat was a Master 1 student and his internship lasted 2 months. Due to the short period of this internship, it had not been possible to analyse all the earthworm samples (90), Martin only studied 30 samples which corresponded to 1 replicate per plot and 3 replicates per treatments; the rest of the samples will be analysed in 2014. Concerning the chemical and physical parameters a new data exploration will be done in 2014.

4.2.5. Results on Dutch site (Lelystad site)

(Study realised by dutch teams, led by WU)

4.2.5.1 Earthworm communities

Data on earthworm populations from spring 2009 to spring 2012 for the conventional and the organic farming system, respectively, have been presented in the previous annual report. Briefly, the results showed for both farming systems that the earthworm communities were strongly dominated by the endogeic earthworm *Aporrectodea caliginosa*.

In the conventional farming system, total earthworm numbers ranged between 29 and 358 ind/m² depending on season and year/crop. Earthworm abundances were higher in autumn than in spring. Total abundance of earthworms tended to be higher under reduced tillage (minimum or non-inversion tillage) compared to mouldbourd ploughing (MP), but this difference was never significant. In total 6 different species were found in the conventional farming system: *Apporectodea caliginosa*, Apporectodea rosea, and Lumbricus rubellus were the more abundant species, and *Lumbricus terrestris*, *Lumbricus castaneus and Eiseniella tetraedra* were present in very low numbers (less than 1% of total community). The abundance of the epigeic earthworm *Lumbricus Rubellus* increased from almost 0 in the ploughed system to up to 29 ind/m² under reduced tillage and this increase was significant in 3 out of 6 seasons (Crittenden et al. 2012a, submitted).

New data collected in the autumn of 2012 after harvest of sugar beet showed a similar pattern but this time the higher total earthworm abundance under reduced tillage was statistically highly significant (p=0.001). The abundances were 263 and 308 ind m-2 for minimum and non-inversion tillage, respectively, and 123 ind m-2 in the ploughed system (Figure 16a). The species that responded positively to the reduced tillage were the endogeic species *Apporectodea caliginosa* and the epigeic species *Lumbricus rubellus* (Figure 16b).

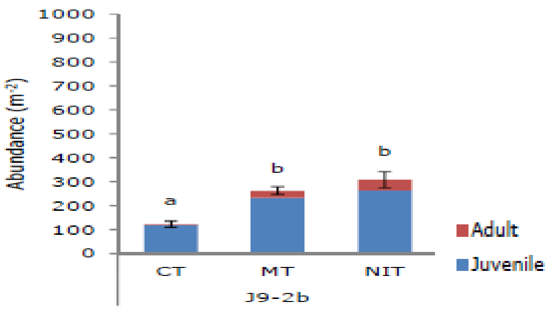

Figure 16a: Earthworm abundance as a function of tillage treatment in autumn 2012 for the Conventional farming system. Samples were taken after harvest of sugar beet and before ploughing (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors.

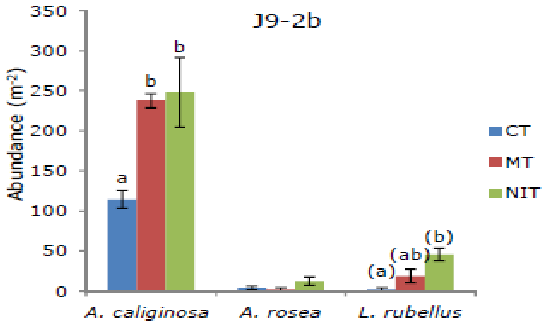

Figure 16b: Earthworm numbers and biomass as a function of tillage treatment in autumn 2012 for the Conventional farming system. Samples were taken after harvest of sugar beet and before ploughing (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors.

In the organic farming system, according to the spring 2009-spring 2012 data reported last year, total earthworm numbers ranged between 21 and 841 ind m-2, depending on season, year/crop and tillage system. In contrast to the conventional system, no clear difference in earthworm numbers was found between autumn and spring except for 2011, which was a very dry spring. Total abundance of earthworms was significantly affected by tillage treatment in 3 out of 6 samplings and in those cases where a significant effect was found the ploughed system showed higher earthworm numbers than the reduced tillage systems. In total 9 different species were found in the organic farming system: *Apporectodea caliginosa*, *Apporectodea rosea*, *Eiseniella tetraeda* and *Lumbricus rubellus* were the more abundant species, and *Lumbricus terrestris*, *Lumbricus castaneus, Apporectodea longa, Allolobophora chlorotica* and *Murchieona minuscula* were present in very low numbers (less than 1% of total community). As for the conventional system, reduced tillage favoured the epigeic species *Lumbricus rubellus* but in this case the effect was not significant. The species that responded positively to ploughing was the endogeic species *Apporectodea caliginosa*. (Crittenden et al. 2012a, submitted).

New data collected in the autumn of 2012 after harvest of potatoes and planting of grass-clover did not show significant differences between the tillage systems (p=0.667). The abundances were 798 and 804 ind/m² for minimum and non-inversion tillage, respectively, and 723 ind/m² in the ploughed system, in line with the range of earthworm densities found in earlier years (Figure 17a). Despite similarity in total earthworm numbers, the epigeic species *Lumbricus rubellus* showed a strong positive response to the reduced tillage (p=0.001) (Figure 17b).

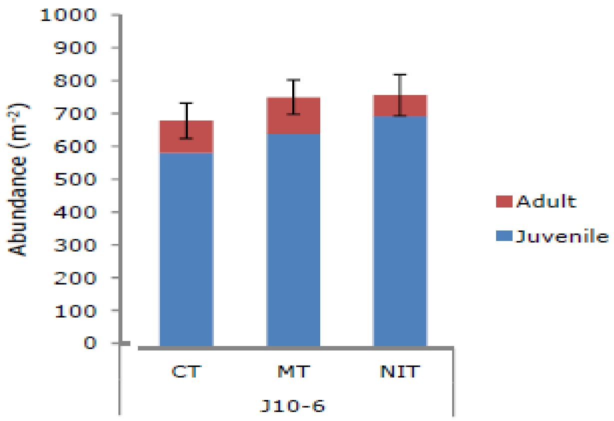

Figure 17a: Earthworm abundance as a function of tillage treatment in autumn 2012 for the Organic farming system. Samples were taken after harvest of potatoes and after seeding of grass clover (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors.

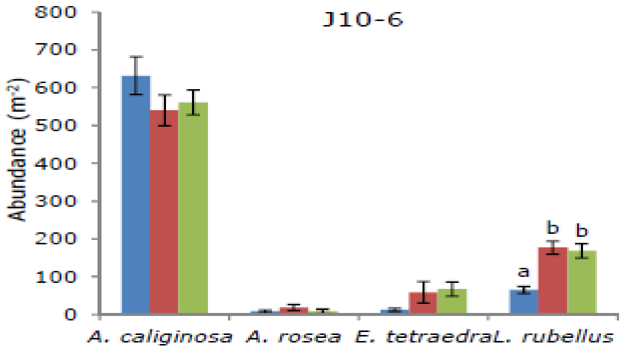

Figure17b: Earthworm numbers and biomass as a function of tillage treatment in autumn 2012 for the Organic farming system. Samples were taken after harvest of potatoes and after seeding of grass clover (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors.

The different response of total earthworm numbers and in particular *A. caliginosa* to tillage in conventional versus 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. In order to test our the hypothesis that interactions between organic matter additions and tillage result in a different response of earthworms to tillage in an organic farming system we started to monitor a second organic parcel.

In the autumn of 2012 we also added one extra parcel to the earthworm assessment which represents another crop within the organic crop rotation. This parcel was under spring wheat in 2012, preceded by cabbage in 2011. Samples were taken after harvest of the wheat and before autumn ploughing. Total earthworm numbers were lower in the ploughed system than in the reduced tillage systems (Figure 18a). Earthworm abundance was 427 ind m-2 in the ploughed system compared to 702 in the minimum tillage system and 660 under non-inversion tillage. The increased abundance of earthworms in reduced tillage was due to the increase in *Apporectodea caliginosa* and no positive effect on *Lumbricus Rubellus* was found. (Figure 18b). In terms of species composition the two organic parcels were similar.

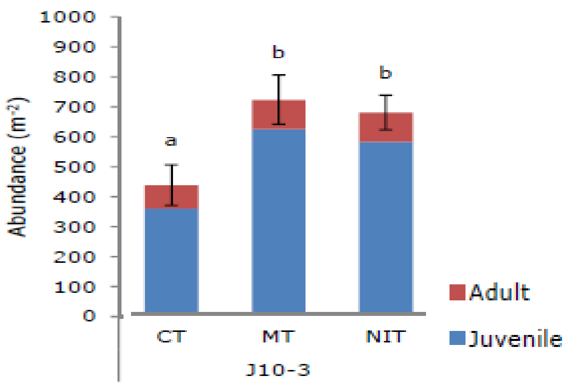

Figure 18a: Earthworm abundance as a function of tillage treatment in autumn 2012 for the Organic farming system parcel J10-3. Samples were taken after harvest of spring wheat and before ploughing (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors.

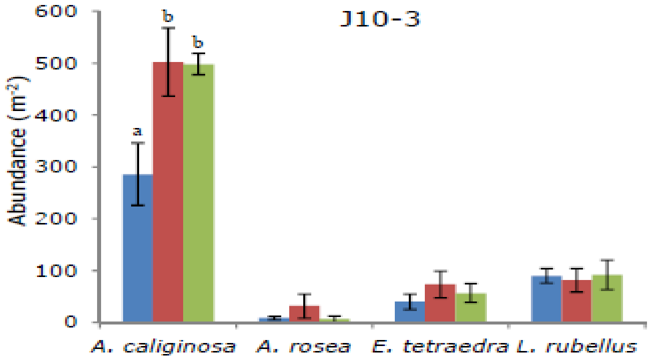

Figure 18b: Earthworm numbers and biomass as a function of tillage treatment in autumn 2012 for the Organic farming system. Samples were taken after harvest of spring wheat and before ploughing (source: Oudshoorn 2013). CT: ploughed system; MT: minimum tillage; NIT: non-inversion tillage. Error bars represent standard errors

In all parcels and systems negligible numbers of anecic individuals were found at the Lelystad site, irrespective of tillage.

4.2.5.2 Soil structure and soil organic matter

Data on soil structure (aggregate stability) and soil organic matter contents (Loss On Ignition method) were collected in fall 2012 in different fields of the BASIS experiment. Aggregate stability as expressed by the percentage of Water Stable Macroaggregates > 250 um was significantly higher under reduced tillage in both farming systems, but only at 10-20 cm depth (Table 10, Figure 19). These results were in line with earlier results found for the other organic parcel (J10-6) (Poot, 2012).

Table 10. Aggregate stability as a function of tillage treatment in autumn 2012 for the Organic and Conventional farming systems within BASIS. WSM: Water Stable Macroaggregates > 250 um (source: Oudshoorn 2013). CT: ploughed system; NIT: non-inversion tillage. Means are followed by standard errors between parentheses.

Field	Tillage	WSM (%)	
		0-10 cm	10-20 cm
J9-2b	CT	34.9 (2.75)	40.0 (2.04)^{a}
Conventional	NIT	39.8 (4.30)	50.2 (1.68)^{b}
J10-3	CT	42.1 (2.18)	45.4 (2.16)^{a}
Organic	NIT	40.5 (3.13)^{A}	52.0 (1.22)^{bB}

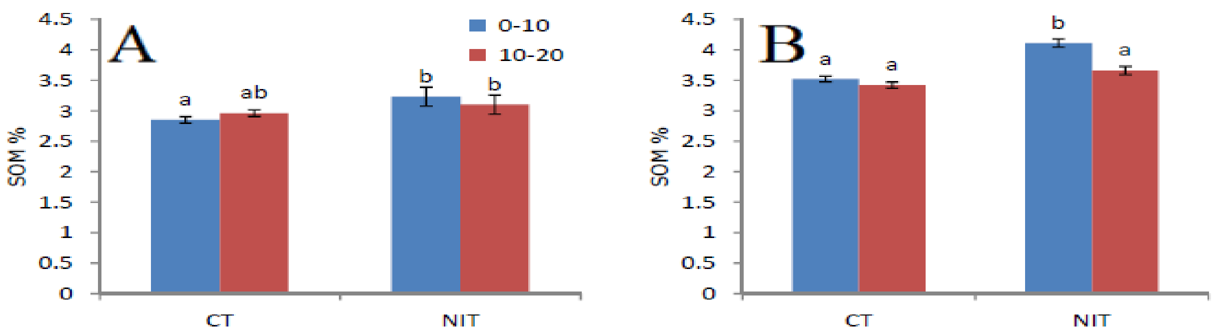

Figure 19. Aggregate stability as a function of tillage treatment in autumn 2012 for the Conventional (A) and Organic (B) farming systems within BASIS. WSM: Water Stable Macroaggregates > 250 um (source: Oudshoorn 2013). CT: ploughed system; NIT: non-inversion tillage. Means are followed by standard errors.

Soil organic matter contents were significantly higher in the reduced tillage system compared to the ploughed system, but only at 0-10 cm depth. These results were obtained 4 years after the start of the trial. These results were in line with earlier results found for the other organic parcel (J10-6), although differences were not significant at that time (Poot, 2012).

To allow for integration or comparison of datasets between the French and Dutch sites it is important to be able to convert our data from soil organic matter to soil organic carbon content. Therefore we used a set of 20 samples from all treatments and soil depths on which we determined soil organic matter using Loss On Ignition as well as soil organic C using the Kurmies method (Poot, 2012). From these data, a conversion factor was calculated between SOM and SOC of 0.41 (s.e. 0.01) for our site. This conversion factor was not significantly affected by treatment nor depth (Poot, 2012).

4.2.6. Results on Dutch site (farmers fields Hoeksche Waard)

Earthworm communities

On average over 4 seasons (spring 2010, fall 2010, fall 2011 and spring 2012) significantly higher earthworm numbers were found under reduced tillage than under moldboard ploughing in farmers fields (Figure 20). The species that contributed most to this increase where *A. caliginosa*, *A. rosea* and *L. rubellus*. Results are in line with what has been found in the Lelystad field trial for the conventional farming system.

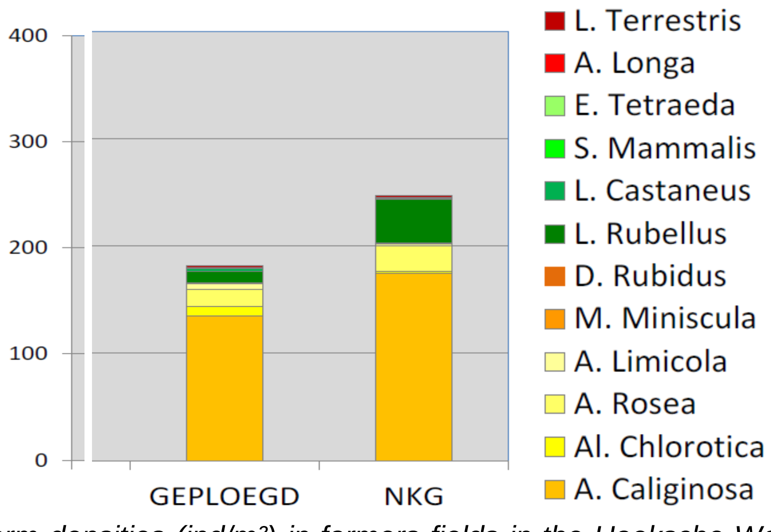

Figure 20. Earthworm densities (ind/m²) in farmers fields in the Hoeksche Waard as a function of tillage. Means of 4 farms and 4 sampling times are given. Geploegd: ploughed system; NKG: Non-inversion tillage.. (source: (Crittenden et al. 2012b, submitted))

4.3 Ecosystem services (WP4)

(realised by French teams, led by UR1, Florent Lelu, 2013)

Ecosystem services was assessed through the yield production measured under FKO trial during 7 years. The weeds was also analysed in order to observe or not a relation between these both parameters.

Concerning ***the weeds***, in most of the case, reduced tillage systems (C8, C15, LA) presented the highest value of weeds compared to conventional ploughing (Figure 21). This result suggests that deep ploughing system is the best action in order to alter the weed pressure; in contrast, the decrease of depth ploughing (AP), or the absence of ploughing (C8 and C15) are not suitable for the management of weeds. The weed pressure increases with the decrease of tillage pressure and could be explained by the fact that ploughing action decrease the stock of weed seeds and the risk of weed pressure (Marmot 2004). Moreover, under organic farming systems, the ploughing action and long crop rotations are identified as the two tools against weeds (Debaeke & orlan do, 1994).

Concerning ***the yield***, in most of the case, the yield was higher under conventional ploughing (CP). This result was observed during three years for triticale crop (2004, 2007, 2010) and peas crop (2006). The decrease of yield under reduced tillage systems could be explained by the increase, in these systems, of competition for water and nutritive elements between crop and weeds (Armal, 2010). This decrease could also be explained by a bad timing between mineralisation and nitrogen request by plant: under reduced tillage systems, the mineralisation arrives latter in the season, after the request by plants (Berner et al., 2008).

However during two years (2005, 2011), yield was higher under very superficial tillage (C8) for wheat and maize crops respectively. The low weed pressure in 2005 could explain this result. Moreover the dried conditions in 2005 and 2009 have delayed the flowering of maize and wheat, especially under ploughing systems. In contrast, under reduced tillage systems, the presence of organic residue on soil surface by maintaining better soil moisture, should have balanced these dried conditions and therefore should have stimulated the flowering.

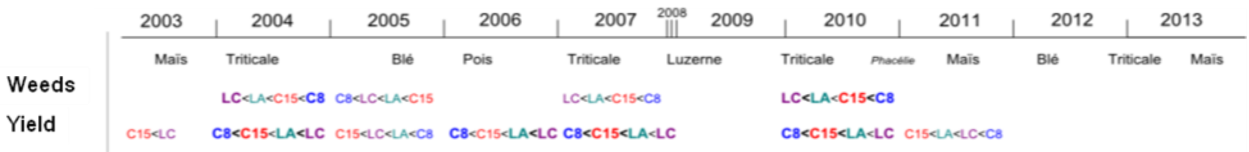

Figure 21: Results of the "year per year" approach presenting the impact of different treatments in FKO trial (C8: reduced tillage 8 cm, C15: reduced tillage 15 cm; AP: agronomical ploughing, CP: conventional ploughing) on weeds pressure and on yield. In bold, the treatments which are significantly different from the other (p<0.05).

The impact of reduced tillage systems on ecosystem services such as yield appears to be very complex, impacted by crop rotation, soil properties and climate conditions. The second step of data analysis will be to identify which driver is the most important for yield, or what is the battery of drivers which acts on this ecosystem service.

4.4 Sociological approach (WP5)

(realised by French teams, led by CRAB, Teatske Bakker, 2013)

The master student, Teatske Bakker, made internship dealing on the Innovation processes in minimum tillage: a qualitative survey in Brittany.

4.4.1 Method

In total, 29 interviews were carried out between the 28th February and the 22nd April 2013. Only 26 farms were taken into account for the analysis of agronomic practices, and all 29 interviews were analysed and used for the sociological aspects. The detail of the interview is in annexe 6.

4.4.2 Agronomic coherence classes

A classification of the cropping systems arised from the wheat and maize management sequences and the analysis at the cropping system level (with the rotations and cover crops). This classification was primarily based on the tillage intensity and the number of changes implemented. The aim of the approach was to establish a classification of farmers based on the level of inclusion of conservation agriculture principles in the cropping system.

The main characteristics of the agronomic coherence classes are summarized in the figure 22.

The first result of this classification is visible through the differences between the class 1 and the two other classes, which are more important than the differences observed between the class 2 and the class 3. Indeed, the first class (deep tillage) can be distinguished with the absence of changes at the scale of the cropping system (only suppression of the ploughing operation). On the other hand, the changes relative to cropping systems (rotations and cover-crops) have been implemented in rather similar ways in these two classes, and the main distinctive feature is the tillage intensity.

In a second step, the common features and the differences between these agronomic coherence classes have been analysed and the main characteristics of each class are summarized in the following scheme.

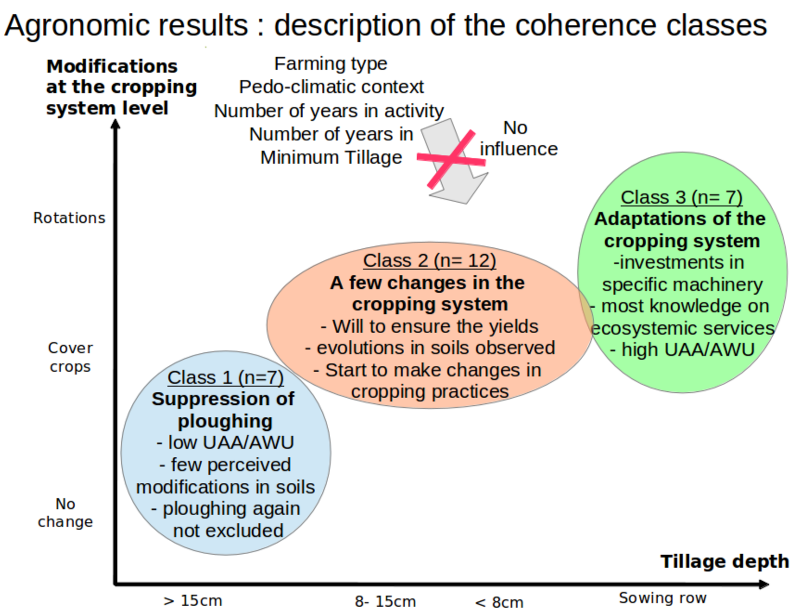

Figure 22: Description of the 3 classes resulting from the agronomic analysis

4.4.3 Sociological analysis

4.4.3.1 Farmers' motivations

Innovation appears as an answer to a non satisfactory situation. Indeed, the first reason mentioned (25 farmers) often refers to economic and social improvements, such as savings on working time and costs. The short time window for cereals sowing after late grain maize harvests is one of the explanations given. For three farmers it has been a consequence of a sudden decrease in labour availability (accident) or material (broken plow). A reduced tillage intensity can also decrease operating costs (machinery wear, fuel consumptions...) while maintaining yields at a similar level. It can also be a strategical choice in the farm management, namely in cases where the breeding activity is the most profitable activity on the farm.

In addition to socio-economic motivations, 6 farmers mentioned they have also faced specific problems on their fields, for example compaction, poor water reserve capacity, drainage, low pH levels or loss of organic matter. This has increased their awareness of soil processes and they had everything to gain by trying a change in practices. For two more farmers, having a « living soil » was the main reason to start using minimum tillage techniques.

Many farmers with initially socio-economic motivations (11 out of 25) express an evolution in their motivations as they gradually became aware of the impacts their tillage practices could have on the soil biology and on the environment. The functions of the soils are interpreted and lead towards the integration of a system and its interconnections.

4.4.3.2 Information sources

When the conversion to minimum tillage techniques occurs with inputs from the Agricultural Chambers, group dynamics play a key role and are perceived as a driving factor. Indeed, groups allow farmers to exchange their experiences, and thus, to dilute a little the risks of each farmer. It can also lead to the implementation of trials and comparisons.

When farmers innovate without the Agricultural Chambers, they sometimes feel isolated because they have difficulties to establish connections with farmers having the same practices in a similar context.

The information sources used by farmers are diversified, but many of them have in common the fact that they enhance the exchanges between farmers. Indeed, 13 farmers are members of BASE, an association started in Brittany on minimum tillage and no-tillage techniques, and 21 are reading « TCS magazine », which is written by this association. Moreover, neighbours and professional contacts have also an important influence, therefore 8 farmers mentioned the example of a leading farmer in their networks.

Cooperatives also play a paradoxal but nonetheless important role. 5 farmers evoked the negative point of view of their technician, whereas 3 farmers were accompanied in their conversion by a technician from a cooperative. It is noticeable as well that farmers establish a clear distinction towards the commercial nature of the advisory service given by technicians from private companies. Finally, among the other stakeholders on this topic, we can mention specialised agricultural magazines (9 farmers), Internet (5 farmers) and independent advisors (3 farmers).

4.4.3.3 Farmers' attitudes

Farmers expressed a differentiation between those who plough and those who don't. Farmers become deviant in their neighbour's eye and also consider themselves different according to a number of criteria. Indeed, many of them (11 persons) talked about a cold enthusiasm of their neighbours for their techniques, and 8 felt they were considered as "fools". This can influence technical choice, namely in regards of residues left on the fields, but can also turn out to be an obstacle for more farmers to convert to minimum tillage.

Furthermore, it appears that farmers also make distinctions inside the group of minimum tillage practioners: 12 persons distinguish farmers making an opportunistic use of minimum tillage techniques from those implementing them associated to conservation agriculture practices (cover-crops, crop rotations).

However, a pragmatic approach of minimum tillage predominates and farmers put things into perspective, namely because farmers alone support all the risks. This last point explains why intermediary minimum tillage systems (medium intensity tillage) are the most prevalent compared to no-tillage. Evolutions are, in most cases, very gradual: the idea that the change of tillage practices takes time is expressed 7 times, and 10 more farmers explained that the machinery is not the most important for a successful implementation of minimum tillage.

4.4.3.4 Expectations towards advisory services

The vision in minimum tillage is systemic, meaning that one considers the different components and their interrelations at different scales (plot, cropping system, farm, and further). It is a new way of thinking, and this change of vision requires from the farmer to enter a learning process. In this process, the soil is no longer considered as an inert support for crop production, but as a complex system. In parallel, minimum tillage techniques need to be adapted to each farm, enhancing the need to enter a learning process made of trials and errors. In our study, farmers made a clear distinction between a systemic vision and a top-down approach. The latter is a type of advisory service that appeared after the Second World War and is based on farmers' supervision.

Moreover, eight farmers said they felt minimum tillage techniques were a way to take control again over their profession. This attitude can be linked to their will to be autonomous. Farmers also consider themselves as pioneers, or as open-minded followers, in link with their feeling of being different from their neighbours. They emphasis on their independence and reject top-down approaches, which they assume institutions and scientists adopt. Recommendations for advisory services are thus to enter the same learning process and change their vision of the soil. An important consequence is that advisor and farmer should both take the learning process of their interlocutor into account. A farmer cannot expect from an advisor to know everything, given the complexity of the systems in focus. An advisor, on the other hand, should take the inputs from the farmer into account. Group dynamic are therefore very suitable, as they allow to combine knowledge from complementary knowledge and experience.

Between personalised advice and group dynamics, farmers expectations towards advisory services differ and multiplying the approaches (group meetings, personalised advice, other tools and supports) allow to broaden the targeted audience. Group dynamics are nevertheless very appreciated, at the condition that they respect the level of each farmer.

The tools implemented by advisory services nowadays appear relevant, but the relation scheme between farmer and advisor should bereconsidered. The function of an advisor becomes richer with the role of group coordinator, and this requires to enter in the same process of adaptation and to consider the stage of each farmer in his learning dynamic. Departing from top-down approaches, advisory services become the ability to co-construct the evolution of a system thanks to the sharing of knowledge between the advisor, the farmer and a group of practitioners.

4.5 Modelling (WP6)

Modelling work package was not really developed during this second year of SUSTAIN project. However, due to the fact that LCA (task 6.2) applied to soil is a quite novel approach for most of SUSTAIN partners, M. Corson (INRA) who leads this task, presented his approach during the different meetings and his plan for 2014. In fact, research for environmental-impact assessment with life cycle assessment (LCA) will begin in earnest in January 2014 with the hiring of a Master's-student intern (search currently underway). With the support of the task leader, the student will develop an LCA indicator that estimates impact of agricultural activities on soil biodiversity. It will be added to the pre-existing LCA indicators of the ACV-SOL approach (soil erosion, change in soil organic matter, soil compaction). The student will then apply these 4 indicators and, when possible, standard LCA indicators (e.g., climate change, eutrophication) to estimate environmental impacts of different types of soil tillage in experimental sites and surveyed farms of the study. Impacts will be reported per ha of field or farm area and per unit mass (kg or t) of field or farm production. The impacts of different types of soil tillage in different soil and climate contexts can then be compared to determine which impacts are lowest. The final analysis phase, interpretation, will attempt to explain which factors or practices decrease or increase impacts.

4.6 Dissemimation (WP7)

4.6.1. University of Rennes

4.6.1.1 Dissemination for multi-stakeholders, farmers, large public

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).

As during the first year of SUSTAIN project, many trainings (27) were given addressed to farmers during this second year of the project.

4.6.1.3 Publications (scientific report)

- Florent Lelu. 2013. Impact des Techniques Culturales Simplifiées sur la qualité des sols en Agriculture Biologique dans un contexte breton : approche biologique, physico-chimique et agronomique. Master 2 student report. University of Tours. September 2013 (Annexe 3).
- Martin Desplat. 2013. Impact du non labour sur la qualité des sols en contexte agricole Breton. Approche biologique et physico-chimique. Master 1 student report. University of Tour. September 2013 (Annexe 5).

4.6.2 INRA

INRA partner did not lead any dissemination action during this second year, however V. Hallaire was strongly involved in the supervision of the french students, especially F. Lelu and Martin Desplat. Moreover, V. Hallaire and G. Pérès supervised a master student (M1), Alexandre Wotowiec who assessed the specific impact of endogeic species on soil structure. Results from this internship are still under analyzed but they will be given in 2014 and will help in the better understanding of relation between soil biodiversity and soil structure (WP2, WP3).

4.6.3 CRAB

4.6.3.2 Dissemination for multi-stakeholders, farmers, large public

- Heddadj, D. 2013. Les techniques culturales sans labour. Kerguéhennec, 8 mars 2013. Presentations at students (25 students) from IUT of Quimper.

4.6.3.3 Publications (scientific report)

- Valentin Dauguet. 2013. Impact des Techniques Culturales Sans Labour sur le ruissellement, l’érosion et les transferts de polluants associés, *dans le contexte Breton.* Professional Licence student report. University of Rennes 1. Octobre 2013 (Annexe 4).
- Teatske Bakker. Processus d'innovation et durabilité des pratiques en TCSL : une étude qualitative en Bretagne. Master 2 student report. School of Agronomy of Rennes – AgrocampusOuest. Octobre 2013.

4.6.4 Wageningen University

Close contacts were maintained with the Farmers Network on Non-Inversion Tillage, through field visits, presentations, master classes and discussions.

4.6.4.1 Presentations at Scientific conferences

- Crittenden, S.J. and Pulleman, M.M. 2013. Integrated soil quality of reduced tillage systems. Poster presentation at the First International Conference on Global Food security. Noordwijkerhout, the Netherlands. 29 September - 2 October 2013.

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

- Pulleman et al. 2013. Onderzoeksresultaten bodemleven en effecten van grondbewerking. Studiemiddag Bodembiodiversiteit, grondbewerking en kwaliteit van reststoffen in de akkerbouw. 3 september 2013. Broekemahoeve, PPO Lelystad. http://www.veldleeuwerik.nl/nieuws/68-verslag-beschikbaar/84/studiemiddag-laat-belang-van-compost-en-grondbewerking-voor-bodemkwaliteit-zien

4.6.4.3 Publications (scientific report and professional)

Scientific report

- Oudshoorn, B. 2013. Does non-inversion tillage positively affect earthworm communities and soil structure in crop rotations including root crops? MSc thesis. Wageningen University, Department of Soil Quality. April 2013.

Professional publication

- Pulleman, M.M. 2012. Soil fertility. In: ELN-FAB. Functional agrobiodiversity: Nature serving Europe's farmers / Uden, G. van, . - Tilburg, the Netherlands : ECNC, - p. 22 - 27.

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

- Crittenden, S.J., Eswaramurthy, T., de Goede, R., Brussaard, L., Pulleman, M.M. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. Applied Soil Ecology (ms submitted after revision Oct 2013)
- Crittenden, S.J., Huerta, E., de Goede, R.G.D., Pulleman, M.M. Earthworm assemblages in reduced tillage and field margin 2 strips: an on-farm study. (ms submitted June 2013)
- Bianchi, F., Mikos, V., Brussaard, L., Delbaere, B., Pulleman, M., 2013. Opportunities and limitations for functional agrobiodiversity in the European context. Environmental Science & Policy , 1-9

4.6.5 PPO

One of the bigger dissemination events that took place during the current reporting period was the organic farmers field day at PPO Lelystad (5 September 2013), where attendees could learn about the experiences and results for reduced tillage systems.


4.6.6 ENCN

ECNC, on behalf of the European Learning Network of Functional Agrobiodiversity, coordinated a publication “ELN-FAB. Functional agrobiodiversity: Nature serving Europe's farmers”, in which soil biodiversity and soil tillage had a prominent role in the chapter “Soil Fertility”, authored by Mirjam Pulleman.

4.7 Others

4.7.1 Students involved

In France

- Florent Lélu (Master 2), master of University of Rennes 1
- Martin Desplat (Master 1), master of University of Rennes 1
- Valentin Dauguet (Licence 3), student of CRAB
- Teatske Bakker (Master 2), master of CRAB

In the Netherlands

- Stephen Crittenden (PhD)
- Joana Frazão (PhD)
- Bas Oudshoorn (MSc)

5. Anticipated use and especially application of results

Results of the project will be of direct use to farmers and farm advisers in northwestern Europe who have an interest in innovation of arable farming systems and are presented to them frequently at various training and dissemination events. Close contacts are maintained with farmers innovation networks in both countries. Other end users include policy makers and scientists with an interest in sustainable farming technologies, impact on soil quality and ecosystem services. They are addressed at targeted events and through professional and scientific publications. Developing LCA assessment that includes soil quality and soil biodiversity indicators is a novel tool that will address needs of European policy makers for a better prediction of anthropogenic threats to European agricultural soils.

6. Conclusion / recommendations

Very interesting results have been obtained in both countries and an important task for the last year of the project is to integrate the data. Finalizing and implementing the joint database is a first priority. Data can then be used for various purposes.

Data sets in each site are characterized by high variability between years. There is a need to better explain the factors responsible for this variation. We will therefore identify potential drivers and attempt to assess their importance in explaining variance in the data set through multivariate statistical techniques. Moreover, some indicators (earthworms, conductivity, bulk density, soil stability) will be measured in 2014 on the farm network in Brittany, in order to assess the variability of the response at regional scale. This approach will permit to test the relevance of the drivers identified during the two first year of SUSTAIN project.

Data integration also allows for joint publications on reduced tillage effects, LCA analysis and ecosystem services evaluation. It is also recommended that the socio-economic study performed among reduced tillage farmers in Brittanny is translated into a similar assessment in the Netherlands. Therefore we put a high priority on finding a student who is interested to develop this task.

Concerning the biological properties, some differences have been found between the different sites. This should be related to the ecological group attribution gave to the different earthworm species. In order to reinforce our results and make links between data, we will try to conduct an experience under controlled situations to clarify the ecological group memberships of *Lumbricus rubellus*.

In fine, the strong effort concerning dissemination will be pursue by different actions: a common meeting with ECOSOM project addressed to stakeholders, national meetings addressed to farmers, and technical brochure and handbook. These actions will complement training to farmers and social events addressed to public.

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Crittenden, S.J., Huerta, E., de Goede, R.G.D., Pulleman, M.M. 2013b. Earthworm assemblages in reduced tillage and field margin 2 strips: an on-farm study. (ms submitted June 2013)

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7. Annexes

Annexe 1 : SUSTAIN-ECOSOM joint meeting programme and presentations

ECOSOM and SUSTAIN meeting

SNOWMAN NetWork

26 & 27 February 2013 - Wageningen

Programme

Tuesday 26/2

8h30-10h00 : **separated meetings**

- Specific discussion for each programme

10h00-10h30: break (snack + refreshment)

10h30-12h30 : **common meeting**

- Theme 1 : reduced tillage (presentation of results)
  - French sites Kerguéhennec FKO + FKT (30 minutes -> **Guénola**) + Discussion (10 minutes)
  - Duch site (20 minutes -> **Steeve**) + Discussion (10 minutes)
  - Duch site (20 minutes -> **Jaap**) + Discussion (10 minutes)
- General discussion (20 minutes)

12h30-13h30 : Lunch

13h30-16h00 : **common meeting**

- Theme 2 : organic matter management (presentation of results)
  - French site Kerguéhennec FKA (20 minutes -> **Guénola**) + Discussion (10 minutes)
  - French sites QualiAgro + Colmar (30 minutes -> **Sabine** ou **Laure**) + Discussion (10 minutes)
  - Transversal theme : Organic polluant (20 minutes -> **Lisa**) + Discussion (10 minutes)
  - Transversal theme : Pathogeneous (20 minutes -> **Géraldine**) + Discussion (10 minutes)
- General discussion (20 minutes)

16h00-16h30: break (snack + refreshment)

16h30-17h30 : **common meeting**

- Transversal theme (methodological approach) : Infiltration (20 minutes -> **Vincent**, Steeve) + Discussion (10 minutes)
- Transversal theme (methodological approach) : Aggregate stability (20 minutes -> **Mirjam,** Safya, Jack)+ Discussion (10 minutes)

17h30-19h00 : **common meeting**

- Dissemination
  - Technical Guide **(Agathe)**
  - Technical guide (Sabine ou Laure)
  - Technical guide (Djilali)
  - Technical guide (Wijnand)
  - European dissemination (Veronika)

Wednesday 27/2

8h30-10h45 : **common meeting**

- Sociological and economical
  - French approach (**Djilali,** 15 minutes)
  - Dutch approach (Wijnand, 10 minutes)
  - General discussion (30 minutes) 9h30
- Ecosystem services
  - Carbone sequestration, soil structure and other ES (**Sabine**, 15 minutes)
  - Carbone sequestration, soil structure, water flux (Mirjam, 15 minutes)
  - Yield production (Djilali, 15 minutes)
  - General discussion (30 minutes)

10h45-11h15: break (snack + refreshment)

11h15-13h15 : **common meeting**

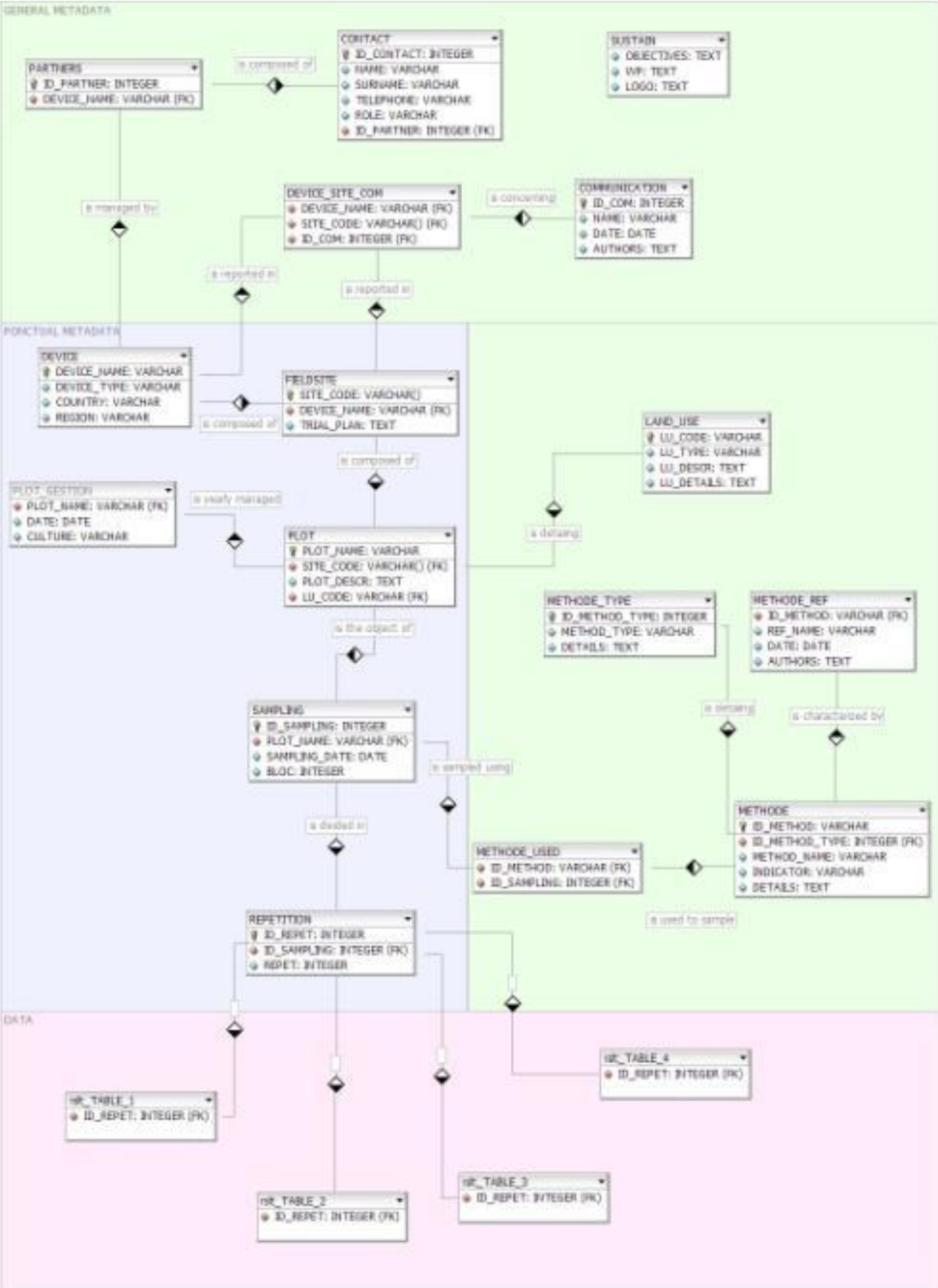
- LCA
  - French approach (**Mickael**, 15 minutes)
  - Dutch experience (Wijnand, 15 minutes)
  - Dutch experience (Simon, 15 minutes)
  - General discussion (15 minutes)
- Communication (colloque, paper) (Guénola, 15 minutes)
- Conclusions : synthesis of the meeting, common organization for 2013 (45 minutes)

13h15-14h00 : Lunch

14h00>

- Time for bilateral meetings for those people who wish to have some time to discuss results or progress on certain topics

Annexe 2 : Schema of the conceptual model of SUSTAIN database



Green Box for the general metadata (e.g. partners, contacts, land uses, sampling method); Blue box: ponctual data (e.g. sampling date, plot, replicate); Pink box: data (e.g. biological data, physical data, chemical data).

Annexe 3 : Florent Lélu's report

Florent Lelu. 2013. Impact des Techniques Culturales Simplifiées sur la qualité des sols en Agriculture Biologique dans un contexte breton : approche biologique, physico-chimique et agronomique. Master 2 student report. University of Tours. September 2013.

Annexe 2_Internship report 2013_SUSTAIN

Annexe 4 : Valentin Dauguet's report

Valentin Dauguet. 2013. Impact des Techniques Culturales Sans Labour sur le ruissellement, l'érosion et les transferts de polluants associés, dans le contexte Breton. Professional Licence student report. University of Rennes 1. Octobre 2013.

Annexe3_Internship report 2013_SUSTAIN

Annexe 5 : Martin Desplat's report

Martin Desplat. 2013. Impact du non labour sur la qualité des sols en contexte agricole Breton. Approche biologique et physico-chimique. Master 1 student report. University of Tour. September 2013.

Annexe 4_Intership report 2013 - SUSTAI

Annexe 6 : Teatske Bakker's questionnaire

Teatske Bakker 2013. Processus d'innovation et durabilité des pratiques en TCSL : une étude qualitative en Bretagne → questionnaire

Annexe 5_SUSTAIN 2013_Questionnaire_