SNOWMAN NETWORK

SUSTAIN project

Soil Functional Biodiversity and Ecosystem Services, a Transdisciplinary Approach

(2011-2014)

Coordinators : D. Cluzeau, G. Pérès

Kick-off meeting, 19-20 November 2013, Paris

Duration: 36 months (stage of the project : 24 months)

Consortium

✓French partners

Guénola Pérès
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Michaël Corson
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Safya Menasseri
Thierry Morvan

Djilali Heddadj

✓Dutch partners

Mirjam Pulleman
Lijbert Brussaard
Steven Crittenden
Ron De Goede

PPO (Applied Plant Research)

Wijnand Sukkel
Gerard Korthals

Ben Delbaere
Veronika Mikos

Project fund

Total Budget : 715.000 €
Request SNOWMAN: 218.000 € (30%)

French Ministery — 168 000 €

SKB — 50 000 €

Dissemination part : 48.000 € (22%)

SUSTAIN aims

Aims :

❑ Understand the effect of reduced tillage systems on soil biodiversity, soil functioning and ecosystem services

❑ Sustainibility (social, economical, environnemental) of reduced tillage systems

❑ Dissemination

SUSTAIN Work plan (7 WPs)

Agricultural practices (tillage, reduced tillage, no tillage)

WP2 : Soil biodiversity
- Earthworms
- Nematodes

WP3 : Soil functions
- Soil structure maintenance
- Water regulation and filtering
- OM and nutrient cycling
- Pest regulation

WP4 : Ecosystem services
-Food production
-GHG mitigation

WP5 : Sociology and economy
- Sociology
- Farm economics

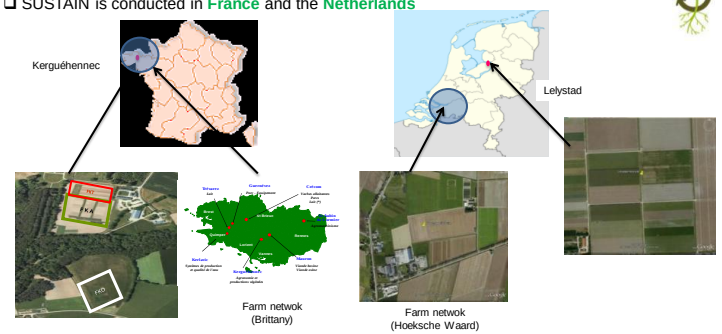
WP6 : Modelling
- Indicator development
- Environmental impact evaluation (LCA)
- System sustainability evaluation

WP1 : Coordination

WP7 : Dissemination

SUSTAIN collaborative approach

❑ SUSTAIN is conducted in **France** and the **Netherlands**



❑ SUSTAIN analyses **new data** & **existing datasets**

➪ allows for a boarder perspective, reflecting different time scales.

❑ SUSTAIN collaborates with ECOSOM

Achievement

	2011-S2	2012-S1	2012-S2	2013-S1	2013-S2	2014-S1	2014-S2
WP1	X	X	X	X	X	X	X
WP2 Biodiversity		X	X	X			
WP3 Function (physical)		X	X	X			
WP4 Ecosystem services				X	X		
WP5 Socio-economy				X	X		
WP6 Modelling					X	X	X
WP7 Dissemination	X	X	X	X	X	X	X

Field campaign (LTO)

Farm network

-> Integration of ES data (LTO)

-> Investigation to farmers

Biodiversity – soil functions (WP2 & WP3) - Achievement 2012-2013

Field campaigns

2 field campaigns on French site (Kerguéhennec)

- march 2012 and march 2013
- in 2012 : french and dutch persons ; in 2013 : french persons + belgium (SAS-STRAT)

- Parameters studied

2013

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

Biodiversity – soil functions (WP2 & WP3) - Achievement 2012-2013

Field campaign

9 field campaigns at Dutch site
(5 dates at Lelystad; 4 dates at Hoeksche Waard)

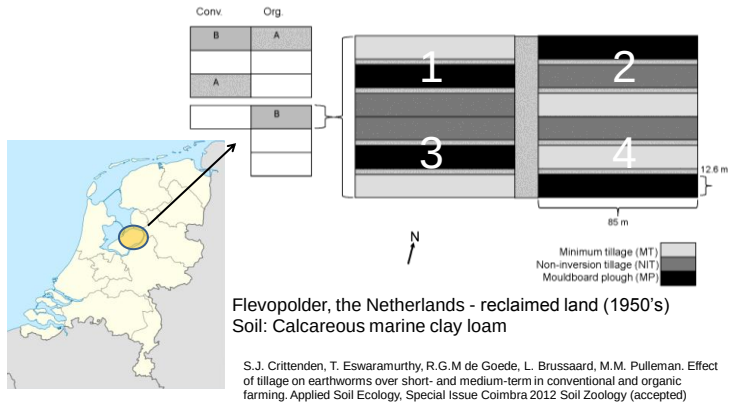
In march 2012 : dutch and french persons + belgium (SAS-STRAT)

- Studied parameters

Earthworm community, nematodes
Hydraulic conductivity estimation, aggregate stability, soil water retention, Penetration resistance, Bulk density
Soil organic carbon

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

Site description, experimental design



Flevopolder, the Netherlands - reclaimed land (1950's)
Soil: Calcareous marine clay loam

S.J. Crittenden, T. Eswaramurthy, R.G.M de Goede, L. Brussaard, M.M. Pulleman. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. Applied Soil Ecology, Special Issue Coimbra 2012 Soil Zoology (accepted)

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

Tillage treatments

Moulboard ploughing (MP) 25-30 cm in autumn + superficial cultivation

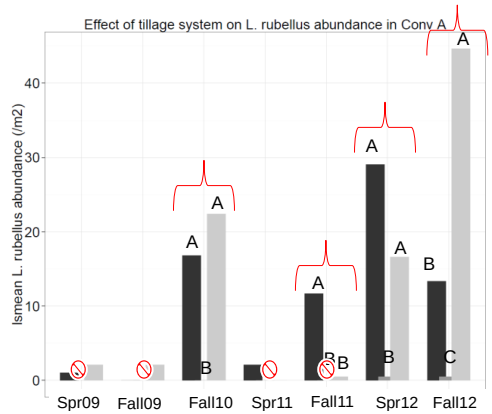
Reduced tillage

Non-inversion tillage NIT
Subsoiling at ca. 20 cm in autumn and superficial cultivation

Minimum tillage MT
Superficial cultivation, subsoiling only when deemed necessary.

S.J. Crittenden, T. Eswaramurthy, R.G.M de Goede, L. Brussaard, M.M. Pulleman. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. Applied Soil Ecology, Special Issue Coimbra 2012 Soil Zoology (accepted)

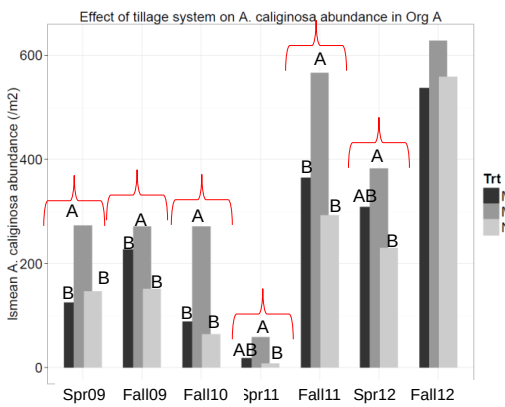
Biodiversity – soil functions (WP2 & WP3) – Results Dutch site



- *L. rubellus* not present at 5 of 7 samplings in MP
- Sig. higher in RT at 4 samplings
- Benefit from more crop residue left of soil surface

S.J. Crittenden, T. Eswaramurthy, R.G.M de Goede, L. Brussaard, M.M. Pulleman. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. Applied Soil Ecology, Special Issue Coimbra 2012 Soil Zoology (accepted)

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

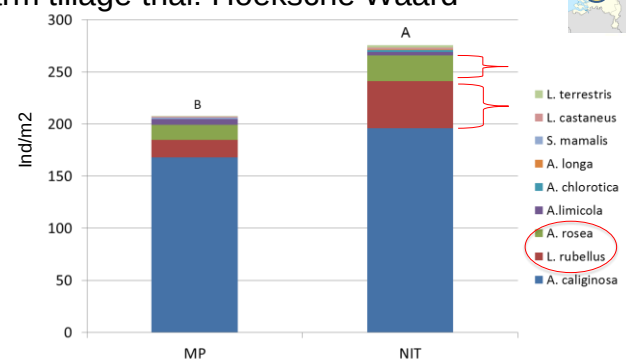


- *A. caliginosa* dominant (76% of all earthworms)
- Sig. lower in reduced tillage at 6 of 7 samplings
- Incorporated manure benefits endogeics

S.J. Crittenden, T. Eswaramurthy, R.G.M de Goede, L. Brussaard, M.M. Pulleman. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. Applied Soil Ecology, Special Issue Coimbra 2012 Soil Zoology (accepted)

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

On-farm tillage trial: Hoeksche Waard



- Similar rotation to Lelystad (including potatoes + sugar beet)
- On private conventional farms (but use animal manures)
- Reduced tillage increased *L. rubellus* + *A. rosea*

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

Linking diversity to function

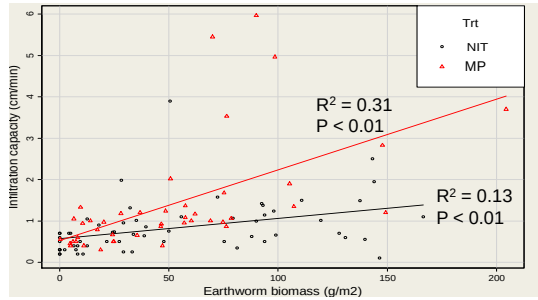
Earthworm species abundances
- *Eiseniella tetraedra*
- *Lumbricus castaneus*
- *Lumbricus rubellus*
- *Lumbricus terrestris*
- *Aporrectodea caliginosa*
- *Allolobophora chlorotica*
- *Aporrectodea rosea*

Soil physical properties
- Soil water retention
- Infiltration
- Soil organic carbon
- Aggregate stability
- Penetration resistance
- Bulk density

Question: Based on our EW data, what relations should we expect ?

Biodiversity – soil functions (WP2 & WP3) – Results Dutch site

Linking diversity to function: an example



"Most research has centered on the effects of anecic earthworm species on infiltration and on *L. terrestris* in particular."
(Shipitalo *et al.*, 2004. C. Edwards (Ed.), *Earthworm Ecology*)

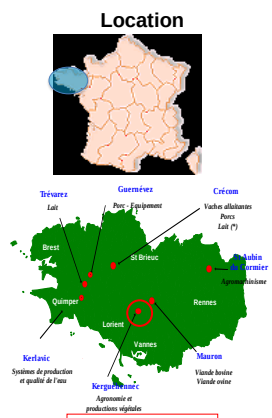
L. terrestris

Relation with Ecosystem service (WP4) – french site - organic

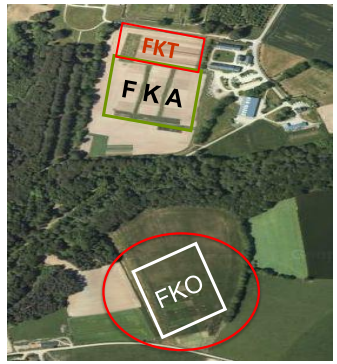
			yield ploughing (ton/ha)	NIT
2009	seed potato	Org B	39.6	101%
	carrot		71.93	79%
	spring wheat	Org A	5.14	108%
	sugar beet	Conv B	93.7	100%
	spring barley	Conv A	9.2	99%
2010	grass clover	Org B	12	108%
	faba bean/ spring wheat		4.51	83%
	carrot	Org A	82.23	84%
	winter wheat	Conv B	11.4	105%
2011	cabbage	Org B	85.6	95%
	potato	Conv A	33.3	95%
	faba bean/ spring wheat	Org A	4.53	110%
	onion	Conv A	88.2	91%
	seed potato		34.4	95%
2012	spring wheat	Org B	5.57	106%
	grass clover		11.22	139%
	potato	Org A	20.16	100%
	seed potato	Conv B	37.6	94%
	sugar beet	Conv A	91.1	103%

Biodiversity – soil functions (WP2 & WP3) – french site

Location



100 km from Rennes



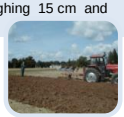
Start of the trial : 2003
Fertilisation (pig slurry or cow manure)

Biodiversity – soil functions (WP2 & WP3) – french site

Site description – Organic trial

Conventional tillage, ploughing
Moulboard ploughing 25 cm and circular spike

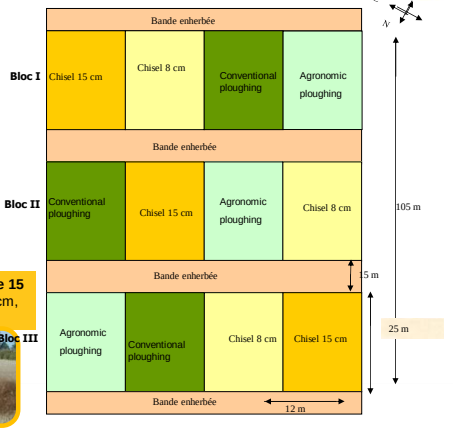
Agronomic ploughing
Moulboard ploughing 15 cm and circular spike



Superficial tillage 8
Harrowing at 8 cm, chisel since 2006

Superficial tillage 15
Harrowing at 15 cm, chisel since 2006

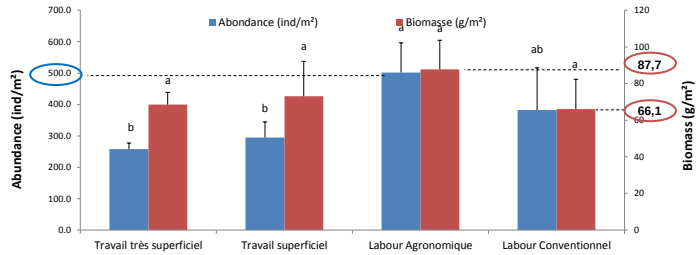
4 plots (12 m X 25 m) X 3 blocs -> 12 plots in total



Biodiversity – soil functions (WP2 & WP3) – french site - organic

2004 2006 2007 2010 2011 2012 2013

Abundance, Biomass of earthworm (2013, after 7 years)



Abundance

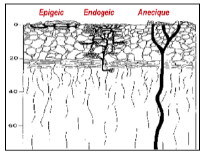
- no significant effect of reduced tillage (last ploughing 1 year ½ → earthworm abundance can recover)
- low depth of ploughing is favourable to abundance, but superficial tillage is depressive

Biomass

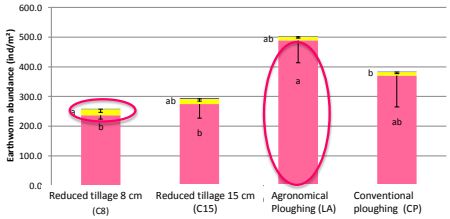
- no significant effect of reduced tillage
- bad effect of conventional ploughing (tendance)

Biodiversity – soil functions (WP2 & WP3) – french site -

2004 2006 2007 2010 2011 2012 201



Earthworm ecological group (in 2013)



- Epigeic : absent *(Cluzeau et al., 2012)*
- Endogeic : dominant *(Cluzeau et al., 2012)*
  positive impact of ploughing (LA, 15cm, p<0.01)

A. caliginosa

A. chlorotica

- Anecics: positive impact of reduced tillage systems, C8 (p=0.012) *(Chan, 2001)*

N. giardi

Biodiversity – soil functions (WP2 & WP3) – french site - organic

2004 2006 2007 2010 2011 2012 2013

Earthworm community

Paramètre	C8	C15	LA	LC	p-value
Abondance totale VdT	218,2	223,1	304,4	266,1	0,090
Biomasse total VdT	76,3 *a*	64,8 *ab*	67,6 *ab*	46,4 *b*	**0,024**
Anéciques	23,6 *a*	20,5 *ab*	15,1 *bc*	12,8 *c*	**0,006**
Endogés	191,3	196,8	283,3	250,5	0,144

Reduced tillage systmes

No impact

earthworm abundance
endogeic abundance

Biodiversity – soil functions (WP2 & WP3) – french site - organic

2004 2006 2007 2010 2011 2012 2013

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Reduced tillage systmes

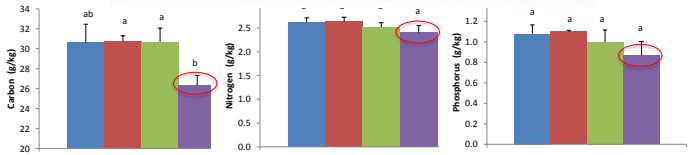
No impact → earthworm abundance, endogeic abundance

Positive impact → earthworm biomass, anecic abundance

Biodiversity – soil functions (WP2 & WP3) – french site - organic

Chemical analysis (2013, after 7 years)

2004 2006 2007 2010 2011 2012 2013



- negative impact of conventional tillage on C (p<0.05), N and P (tendance) (0-15 cm)
- strongly related to OM

2004 2006 2007 2010 2011 2012 2013

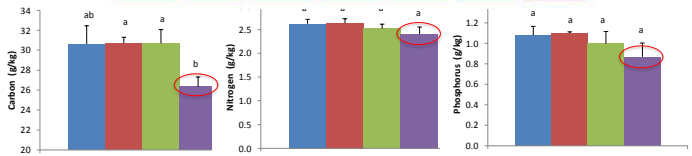
Paramètre	C8	C15	LA	LC	p-value
Matière Organique (0-5 cm)	5,4 *a*	4,8 *ab*	4,8 *ab*	4,2 *b*	**0,043**
Matière Organique (5-15 cm)	4,6 *ab*	4,3 *b*	4,8 *a*	4,3 *b*	**0,005**
Matière Organique (15-25 cm)	4,2 *a*	3,9 *b*	4,1 *a*	4,3 *a*	**0,003**

✓ positive impact of reduced tillage, but limited to 0-5 cm

Biodiversity – soil functions (WP2 & WP3) – french site - organic

Chemical analysis (2013, after 7 years)

2004 2006 2007 2010 2011 2012 2013



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✓ positive impact of reduced tillage, but limited to 0-5 cm

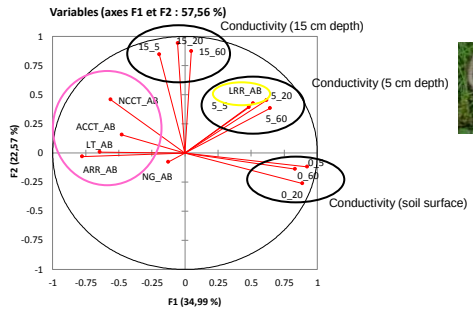
✓ high stratification of OM depending on practices

- decrease from top to sub-soil for reduced tillage system (reduced tillage systems)
- homogeneity under ploughing system, folllowing the ploughing depth

Biodiversity – soil functions (WP2 & WP3) – french site - organic

Linking diversity to function

2004 2006 2007 2010 2011 2012 2013



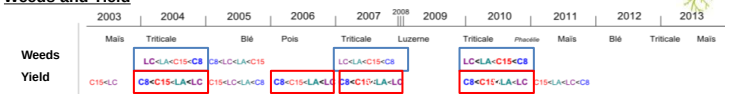
L. rubellus positively correlated with hydraulic conductivity at soil surface and 5 cm depth → epi-anecic species creates vertical and opend burrows at soil surface

Endogeic species negatively correlated with hydraulic conductivity → endogeic *(Francis et al, 2001)*

Relation with Ecosystem service (WP4) – french site - organic

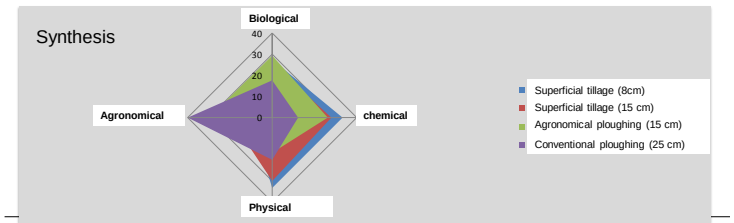
2004 2006 2007 2010 2011 2012 2013

Weeds and Yield



• Weeds : increase of weed pressure under reduced tillage system → ploughing limits the risk of weeds (Mamarot, 2004)

• Yield : decrease under reduced tillage systems → presence of weeds increase the competion for wtaer and nutrients resource *(Armal, 2010)*

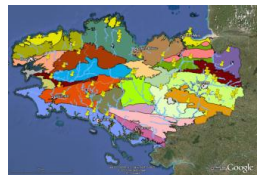


Economical- social aspect (WP5) - France - Brittany – Methods

Methods

❑ Sampling

List of farmers (60 farmers) obtained thanks to 4 local field advisors (departemental agricultural chambers), all over Brittany



« physiographic entities » map (INRA-Sols de Bretagne): pedoclimatic conditions

General Agricultural Inventory (2010)

Selection of the targetted farms

→ 29 farms

4 main farming systems:
-Cattle (dairy or meat production)
- Off-land livestock (pigs, poultry)
- Mixed farming system
- Crop farm

Economical- social aspect (WP5) - France - Brittany – Methods

Methods

❑ Sampling

- 2 populations interviewed:
  - Farmers using reduced tillage techniques for more than 5 years, in order to trace the process they went through.
  - Farmers recently converted (less than 5 years) to reduced tillage practices

❑ Questionnaire

- **General overview of the farm**
  - Name, type of structure, productions, history
- **Tillage practices**
  - Soil types on the farm, crop rotations
  - Machinery (description and associated costs)
  - Cropping patterns, practices
  - Crop management (soil physical properties, fertilisation, pests and diseases management)
- **Environmental impacts**
  Fuel consumption, pesticide use, fertilization, soil cover
- **Economic results**
  Yields, prices, detailed costs
- **Sociology**
  Motivations, difficulties, social interactions, learning dynamics, quality of life
  Ecosystemic services

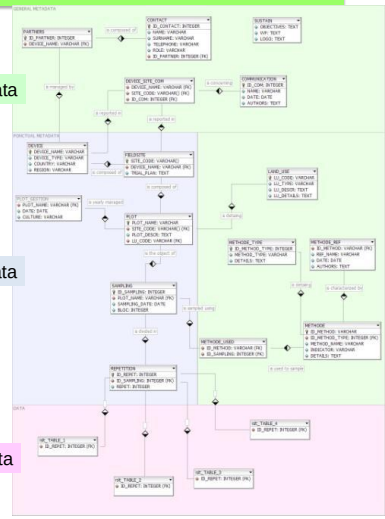
Modelling (WP6) – data base

General metadata

Conceptual model of the database

Ponctual data

Data



Dissemination (WP7) – Tasks 2012 & 2013

Meetings

- SNOWMAN meetings (→ 2)
- Annual mettings
  - 2 common meetings with ECOSOM (Paimpont 2012, Wageningen 2013)
  - next SUSTAIN meeting will be in december (3-4 december, Paimpont)


- Progress meetings (→ 8)
  - field campaign management,student training, result discussion
  - final stakeholders meeting (Ingrid van Reijsen (SKB) + Agathe Revallier (Veolia-ECOSOM)

collaborations

- **Student exchanges, student collaboration**

→ **Scientific reports -> 12 reports** from students : Master report, MSc thesis, Intership report

Dissemination (WP7) – Tasks 2012 & 2013

For scientists

-**Presentations at scientific conferences -> 7 presentations (oral, poster)**

Eurosoil (Bari, Italie),
International Symposium on Managing Soils for Food Security and Climate Change Adaptation and Mitigation,
International Colloquium on Soil Zoology (Coimbra, Portugal),
Journée de la mesure

1 Facilitated workshop at European stakeholder meeting

Sukkel, W. & Pulleman, M. Soil conservation in NWE. Facilitated workshop at ELN-FAB Seminar "Functional agrobiodiversity in NW Europe: What does the future hold?". 11-12-2013, Brussels.

- **Article in peer-reviewed journal -> 3**

- Pulleman et al., 2012. Soil biodiversity, biological indicators and soil ecosystem services-an overview of European approaches. Current Opinion in Environmental Sustainability, 4(5), 529–538

- Bianchi et al. 2013. Opportunities and limitations for functional agrobiodiversity in the European context. Environmental Science and Policy 27.
- Crittenden et al. 2013. Effect of tillage on earthworms over short- and medium-term in conventional and organic farming. (ms submitted)

Dissemination (WP7) – Tasks 2012 & 2013

For farmers

- **Publications (technical review, popular review) -> 2**

- Heddadj, D. 2012. 10 ans de recherche sur le travail du sol. Communication à la revue TCS, n°69, sept/oct, 2012.
- Berg, G.A. van den; Rozen, K. van; Pulleman, M.M. (2012). Worm blij met natte zomer : Interview met Klaas van Rozen en Mirjam Pulleman. Boerderij 97 (49). - p. 40

Farmers field day → 1

PPO Bioveldday. Resultaten proefvelden systeem telen met vaste rijpaden en alternatieve systemen van grondbewerking. Lelystad, 5 September 2013.



Presentations and workshops for farmer networks → 2

- Pulleman et al. 2013. Onderzoeksresultaten bodemleven en effecten van grondbewerking. Studiemiddag Bodembiodiversiteit, grondbewerking en kwaliteit van reststoffen in de akkerbouw. 3-9-2013. PPO Lelystad.
- Pulleman et al. 2013. Diversiteit van regenwormen - Effecten van grondbewerking en akkerranden. Presentation at regional meeting of farmers network Hoeksche Waard. 4-11-2013.

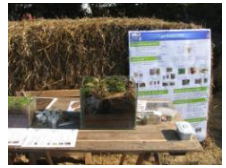
Dissemination (WP7) – Tasks 2012 & 2013

For multi-stakeholders, farmers, large public

-> more than 70 presentations, trainings







SUSTAIN – Time table 2014

	2011-S2	2012-S1	2012-S2	2013-S1	2013-S2	2014-S1	2014-S2
WP1	X	X	X	X	X	X	X
WP2 Biodiversity		X	X	X	X		
WP3 Function physic		X	X	X	X		
WP4 Ecosystem services					X	X	
WP5 Socio-eco					X	X	
WP6 Modelling					X	X	X
WP7 Dissemination	X				X	X	X

-> farm network (F)

-> Data base and data integration

-> Investigation to farmers (NL provisional)

-> Identification of soil indicators

-> LCA

-> Dissemination

Dissemination actions:

- Presentations at 3 international soil conferences (EGU, WCSS, ISEE)
- Presentation at Green Carbon Conference, Brussels 1-3, 2014
- Scientific publications
- Presentations and workshops for farmer networks, farmer field days and training
- Social events adressed to large public

Dissemination (WP7) – Tasks 2014

Brochure

- not a technical guide
- focusing on Reduced Tillage

In France, a working-group will meet in december to start working on the brochure, involving dutch colleagues

Hand-book

Leaded by PPO, in dutch.

Dissemination (WP7) – Tasks 2014

Meetings

❑ **Orientation committee**

- C. Gardi (JRC), F. Thomas (BASE)
- JF Vian (PEPITES), M. Rutgers

→ January –February 2014

❑ **Adressed to farmers (2)**

- at national level
- based on existing network
  - in France (CRAB) → June 2014
  - in the Netherlands (PPO)

❑ **Adressed to stakeholders (policy makers, advisors …) (1)**

- Common meeting with ECOSOM

→ September 2014

Contexte d'étude	Objectifs	Matériels et méthodes	Résultats & Discussions					Conclusion Perspective
			Biologiques	Chimiques	Physiques	Agronomiques	Relations	
●●●●	●●	●●●●●	●●●○○○	○○	○○	○	○	○○

▪ Paramètres biologiques : Espèces lombriciennes 2013

		C8	C15	LA	LC
epigeic	L. castaneus (LC)	0,0	0,6	0,0	0,2
	L. r. castaneoides (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. riardi (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

Structure spécifique :

• Espèces dominantes : ACCT, NCCT, ARR et NG ➔ espèces répertoriées dans contextes similaires *(Piron, 2008)*

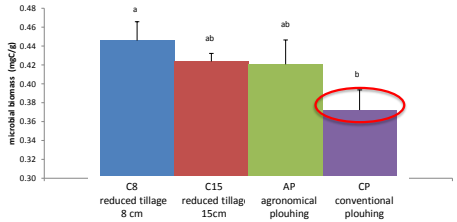
• Seuls NG suit le gradient de réduction de travail du sol ➔ NG = anécique ; LRR = épi-anécique *(Bouché, 1972)*

• Pas d'impact du travail sur richesse mais sur stabilité des communautés lombricienne ➔ tendance en accord avec littérature *(Van Capelle, 2012)*

Biodiversity – soil functions (WP2 & WP3) – french site - organic

Microbial biomass

2004 2006 2007 2010 2011 2012 2013

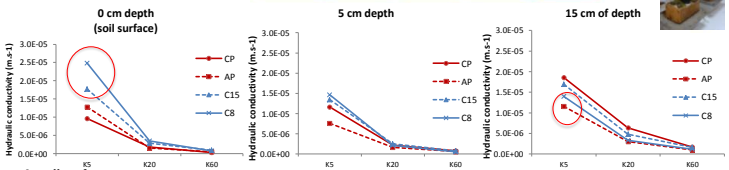


▪ Negative impact of conventional ploughing

2004 2006 2007 2010 2011 2012 2013

Biodiversity – soil functions (WP2 & WP3) – french site - organic

2004 2006 2007 2010 2011 2012 2013



At soil surface
✓ positive impact of reduced tillage on hydraulic conductivity → higher macroporosity connected to soil surface (biological action)

At 5 cm depth
✓ no difference between treatments

At 15 cm depth
✓ positive impact of conventional ploughing on hydraulic conductivity → macropores due to mechanical action

2004 2006 2007 2010 2011 2012 2013

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

For each depth → no significant effect of tillage system → high heterogeneity (p>0.1)
However, in tendance : comfirmation of results obtained in 2013
At soil surface → positive impact of reduced tillage on hydraulic conductivity (tendance)
At 15 cm depth → positive impact of conventional ploughing on hydraulic conductivity → macropores due to mechanical action