INPUT OF ORGANIC WASTE PRODUCTS

HOW DOES IT AFFECT THE ECOSYSTEM SERVICES PROVIDED BY SOIL?

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Returning to the soil Organic Waste Products (OWP) such as manure, sludge or compost is possible when these OWPs present an agronomic interest due to the input of organic matter (OM) to soil and nutritive elements for crops. Organic matter being at the heart of soil functions, spreading OWPs may impact a number of ecosystem services[1] provided by soils by modifying OM quantities and dynamics.

However, Organic Waste Products (OWP) are very diverse due to the different origins of the products (agricultural, urban, and industrial) and treatments before spreading (liming, composting, anaerobic digestion...). Thus, the intensity of the effects of these products on the ecosystem varies greatly. On the short term, only the effects due to the input of nutritive elements are visible. On the medium and long terms, the effects of the OM input become visible and can be studied.

Medium and long term field trials have thus made it possible to study these effects, their dynamics and their interactions with soil ecosystem services. They were carried out within two pilot sites: the QualiAgro site since 1998 and the Colmar trial platform since 2000.

In the context of this project, the ecosystem services studied are:

- **Provision services** through agricultural production.
- **Regulation services:**
  - (I) soil, water and plant quality regulation through the accumulation, filtration and dissipation of mineral and organic contaminants, and the resilience of pathogens in the soil,
  - (II) available water quantities regulation (infiltration, water retention),
  - (III) erosion regulation,
  - (IV) climate control through the balance of carbon storage versus emissions of greenhouse gases, etc.
- **Support services** such as the stability of soil structure.

Moreover, to ensure that OWPs continue to be returned to the soil, it is necessary to make sure OWPs are safe and consider the disservices[2] they may generate as part of an overall assessment of the practice.

10 summary sheets on the effects of OWPs on ecosystem services.
The details of the "field trials" are set out on the central pages of this brochure (pages 14 - 15)

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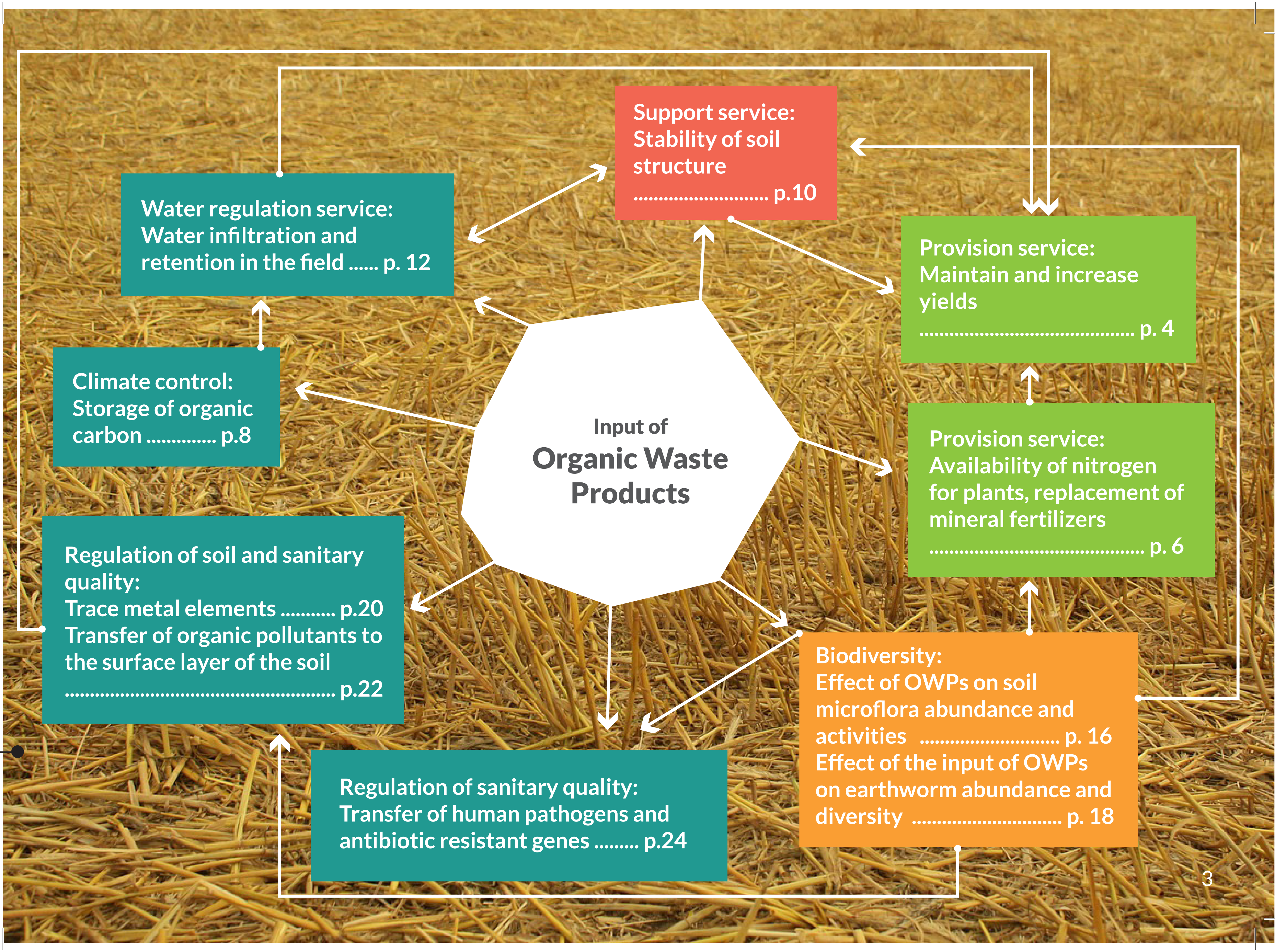
[1] ***Ecosystem services*** *are the benefits people obtain from ecosystems, according to the Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.*

[2] ***Dissservices*** *correspond to dysfunctions of ecosystems from human point of view.*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PROVISION SERVICE

MAINTAIN AND INCREASE YIELDS

One of the first results of the regular input of OWPs is to maintain, if not to increase agricultural production yields.

On the QualiAgro site, the average yields are between 80 and 100 qx/ha for wheat and between 100 and 120 qx/ha for maize (15% humidity) on plots receiving mineral supplementation with or without OWP input (see p.14).

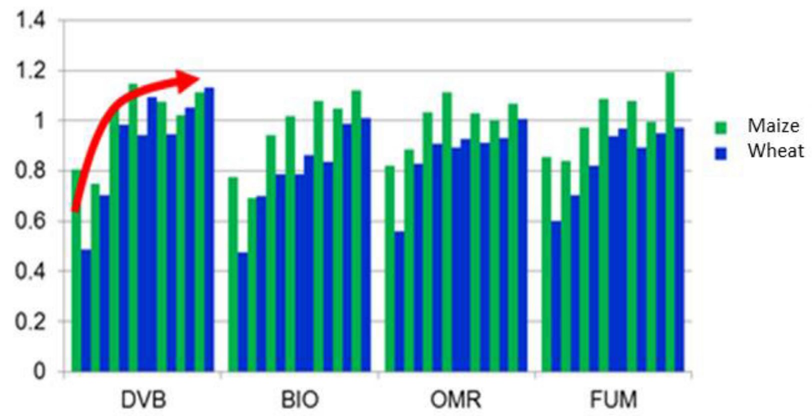

Figure 2: *Relative yields (yields with OWP treatments and without mineral N / yields with mineral N fertilizer treatments only) of maize (in green) and wheat (in blue) rotating over the years as part of the QualiAgro experimental system (from 1999 to 2013)*

Figure 2 illustrates the ability of OWP inputs to reach similar yields as mineral fertilization and its evolution over time. If the ratios are superior to 1, this means that the yields obtained with OWP inputs are better than those obtained with mineral fertilizers.

During the early years of the trial, OWP inputs did not make it possible to reach yields comparable to those obtained with mineral fertilizers (ratios<1). However, after 3 or 4 spreadings (5-7 years), maize yields (in green) reach the same levels on plots who received OWPs only and those who received mineral fertilizers only (control plots, TEM).

As the maize crop is sowed after the spreading of OWPs, it benefits fully from the portion of readily available nitrogen (N). The relative yields exceed 1 in all the plots who received OWPs. This effect on yields is essentially due to the increase in available nutritive elements, especially nitrogen, following the inputs of OWPs.

For wheat (in blue), relative yields exceed 1 in the case of sludge compost (DVB) after 5 spreadings. The nutritive elements in sludge compost are more readily available than with other types of OWP. With other treatments, the relative yield only exceeds 1 from the 7th spreading. Nitrogen being less available two years after spreading, wheat crops do not benefit from the same quantity of available nitrogen than maize crops. This may explain the difference in the relative yields obtained.

OWP inputs partially replace traditional mineral fertilizers (see p.6).

Finally, it should be noted that a threshold in yield increase seems to be reached with organic treatments, highlighting a «fertility balance» reached with OWPs.

TO REMERBER

Fertilizing with a regular input of OWPs, it is possible to reach equivalent or superior yields to those obtained with mineral nitrogen fertilizers only if there is a significant enough increase in soil organic matter.

For maize, which is sowed after the spreading, mineral fertilizers can be dispensed with completely after a few years of OWP spreading.

PROVISION SERVICE

AVAILABILITY OF NITROGEN (N) FOR PLANTS, REPLACEMENT OF MINERAL FERTILIZERS

OWPs can partially replace mineral nitrogen fertilizers supplied to crops. During the growing season, OWPs contribute to supplying nitrogen (N) to plants due to their content in mineral N and the intense mineralization of organic N on the short-term. On the longer term, OWPs also contribute to the N supply through the mineralization of the increased soil OM.

On the QualiAgro and Colmar sites (see p.14 et 15), the total N content of the studied OWPs is between 4 and 20 kg of nitrogen (N) per ton of raw matter, 4 to 68% of which is readily available in the year following the input (initial mineral N + mineralized organic N). More specifically, for one ton of sludge input, 8 kg of N shall be available to the crop. Sludge sets itself apart from other types of OWPs by its rapid mineralization after spreading. It is a fertilizing OWP (Figure 3).

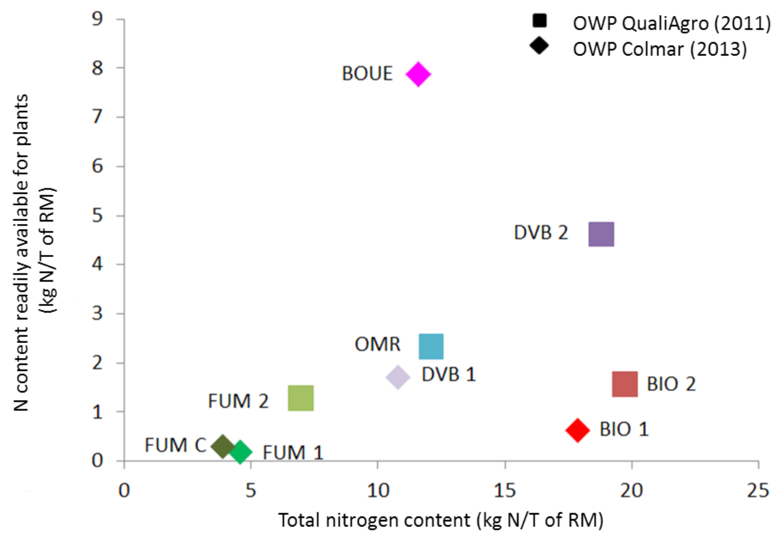

Figure 3: *Relation between the total nitrogen content and the nitrogen content readily available for crops with OWPs used on the Colmar (1) and QualiAgro (2) sites*

On the longer term, after several spreadings, the nitrogen (N) input due to the mineralization of soil OM is between 17 and 66 kg N/ha, respectively for DVB and manure used in Colmar. It varies from 56 to 106 kg N/ha on the QualiAgro site, respectively for OMR and BIO treatments and is linked to the strong increase in OM (Figure 4). In Colmar, sludge, which is highly fertilizing, maintains a higher long-term N availability.

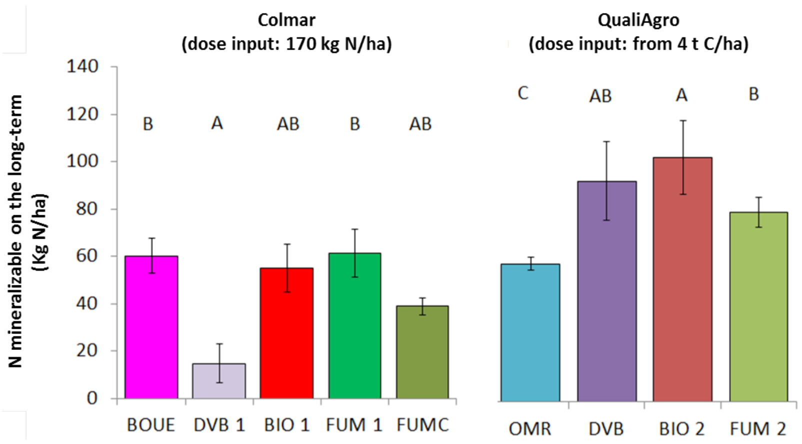

Figure 4: *Increase in the potentially available N* (in kg N/ha) compared to control treatments after 6 and 7 OWP spreadings on the Colmar and QualiAgro sites*

However, the fertilizing value of OWPs has impacts on the environment:

- Mineral ammonia nitrogen (N) can volatilize. Emissions of N_2O can follow OWP inputs. However, laboratory measurements show very low N_2O emission factors, between 0.2 and 0.8% of the total N input.
- Poor control of the available nitrogen as compared to plant uptake can lead to a risk of excess nitrates leaching in the soil.
- OWPs provide different nutritive elements at the same time, thus the balance of elements must be ensured (N and P in particular) to avoid the risks of excesses in the soil which could affect water quality.

TO REMERBER

OWP inputs can partially replace mineral nitrogen fertilizers:

- *On the short term, the amount of nitrogen (N) input for the plants depends on the mineral N content and the mineralization speed of organic N contained in OWPs. Some types of OWPs, such as sludge, can be used as an organic fertilizer.*
- *On the longer term, the increase in soil OM, supplied by amending OWPs also contributes to replacing mineral nitrogen fertilizers.*

* ***Statistical processing:*** *the letters (A, B and C) indicate significant differences in the effects of the different treatments.*

STORAGE OF ORGANIC CARBON (C)

OWP inputs contribute to increasing organic carbon (C) stocks in the soil. Depending on the characteristics of their OM, all OWPs do not have the same storage capacity.

On the QualiAgro site (see p.14), OWP inputs are dosed to provide 4 tons of C per hectare, which corresponds to doses of 20 to 30 t raw matter/ha for each spreading, or 2 to 3 times the traditional dose of organic amendments input by farmers. These substantial inputs generate significant increases of C stocks in the soil.

Whereas C stocks remain constant with the control treatment, these increases are different with each organic treatment (Figure 5).

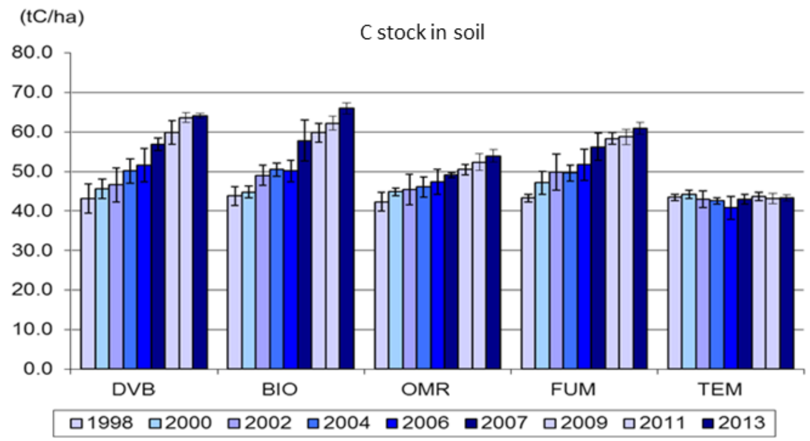

Figure 5: *Evolution of C stocks in organic and control treatments on the QualiAgro site from 1998 to 2013 (plots with additional mineral fertilizer)*

It is possible to calculate the stored carbon efficiency of the different types of OWPs as the ratio between the difference of C stocks in the control and amended treatments and the quantity of C provided by the OWPs (Table 1).

OWP	C storage efficiency (in t C_{soil}/t C_{OWP})
OMR	0,36
FUM	0,54
DVB	0,60
BIO	0,77

***Table 1.** Average carbon storage efficiency of the amended soils of the QualiAgro experiment between 1998 and 2013*

The more efficient OWPs are those characterized by the most stable OM (biowaste compost, BIO, and mixed sludge and green waste compost, DVB, in the QualiAgro trial).

However, on the Colmar site (see p.15), the input of OWPs calculated to provide nitrogen doses in compliance with common practices (170 kg N/ha), have very little impact on C stocks in the soil.

These increases in soil OM explain many of the observed differentiating effects of the different treatments.

Furthermore, in order to draw up a full carbon footprint for the practice and conclude to a positive effect of OWP inputs as “carbon storage” in the soil, the emissions of greenhouse gases generated while supplying the OWPs must be taken into account. These greenhouse gas emissions could counterbalance the observed increase in carbon stocks in the soil and neutralize the carbon footprint of the practice.

TO REMERBER

OWP inputs increase the storage of organic carbon in the soil with varying efficiency according to the type of OWP used (low for OMR compost and sewage sludge - maximum for biowaste compost).

The «carbon storage» effect of the OWP input is to be put into perspective in light of the carbon footprint that includes the greenhouse gases generated by this practice as compared to mineral fertilization.

SUPPORT SERVICE

STABILITY OF SOIL STRUCTURE

Soil structure determines its porosity, which enables roots to anchor themselves in the soil and water and gases to circulate in order to ensure soil oxygenation. The stability of the structure is the ability of soil aggregates to resist the disintegrating action of water during rainfalls.

This property is a good indicator of soil sensitivity to surface sealing[3] and thus to erosion. Surface sealing asphyxiates the soil and may prevent seeds from germinating. Erosion leads to the loss of soil and fertility, and affects the environment: particles swept away by water on the surface, mudslides, etc.

In decarbonated silty soils, such as those of the QualiAgro site (see p.14), OM stocks and biological activity are the two elements determining structure stability. The stability of the structure was measured from 1999 to 2007 on the QualiAgro site according to the Afnor method (standard X31-515). The results are expressed in average size of aggregates after several disintegration tests. Due to climate-related in-year variations in the results obtained, these need to be expressed in comparison to the control treatment where no organic matter was applied.

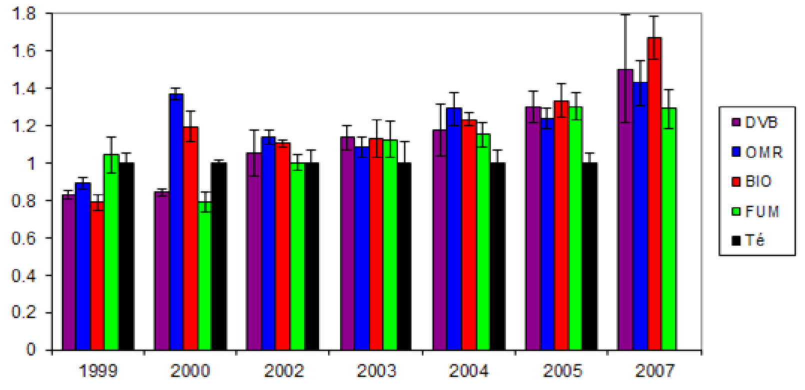

Figure 6: *Evolution of the stability of soil structure for soils receiving OWPs expressed as compared to the results obtained in the control soil without organic input, on the QualiAgro site between 1999 and 2007 (Annabi et al., 2011)*

Repeated OWP inputs generate a gradual improvement of the stability of the soil structure in the organic treatments (Figure 6). This improvement is correlated to the increase in OM content in amended treatments.

[3] ***Surface sealing:*** *Soil defect which presents surface induration (or crust) due to the degradation of its fine blocky structure and porosity through the action of rainfalls.*

RESISTANCE TO PENETRATION

This property is measured by the pressure applied when driving a cone penetrometer into the soil. The higher this is, the more energy will be needed to work the soil.

On the QualiAgro site, the plow pan is slightly thicker and more compacted on plots receiving organic treatments, probably due to the increased traffic of machines due to spreading. However, within the plowed layer, the resistance to penetration is lower in amended plots than in control plots, which indicates less compaction and a more open structure (Figure 7).

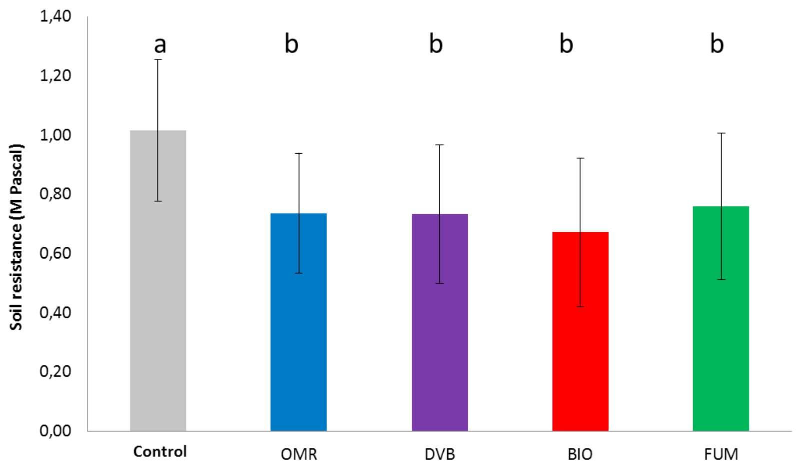

Figure 7: *Average resistance to penetration in the plowed layer (0-20 cm) with the different treatments* for the QualiAgro trial.*

TO REMERBER

Successive OWP inputs lead to a gradual increase in structural stability and a lower resistance to penetration.

The high content of organic matter in amended soils leads to higher physical fertility for these soils.

* ***Statistical processing:*** *the letters (A, B and C) indicate significant differences in the effects of the different treatments.*

WATER INFILTRATION AND RETENTION IN THE FIELD

Water infiltration and retention correspond to the capacity of agricultural soil to regulate the quantity of water that can be absorbed and retained in the upper layers of the soil. Among others, this makes it possible to reduce irrigation. The ability of soil to regulate the infiltration speed of water excesses contributes to limiting erosion and anoxia risks. Organic matter plays an important role in both of these soil properties.

Measuring infiltration speed is a good indicator of the soil's regulation ability. It is measured with the double ring method and corresponds to the volume of water able to infiltrate the soil in saturated conditions, in a given time frame (expressed in mm/h).

Infiltration is also linked to the volume of soil pores, within which water can infiltrate and be retained. The pore volume of the soil is estimated by the volume of water necessary to saturate it (expressed in mm).

Both of these properties were measured on the QualiAgro site (see p.14) for the three organic treatments OMR, BIO and FUM and for the control treatment without organic input (TEM).

Water infiltration speed is stable and quicker for soils amended with BIO and FUM treatments than for soil who received the control treatment. The effect of the OMR compost treatment is not significantly different from the control (Figure 9). Moreover, the pore volume tends to be greater for amended plots than for control plots. To be noted: the latter is at its maximum with the OMR treatment (Figure 10).

Figure 8: *Water Infiltration rate measurement by the double ring method*

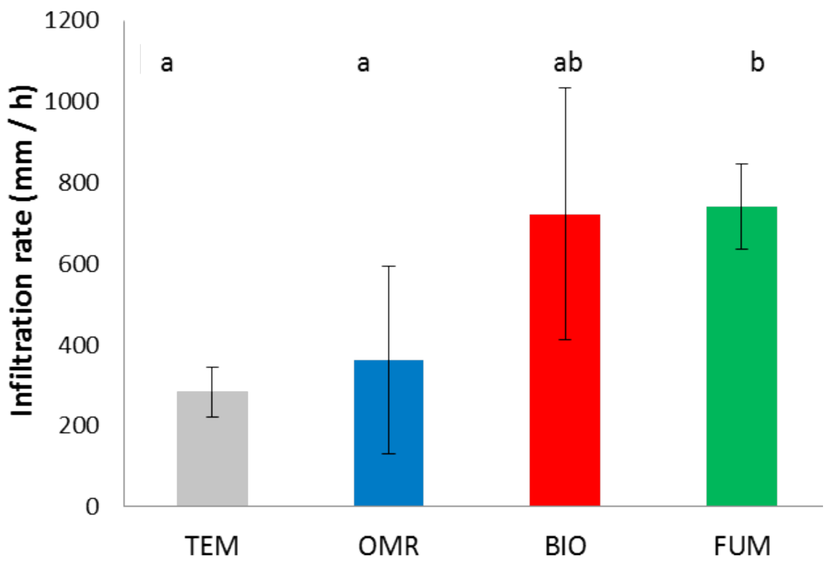

Figure 9: *Water infiltration speed for 4 control and amended treatments on the QualiAgro site**

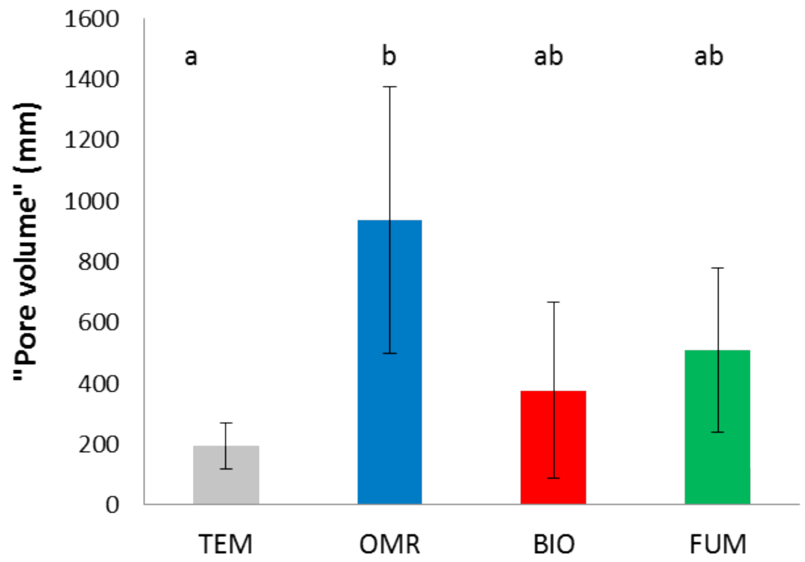

Figure 10: *Pore volume of the soil profile for 4 control and amended treatments on the QualiAgro site, represented by the quantity of water needed to saturate the sol profile**

TO REMERBER

The greater organic matter (OM) content in amended soils results in a greater capacity for retaining water and a greater speed of infiltration of excess water.

The input of organic amendments enables better water regulation in the field.

* ***Statistical processing:*** *the letters (A, B and C) indicate significant differences in the effects of the different treatments.*

QUALIAGRO EXPERIMENTAL SYSTEM

The QualiAgro site is a medium- to long- term experiment initiated in 1998 as part of a joint INRA and Veolia Research & Innovation project. The QualiAgro site is part of the SOERE PRO sites (environmental research, monitoring and experimentation systems for organic waste products), a field trial network dedicated to the study of repeated OWP spreadings.

Description of the site:
Location: The Yvelines (78), on the Alluets-le-Roi plateau, 30 km west of Paris.
Climate: modified oceanic climate with an average temperature of 11°C and an average precipitation of 600 mm.
Type of soil: luvisol on loess (decarbonated loamy-clayey soil up to 1 m deep, surface pH of 6.9), typical of the Parisian region.
Area: 6 hectares segmented into 4 treatment replication blocs each divided into 10 plots of 450 m².

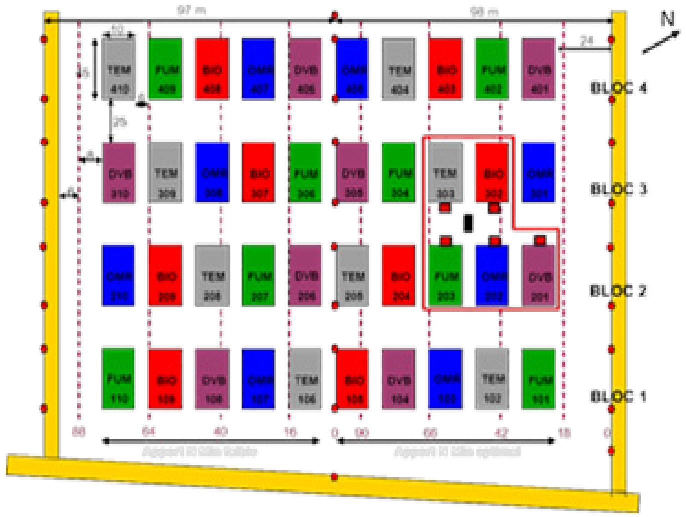

Figure 11: Plan of the QualiAgro experimental field trial

Objective of the trial:

The objective of this trial is to compare the effects of the repeated input of different types of OWPs on agricultural system compartments (soil, plants, water, air). The effects of 4 organic amendments are being studied and compared to control treatments (**TEM**) with no organic input:

1. A biowaste compost (**BIO**), from the selective collection of fermentable household waste composted with green waste
2. A residual household waste compost (**OMR**), from the composting of residual household waste after sorting out packaging upstream (paper/cardboard, plastic, glass)
3. A sludge compost (**DVB**), from the composting of sewage plant sludge mixed with green waste
4. Manure from dairy cattle (**FUM**)

Trial management:

Simple crop rotation: wheat-maize with export of wheat straw and restitution of maize residue.
OWP inputs were carried out every 2 years since 1998 on wheat stubble, to the amount of 4 t C/ ha.
The trial is divided into 2 sub-tests:

- Half of the plots receive optimal mineral nitrogen fertilization in addition to OWPs (noted +N);
- The other half receive minimal mineral fertilization (half or ¼ of the optimal fertilization on wheat only, noted -N).

Moreover, five plots are equipped with sensors for measuring water content and potential, and temperature over the whole soil profile. In these 5 plots, 2 levels of lysimeters at 45 and 100 cm deep are also present to collect water in the soil for analysis.
More information is available at **http://www6.inra.fr/qualiagro**

THE COLMAR PLATFORM

The Colmar platform was initiated in collaboration with SMRA (mixed syndicate for agricultural recycling of Haut-Rhin) and ARAA (association for the agronomic renewal in Alsace) in 2000. It is also a SOERE PRO site, located within the Experimental unit of the INRA of Colmar in Alsace.

Description of the site:
Location: Colmar (in Alsace).
Climate: continental climate with an average temperature of 10.5°C and an average precipitation of 560 mm.
Type of soil: silty limestone soil from loess, typical of the Alsace plain. It is carbonated over the whole height of the profile (1m deep on average).
Area: 2.26 hectares segmented into 4 treatment replication blocs each divided into 12 plots of 90 m². An additional bloc includes 6 plots where no treatments are applied and 6 plots constituting the «adjacent zero N» treatments.

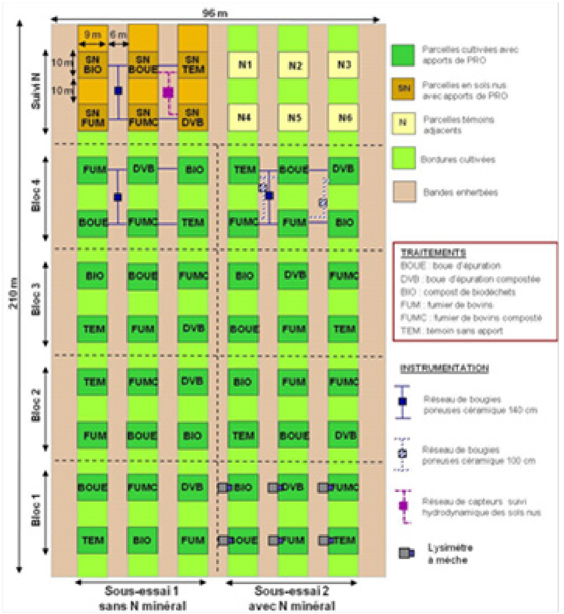

Figure 12: *Plan of the Colmar platform*

Objective of the trial:

The objective is to compare the effects of the repeated input of different OWPs on the agricultural system compartments. Five types of OWPs are tested and compared to a control treatment (**TEM**):

1. Sludge from urban wastewater treatment (**BOUE**)
2. The same sludge composted (**DVB**)
3. Biowaste compost (**BIO**)
4. Cattle manure (**FUM**)
5. Composted cattle manure (**FUMC**)

Trial management:

Crop rotation is typical of the Alsace plain: maize, wheat, beetroot, and barley with restitution of all the crop residues.

OWPs are input every two years, before maize or beetroot, at the beginning of the year. The doses input are calculated to provide 170 kg N/ha. Spreadings are carried out manually.

The trial is divided into 2 sub-tests:

- the first lot only receives the OWPs
- the second lot is supplemented in mineral nitrogen fertilizers dosed according to the plants' needs.

BIODIVERSITY

EFFECT OF OWP ON SOIL MICROFLORA ABUNDANCE AND ACTIVITIES

Due to the provision of OM, OWP inputs stimulate the abundance, diversity and activities of microorganisms in the soil which are involved in many ecosystem services:

- making nutritive elements available for plants through the mineralization of organic N,
- protecting crops through for example, antagonisms with pathogens,
- controlling erosion through stabilizing the structure,
- decontaminating soils and water through the degradation of organic micropollutants.

The intensity and persistence of the effects of OWPs on microflora depends on: the quantity and frequency of the inputs, the characteristics of the OM contained in the OWP depending on its origin and treatments applied to it, and the pedoclimatic conditions.

On the QualiAgro site (see p.14), the regular input of composts and manure gradually increase the soil's OM content (see p.4). This results in the similar increase of the total microbial biomass, to a factor of 1.4, with all organic treatments after 7 inputs (Figure 13).

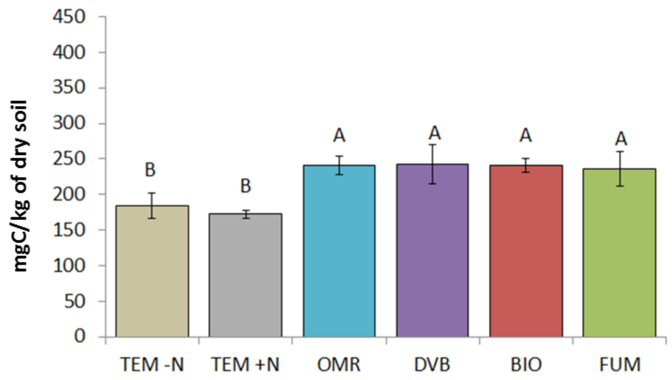

Figure 13: *Long term effect* (after 7 spreadings, QualiAgro) of OWP inputs on the total microbial biomass*

On the shorter term, in the weeks following the OWP input, the effects on soil microorganisms are more intense and vary depending on the organic treatment. Indeed, the total microbial biomass increases to a factor between 1.2 and 1.9 just after the 8th spreading (Figure 14).

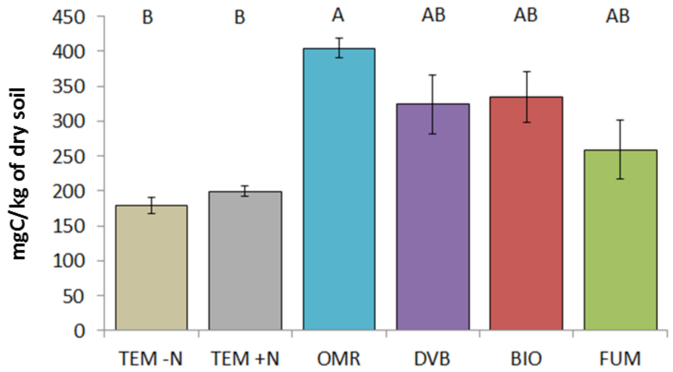

***Figure 14:** Short term effect * (3 weeks after the 8th spreading, QualiAgro) of OWP inputs on the total microbial biomass*

The most effective OWP is the residual household waste compost (OMR), rich in easily biodegradable C which is readily available for microorganisms, with a very pronounced and significant effect on fungal microflora.

To be noted: more specific microorganisms such as nitrifying bacteria, responsible for transforming ammonium into nitrates, are significantly stimulated just after spreading, in the plot amended with the sludge compost (DVB, Figure 15), most likely due to the latter's high content in ammonium. OWP inputs do not affect denitrifying populations, responsible for the reduction of nitrates into N_2O then N_2 in anaerobiosis conditions.

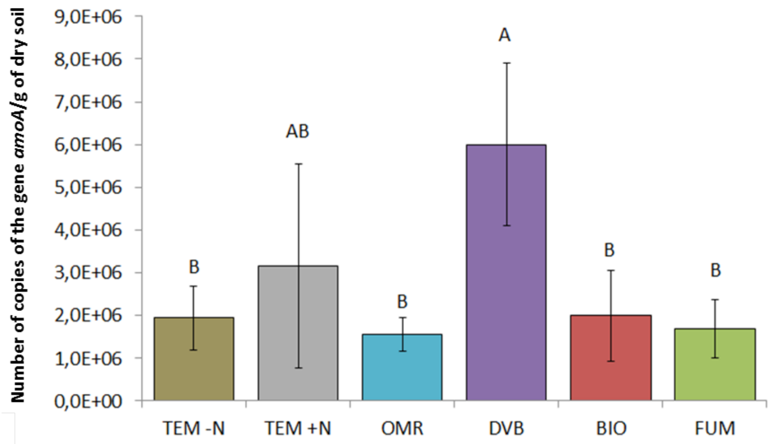

***Figure 15:** Short term effects of OWP inputs on the abundance of nitrifying bacteria* (3 weeks after the 8th spreading, site QualiAgro)*

On the Colmar site, where the quantity of organic matter provided by OWPs are much lower, no stimulation of soil microflora was observed on either the short or long term.

TO REMERBER

OWPs stimulate the soil microbial biomass soon after spreading and the effects persist on the medium and long term.

* ***Statistical processing:** the letters (A, B and C) indicate significant differences in the effects of the different treatments.*

EFFECT OF THE INPUT OF OWP ON EARTHWORM ABUNDANCE AND DIVERSITY

Earthworms are considered as the soil «engineers». Their activity enables plant residues to be buried in the soil profile and mixed with the mineral matrices of the soil. The tunnels dug by earthworm participate in soil porosity and contributes to the infiltration and circulation of water in the soil.

On the QualiAgro site (see p.14), after 7 spreadings, the number of earthworms had increased due to the successive inputs of OWPs. The intensity of the increase is not linked to the increase in OM in the soil. Indeed, it is more significant with the Manure treatment whereas observed OM content is highest with DVB and BIO treatments (Figure 16a). OWP inputs also modify the distribution of the types of earthworms with an increase in anecic worms compared to the control treatment (Figure 16b).

The low earthworm diversity obtained on the QualiAgro site can be attributed to the agricultural usages and practices implemented on this «arable crop» site. The control plots contain less anecic worms (*L. terrestris*) than all the other treatments, this species being favored by amendments. Indeed, *L. terrestris*, which feeds on surface matter that is little degraded, seems to be more sensitive to the input of organic matter than the endogean species (*N. caliginosus*) which favors more broken down organic matter taken from the soil.

[4] ***The anecics*** *are an ecological category of earthworm, grouping pigmented species, large sizes, living in generally vertical and permanent galleries and feeding on organic matter mainly from surface.*

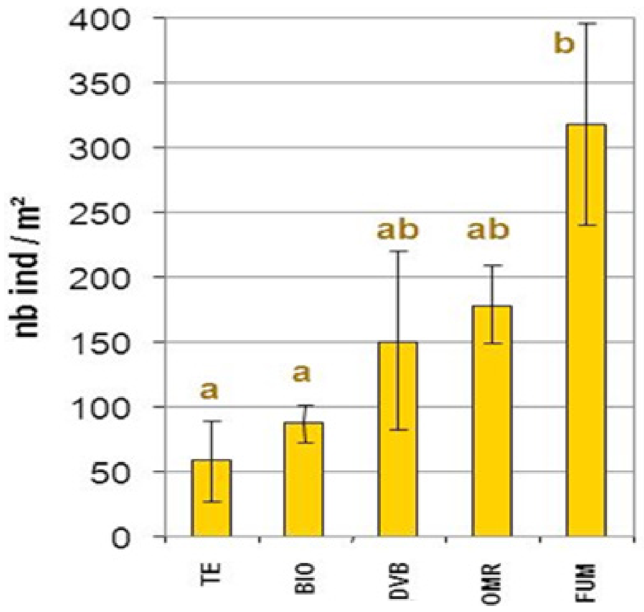

__Figure 16 a:__ Effect of the repeated input of OWPs on the abundance of earthworms in the plowed horizon (Peres et al., 2011 as part of the «ADEME Bioindicateurs» program)

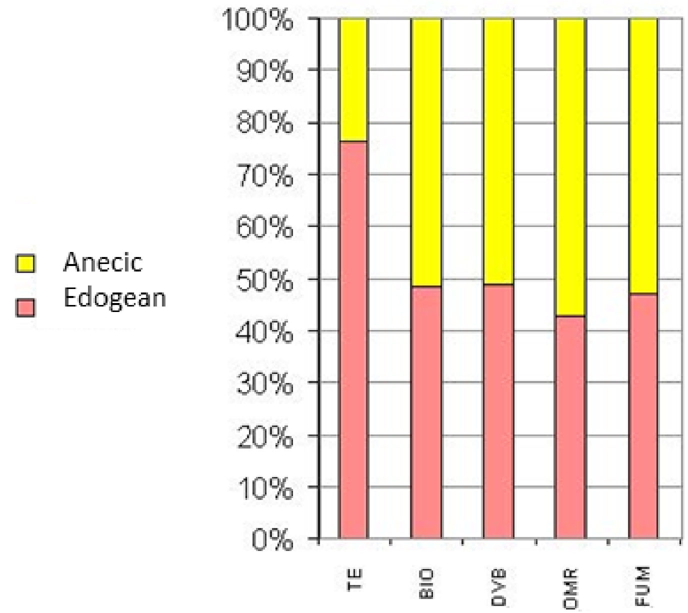

__Figure 16 b:__ Distribution of earthworms within the main worm families (Peres et al., 2011 as part of the «ADEME Bioindicateurs» program)

TO REMERBER

In the agricultural context, where earthworms are few, repeated OWP inputs increase the density of earthworms and the proportion of anecic worms who contribute to the incorporation of OM from the OWPs into that of the soil and to the increase of soil macro-porosity through digging tunnels.

__Note:__ Results obtained as part of the ADEME "Bioindicators" program at the QualiAgro site, in the spring of 2009. For more information: G. Pérès, F. Vandenbulcke, M. Guernion, M. Hedde, T. Beguiristain, F. Douay, S. Houot, D. Piron, L. Rougé, A. Bispo, C. Grand, L. Galsomies, D. Cluzeau. The use of earthworms as tool for soil monitoring, characterization and risk assessment. Example of a Bioindicator Programme developed at National scale (France). 2012. Pedobiologia 54, 77–87

* ***Statistical processing:*** *the letters (A, B and C) indicate significant differences in the effects of the different treatments.*

REGULATION OF SOIL AND SANITARY QUALITY

TRACE METAL ELEMENTS

In order to conclude to the interest of returning OWPs to the soil and their use in agriculture, it is necessary first to guarantee to farmers the safety of this practice. The input of organic and mineral contaminants is one of the major questions concerning this practice. Since the setting up of the QualiAgro trial (see p.14), the evolution of the concentrations in Trace Metal Elements (TME) in soils and plants has been monitored and compared to the flows input through OWPs.

Since 1998, concentrations in Copper and Zinc increased in the OWP burying horizons (Figure 17). These increases are observed with all organic treatments. As the OWP inputs are three times superior to the usual doses spread, the 15 years of testing on the QualiAgro site represent the effects of 45 years of traditional practice. However, the concentrations measured are comparable to those measured in similar soils in the region. The increase in other TMEs are much lower to insignificant. The flows of TMEs input through OWPs remain in the OWP burying horizon. The flows absorbed by the plants are very low and are similar with all the treatments, including the control: there is no impact on crop quality (Copper and Zinc in maize grains as example in Figure 18). Flows measured in water are also very low.

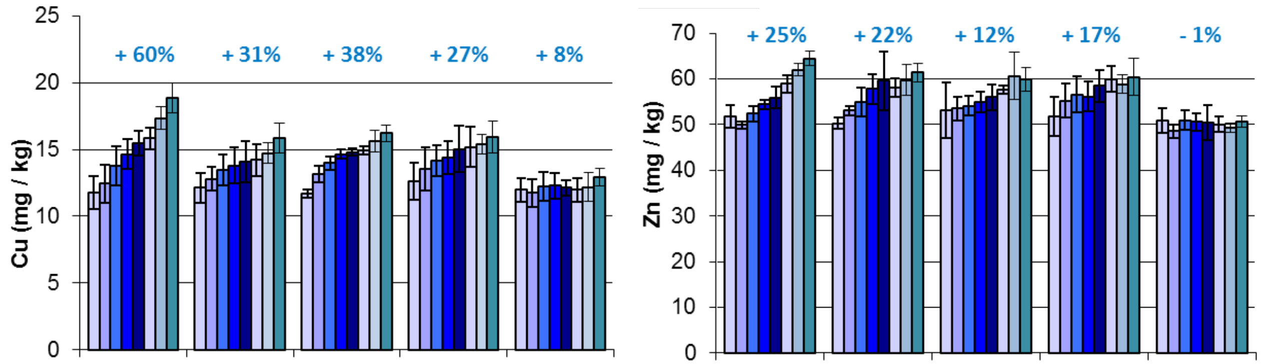

Figure 17: *Increase between 1998 and 2013 of the content in Copper and Zinc for the different treatments and linked to the successive inputs of OWPs on the QualiAgro site*

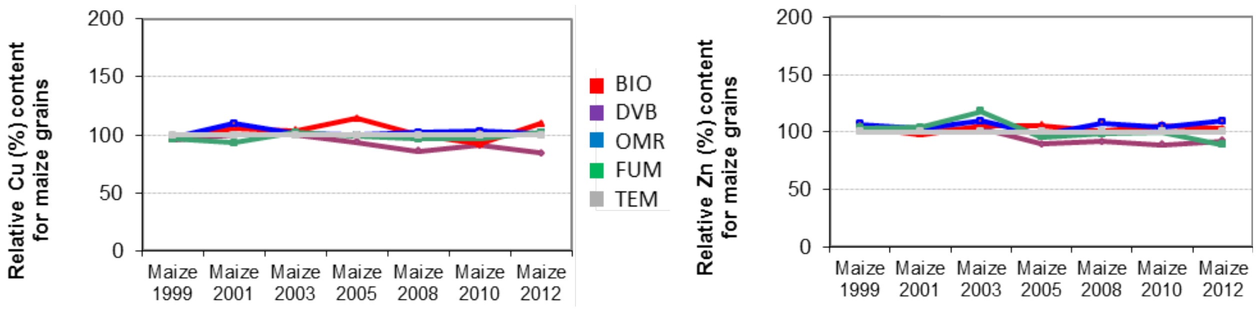

Figure 18: *Content in Copper (left) and Zinc (right) of maize for the different OWPs spread since 1999 on the QualiAgro site as a % compared to grains harvested in the control plots*

TO REMERBER

High inputs of OWPs increase the content in certain trace metal elements in the soil, while remaining within the same range as those found in similar types of soil and without transfer to harvests.

TRANSFER OF ORGANIC POLLUTANTS TO THE SURFACE LAYER OF THE SOIL

Persistent Organic Pollutants (POP) are found almost everywhere in our environment, including in the most isolated regions such as the Arctic where these compounds have never been used. OWP inputs constitute a source of POPs in soils. OM inputs from OWPs will also modify the relations between POPs and soil OM which conditions the availably of POPs. Indeed, the presence of POPs in the soil does not systematically mean that these are available and will be transferred to crops growing in this soil.

Chlorinated dioxins and furans, brominated dioxins and furans, PCBs, and PBDEs, a class of brominated flame retardants, were studied in different field tests in France and Sweden. These contaminants are present in control soils, without any input of OWPs, in low concentrations and can be explained by atmospheric deposits.

The amendments used in the field trials all contain POPs, but the contents are mainly low and vary greatly between the different types of amendments and the POPs concerned (toxic dioxin concentrations in the different OWPs from 2 to 27 ng/kg RM). OWP doses input on the different sites studied often exceed usual doses applied in France and Sweden. POP concentrations increase in most amended soils, however, the observed increases are inferior to the flows of POPs provided by the amendments. This may be explained by the degradation of the compounds, their interactions with soil OM which renders them unrecoverable or their transport into deeper soil layers. Moreover, the results show that concentrations may be lower in amended soils than in control soils with no amendment input, which is the case for PCBs on the Colmar site (Figure 19).

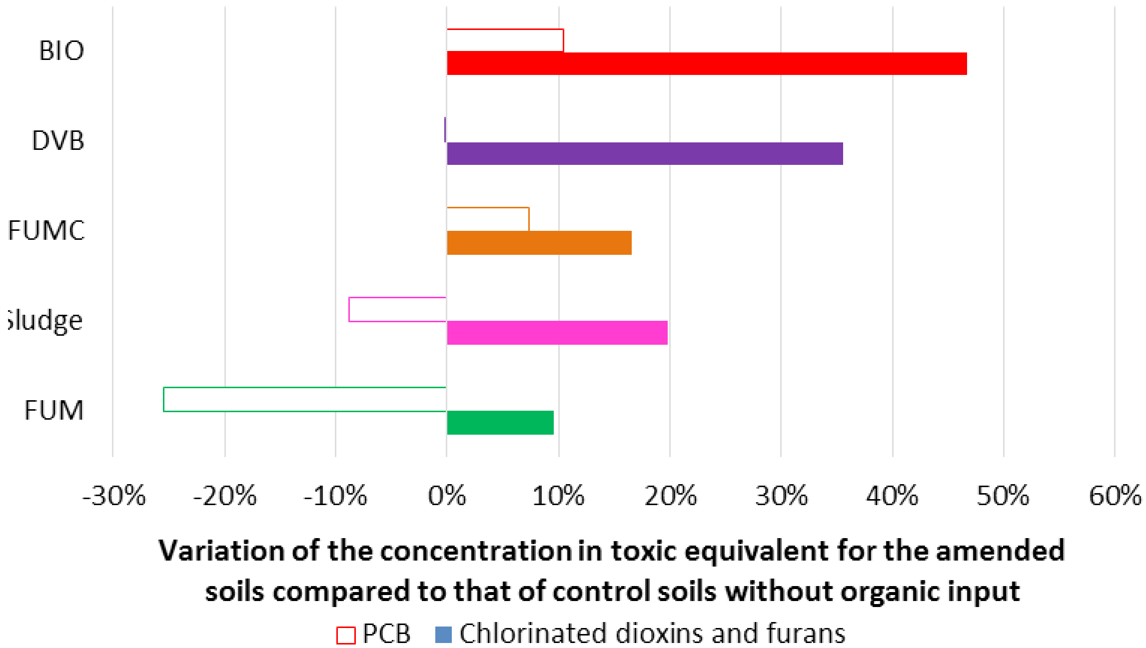

Figure 19: *Evolutions of the concentration in toxic equivalent for two POP categories: chlorinated dioxins and furans (filled bars) and PCBs (outline bars) in amended soils compared to the control soil on the Colmar site, two years after the last spreading*

TO REMERBER

The transfer of Persistent Organic Pollutants (POP) to the soil through spreading is specific on every site and depends on several factors linked to the soil and amendments. However, the concentration in the soil after OWP input does not vary much compared to control soils without inputs.

REGULATION OF SANITARY QUALITY

TRANSFER OF HUMAN PATHOGENS AND ANTIBIOTIC RESISTANT GENES

OWPs from urban or agricultural origin may contain human pathogens and antibiotic-resistant bacteria. The use of these OWPs raises the question of the becoming of these pathogens and antibiotic resistant genes in amended soils and environmental matrices, and even of their transfer to primary plant or animal agricultural productions.

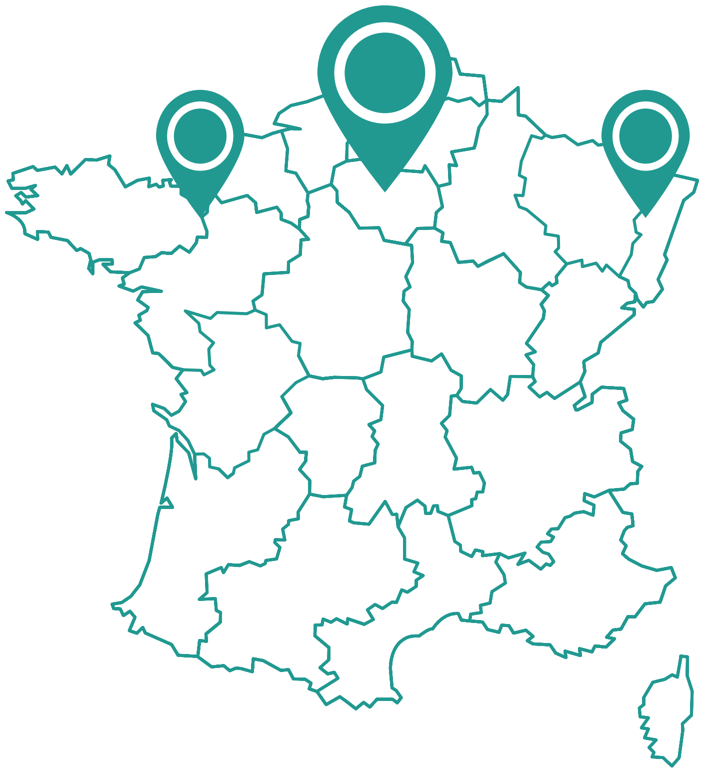

Figure 20: *Location of the 3 field tests: Rennes, Feucherolles (QualiAgro) and Colmar*

A widespread food pathogen (*Listeria monocytogenes*), two bacteria indicating fecal contamination (*Escherichia coli and Enterococcus faecalis*), and an antibiotic resistant gene (*bla* CTX-M) were sought in the amendments and soils amended by 11 different OWPs, composted or not and used on three experimental sites in France, by associating culture detection and quantification methods and/or molecular detection.

Very low quantities of *L. monocytogenes* was detected in two of the amendments used but never in the amended soils. Bacteria indicating fecal contamination (in particular *E. coli*) and the antibiotic resistant gene were found in the sewage plant sludge and manure. Composting the sludge and manure leads to a great reduction of the content in fecal bacteria and resistant genes. Without composting OWPs, the soils amended with urban sludge or manure may be contaminated by fecal bacteria and resistant genes over periods lasting at least one month after spreading.

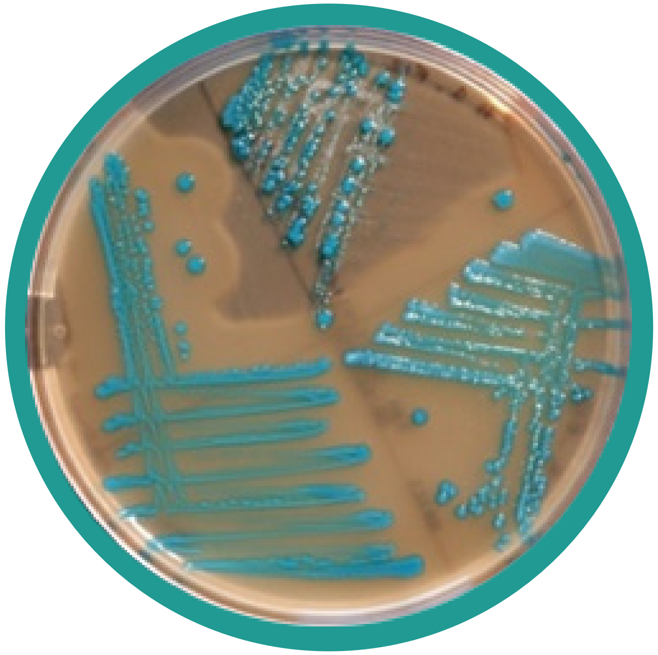

Figure 21: *Culture in a Petri dish*

TO REMERBER

It is possible to greatly reduce the propagation of fecal bacteria and antibiotic resistant genes by composting OWPs before spreading these onto agricultural soil. Spreading raw urban sludge (non-composted) seems to be the most risky practice as regards the propagation of antibiotic resistant genes.

THE 4 PARTNERS OF THE ECOSOM PROJECT

VEOLIA RECHERCHE ET INNOVATION

Through its dedicated structure – Veolia Research & Innovation (VERI), the Veolia Group mobilizes its 850 researchers and developers as well as six worldwide research centers around four objectives: preserving resources, limiting impacts on natural environments, reducing greenhouse gas emissions and managing sustainable urban development. Drawing on its recognized scientific excellence, VERI aims to fully respond to the needs of industrial and municipal customers, improve the overall performance and productivity of Veolia processes and those of its customers, while anticipating tomorrow's needs.
Through its Recycling activity and its «SEDE Environnement» subsidiary, the VEOLIA Group contributes to recovering Organic Waste Products.
VERI has coordinated the preparation of this brochure and was in charge of the dissemination of the results of ECOSOM project.
http://www.sede-environnement.com
http://www.veolia-proprete.fr

ALTERRA

Alterra is an integral part of the University of Wageningen and is the main Dutch research and expertise center for rural zones. Alterra aims to train and carry out strategic and applied research to support the development of policies and territorial management for rural zones. Alterra is involved in every ecosystem aspect: soil, water, climate and the use of land. Its research work, led at local, regional, national and international levels, contributes to the sustainable use of natural resources and to the sustainable design and management of the environment.
Alterra has coordinated measurements of the physical properties of soils link with earthworm activity and was in charge of the section on the effects of reduced tillage.
http://www.wageningenur.nl/fr.htm

UMEA UNIVERSITY

The Chemistry Department of the University of Umeå, in northern Sweden, is one of the largest departments of the Science and Technology Faculty with its 220 members. Research within the Chemistry Department is grouped into 3 areas: environmental chemistry and biogeochemistry, biological chemistry, and technical chemistry.
Umea University quantified the organic contaminants in the project sites.
www.chemistry.umu.se

INRA

The French National Institute of Agronomic Research (INRA) is the number one European research institute for agriculture. It supports economic and social innovation in the fields of food, agriculture and environment. Two Joint Research Units («Unités Mixtes de Recherche», UMR) participated in the ECOSOM program:

- (1) The UMR INRA-AgroParisTech «Environment and arable crops» (EGC) in Grignon, whose researches aim to describe and model the functioning of agricultural systems representative of arable crops in northern Europe in terms of their interactions with biotic and abiotic environmental factors (climate, soil, pollutants, pathogens), (http://www6.versailles-grignon.inra.fr/egc);
- (2) The UMR INRA-AgroSup in Dijon, whose researches concern biotic interactions (in particular plant-plant and plant-microorganisms) within agricultural systems in order to design innovative and environmentally friendly crop systems; (http://www6.dijon.inra.fr/umragroecologie).

AgroParisTech is a partner of the UMR EGC and trains some 2,000 students every year in the fields of life sciences and environment (http://www.agroparistech.fr).

INRA has been in charge of coordinating the ECOSOM project, the section on microbial activities and the assessment of the soil resilience toward pathogens.

SNOWMAN

The SNOWMAN network brings together public institutions in Europe who are competent as regards environment in order to deepen and promote knowledge of the sustainable management of soils. Through its members, it coordinates and finances European calls for projects on the subject of soils and groundwater in Europe.

For more information go to:
http://www.snowmannetwork.com

THE ECOSOM PROJECT

For 3 years, the research work of the ECOSOM project focused on the recycling of Organic Waste Products (OWP) for agriculture with an overall aim to improve the ecosystem services provided by soils to farmers.

Organic Matter and soil structure are at the heart of the issue as the key factors for soil functions and the provision of the ecosystem services, such as maintaining a functional biodiversity, climate and water regulation, agricultural production, etc.

Understanding the biological, chemical and physical mechanisms linking this agricultural practice to ecosystem services was subject to experimental monitoring based on long term field trials where different types of Organic Waste Products were studied for over 10 years.

Today, sustainable soil management is one of the main environmental stakes in terms of protecting agricultural soils, a resource that is increasingly monopolized and degraded.

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