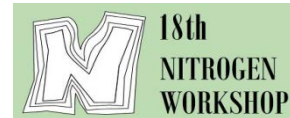# Contribution des membres du RMT Fertilisation & Environnement au 18^e « N workshop »

Contribution of members of the Fertilization & Environment Technological Network to the 18th "N workshop"

The nitrogen challenge: building a blueprint for nitrogen use efficiency and food security

Lisbonne 30 Juin – 3 Juillet 2014.
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Communications sous forme de communication orale ou poster.

Beillouin D., A. Schneider, B. Carrouée, L. Champolivier, C. Le Gall, M.-H. Jeuffroy. **Short and medium term effects on nitrogen leaching of the introduction of a pea or a oilseed rape crop in wheat-based successions**.

Cohan J.P., J. Labreuche, A. Bouthier, E. Justes . **Leguminous cover-crops effects compared to non-leguminous on nitrate leaching and nitrogen supplying to the succeeding corn and spring barley**.

Drouet J.L., F. Laurent, P. Durand, G. Billen, P. Cellier, O. Maury, S. Potok, P. Faverdin, C. Fléchard,J. Garnier, A. Guy, C. Hénault, C. Mignolet, H. Monod, A. Probst, S. Sorin, G. Tallec, M. Beekmann, E. Ceschia, C. Le Gall, T. Morel, G. Quesnel, E. Ramat, B. Zeller. **ESCAPADE to quantify nitrogen losses in territories and assess mitigation strategies**

Gaudnik C., L. Joly, G. Alavoine, A. Cantarel, N. Dumélié, T. Decarpenterie, C. Georget, S. Recous. **Potential emissions of N2O from vineyard soil: simulation of rain and fertilization events under controlled conditions.**

Le Roux C., J.-M. Machet, N. Damay. **Nitrogen mineralization of subarbeet vinasses in interaction with catch crops.**

Machet J.-M., C. Le Roux, N. Damay. **Azofert®: a dynamic decision support for fertilizer advice adapted for organic products and catch crops**.

Redin M., S. Recous, G. Dietrich, A.C. Skolaude, B. Chaves, I.C. Pfeifer, C. Aita, S.J. Giacomini. **Interactions between the chemical quality of crop residues and their location in soil: how Nitrogen availability controls mineralization of C and N ?**

Vertes F., B. Mary. **Part of grassland in ley-arable rotations is a proxy for predicting long term soil organic matter dynamics**.

SHORT AND MEDIUM TERM EFFECTS ON NITROGEN LEACHING OF THE INTRODUCTION OF A PEA OR A OILSEED RAPE CROP IN WHEAT-BASED SUCCESSIONS

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Background and Objectives

Legume crops are the only natural source of nitrogen (N) input in cropping systems (besides organic manure) and enable to reduce some environmental impacts associated with the production and use of synthetic fertilizers. Moreover, in arable cropping systems, wheat benefits from the preceding effects of oilseed rape and pea crops reaching a a higher yield with less nitrogen fertilizer. However, several studies have demonstrated higher soil mineral nitrogen (SMN) and leaching risks following a pea or oilseed rape crop compared to cereals. Nevertheless, effects of oilseed rape or pea on N leaching risks during the second winter after the given crop still remain unclear. Parsimonious previous studies (Thomsen et al. 2001; Hauggaard-Nielsen et al. 2003) suggested a lower SMN and leaching risk during the second winter after pea cultivation. This paper reports a study of the comparative effects of winter pea, oilseed rape and wheat on the SMN and leaching risks during the first and second winter after the harvest of these crops. An assessment of the long term effect of the introduction of a pea or oilseed crop in wheat-based successions on N leaching is also conducted at succession scales over 20 climatic years.

Materials and Methods

Two field experiments were carried out from 2007 to 2011 at INRA Grignon Experimental unit, 40 km West from Paris and at CETIOM experimental station, 150 km North-east from Paris. Soft wheat (250 seeds m⁻²), winter pea (90 seeds m⁻²) and winter oilseed rape (50 seeds m⁻²) were sown every year in order to compare eight crop sequences. The soil was bare in autumn. All plots were statistically randomized with 4 replicates. The SMN was measured at least three times over the winter periods in the Grignon trial and only after harvest in the Holnon trial. Effects of harvested crop and the preceding crop on the SMN both after harvest and at the beginning of winter were studied through linear and mixed models using R statistical software. The soil nitrogen fluxes below the rooting zone for various crop successions were then predicted using the post-harvest SMN measurements of Grignon trial. Predictions were performed with the LIXIM model (Mary et al., 1999), run on 20 climatic years.

Results and Discussion

The SMN at the beginning of the winter in the first autumn after the pea and oilseed rape crops were significantly higher than the SMN after the wheat crop, respectively +26 kg N ha⁻¹ and +14 kg N ha⁻¹ for the Grignon trial. Moreover, due to the shallow root system of the pea, there was a marked vertical gradient in the soil, with 34% of SMN recovered in the deepest layer of the soil profile. Our simulations confirmed, in accordance with previous studies, that, without catch crop in autumn, the risk of N leaching was significantly higher at the beginning of the winter after pea compared to wheat. On the opposite, during the second autumn, the SMN after the wheat crop, with pea or oilseed rape as preceding crops, were significantly lower than the SMN after wheat, with wheat as preceding crop. Discrepancies were -17 and -18 kg N ha⁻¹ for SMN in autumn for the Grignon trial, respectively for oilseed rape and pea as preceding crops, compared to wheat as preceding crop. The simulations with LIXIM confirmed this reduced nitrogen leaching risks during the winter following wheat if the preceding crop was a pea or an oilseed crop. This result could be explained by better N absorption

conditions for the cereal with oilseed rape or pea preceding crops, mainly due to a safer root system, as several root diseases can occur on a second wheat crop. There is probably another reason, as in our experiment, we did observe a higher dry matter and yield for wheat with oilseed rape or pea preceding crops, but no higher N uptake. The simulations performed for various successions showed that including a pea crop did not result in higher values of N leaching than successions with only wheat crops, meaning that the opposite risks of leaching the first and second years after pea generally compensated each other.

Conclusions

Our results demonstrated that N leaching should be analyzed at the scale of crop successions, in order to take into account the effects of the preceding crop, the crop in place and the intercrop management. At this multi-year scale, the introduction of a legume crop such as pea in cereal-based successions led to a similar or lower risk of nitrate leaching. In addition, this study confirmed one environmental interest of diversifying wheat-based successions with the introduction of a pea or oilseed rape crops.

Acknowledgment

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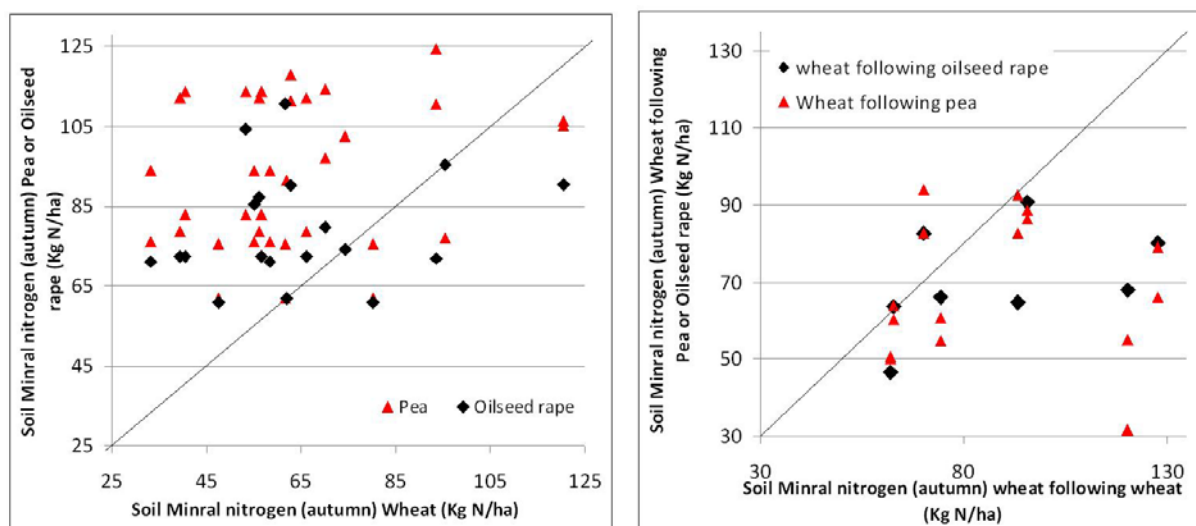
Fig 1: Soil mineral nitrogen in autumn after a pea, a oilseed rape or a wheat crop (left) and soil mineral nitrogen in autumn after wheat which follows a pea, an oilseed rape or a wheat as the preceding crop (right).

LEGUMINOUS COVER-CROPS EFFECTS COMPARED TO NON-LEGUMINOUS ON NITRATE LEACHING AND NITROGEN SUPPLYING TO THE SUCCEEDING CORN AND SPRING BARLEY

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Backgrounds and Objectives

Nowadays in Europe and then in France, it becomes necessary to elaborate agricultural systems less reliant on synthetic fertilizer-N due to 1) the progressive rising of fertilizer prices, 2) the need of decreasing GHG (Green House Gaz) and ammonia emissions. Nevertheless, these systems should provide high yields and grain protein contents to satisfy the food security and market demands. So, the reduction of synthetic fertilizer-N must be counterbalanced by other nitrogen sources. Among them, leguminous cover-crops (LCC) have the advantage of introducing "free" atmospheric nitrogen without leading to a too strong change in the current agricultural systems. Since 1992 and the first Nitrate Directive program, agronomists have acquired wide knowledge about non-leguminous cover-crops (NLCC) but not on LCC due to their regulatory ban. Nitrate Directive update in 2009, allowing leguminous cover-crop under specific conditions, changed this situation and triggered a wide research program supported by several organizations in France with three questions to answer: 1) What is the effect of LCC on nitrate leaching? 2) What is their effect on nitrogen supplying of succeeding spring crops, in order to evaluate their potential to improve agricultural systems independence from synthetic fertilizer-N? 3) What are their technical specificities to obtain enough biomass, to provide the first two effects? This paper will put forward the main conclusions of points 1 and 2.

Materials and Methods

27 annual and 4 long-term experiments were carried out from 1991 to 2013 in several French regions and on the main soil types encountered in the country. All plots were statistically randomized with at least 3 replicates. LCC species studied were: pea, faba bean, vetch, several clover species and lentil. NLCC controls were: white mustard, fodder radish, rye-grass, spring oat, rye and phacelia. We also tested some mixtures of LCC and NLCC (MCC). Cover-crops termination dates ranged from November to February. Sowing dates ranged from mid-February to the beginning of April for spring barley, and from mid-March to mid-May for corn. Nitrate leaching was evaluated considering reduction of soil mineral-N content at the beginning of leaching period (compared to bare soil) in all experiments and with porous cup/lysimeters monitoring in two long term trials. N supplying to succeeding spring crop was calculated using soil nitrogen balance based on soil and plant N content measurements at the end of winter and at harvest. In 6 experiments, we also simulated N mineralization kinetics after cover-crop incorporation with INRA Lixim software (Mary et al. 1999) using regular soil mineral-N content measurements.

Results and Discussion

LCC led to a twofold less reduction of soil mineral-N content at the beginning of the leaching period than NLCC and mixtures (figure 1). This result was confirmed by porous cups/lysimeters monitoring. Nevertheless, LCC effects on nitrate leaching was different from zero, allowing them to be used as nitrate catch crop in situations where leaching risk is low to medium (deep soils, no slurry applications…). MCC showed the same display than NLCC, allowing them to be used in all agricultural situations.

LCC showed the highest N supplying effect to succeeding spring barley and corn (figure 2-a). NLCC effect was variable and could sometimes lead to N supplying depletion (figure 2-a). The difference between LCC and NLCC is linked to their effects on soil mineral-N content before leaching and to their mineralization kinetics which imply different N dynamics release (figure 2-b). More than the type of cover-crop, it seems to be the C/N ratio which determines the mineralization kinetics and explain some differences between experiments. It is consistent with results obtained under laboratory conditions (Justes et al. 2009) and in well-known published results obtained in field trials (Laurent et

al. 1995). The acquisition of N from soil and atmosphere allows LCC (and MCC) to reach very low C/N ratio and so to provide larger amount of N than NLCC.

Conclusions

Our results showed that LCC and MCC could at once simultaneously reduce nitrate leaching and supply large amount of nitrogen to succeeding spring barley and corn. It is confirmed by a recent and large modelisation study conducted by INRA (Justes et al. 2012). The challenge is now to define technical specifications to grow LCC and MCC in most French agricultural situations.

Acknowledgement

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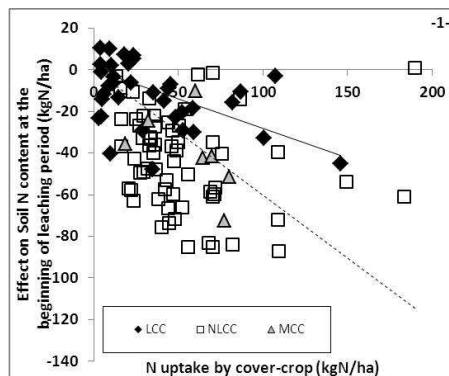
Figure 1: effect of LCC, NLCC and MCC on the reduction of soil mineral-N content at the beginning of the leaching period (compared to bare soil). Lines = linear models fitted with LCC (plain) and NLCC+MCC (dotted) data. Models are statically different (F test P-value < 0.0000).
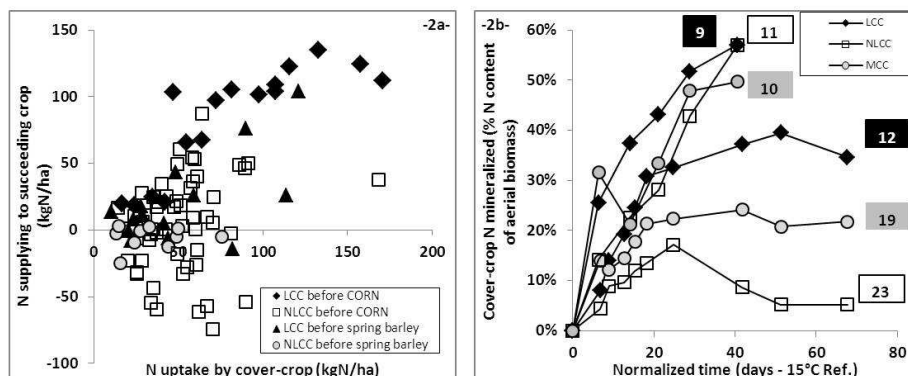
Figure 2: a- Nitrogen supplying to corn and spring barley of LCC (+MCC) and NLCC compared to nitrogen uptake / **b-** Nitrogen mineralization kinetics after cover-crops termination in 2 field trials. Labels = C/N ratio.

ESCAPADE to quantify nitrogen losses in territories and assess mitigation strategies

J.-L. Drouet[1], F. Laurent[2], P. Durand[3], G. Billen[4], P. Cellier[1], O. Maury[1], S. Potok[5], P. Faverdin[6], C. Fléchard[3], J. Garnier[4], A. Guy[7], C. Hénault[8], C. Mignolet[9], H. Monod[10], A. Probst[11], S. Sorin[12], G. Tallec[13], M. Beekmann[14], E. Ceschia[15], C. Le Gall[16], T. Morel[17], G. Quesnel[18], E. Ramat[19], B. Zeller[20]

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Background and objectives

One of the agro-environmental and socio-economic challenges of agriculture is to maintain agricultural production while limiting the use of nitrogen inputs. The development of the Haber-Bosch process on an industrial scale in the XXth century to produce ammoniacal nitrogen from atmospheric dinitrogen allows the entry of large amounts of nitrogen in production systems. This feeds a cascade of processes within agroecosystems and losses of nitrogen to the environment at each stage of the cascade (Fig 1) with many environmental and societal impacts (degradation of air, water and soil quality, impacts on greenhouse gas balance, biodiversity and human health…). The overall costs of nitrogen losses in Europe are estimated between 70 and 320 million euros per year and thus exceed the direct economic benefits of the use of nitrogen in agriculture (Sutton et al., 2011). A major challenge is to better understand the processes involved in the nitrogen cascade and nitrogen losses to the environment, to integrate them by taking into account spatial and temporal interactions within landscape mosaics, to quantify them from modelling approaches combined with experiments and inventories, to assess agro-environmental scenarios of nitrogen management in territories, and to propose innovative mitigation strategies of nitrogen losses and/or adaptation strategies of production systems to global change. Since classical approaches at plot or farm scale do not make possible to control all impacts, levers must also be sought at larger scales (Cellier et al., 2011). In this context, the overall objective of the multidisciplinary project ESCAPADE (2013-2017) is to analyze the effect of agricultural activities and landscape mosaics on the nitrogen cascade in territories, with an approach that combines production of scenarios, modelling tools and observations of flows of different forms of reactive nitrogen (NO_3^-, NH_3, NO_x, N_2O…). The project mainly focuses on landscapes defined as areas from a few km^2 to a few tens of km^2 and also on larger areas from hundreds to thousands of km^2.
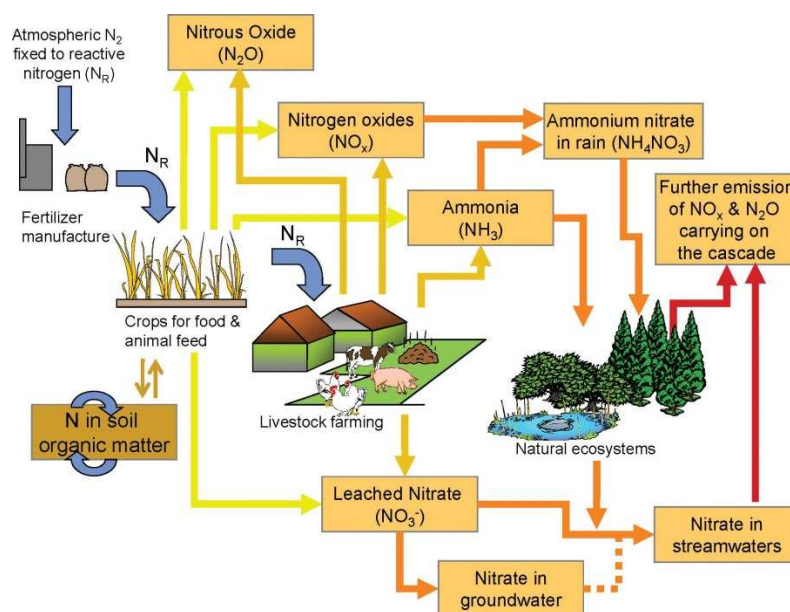

Figure 1: Simplified diagram of the nitrogen cascade (from Sutton et al., 2011).

Materials and methods

The ESCAPADE project is organized into four main scientific tasks (Fig. 2). Under task 1, agro-environmental scenarios related to management of nitrogen and landscape mosaics are built at the classical scales of the plot (types, quantities and dates of nitrogen inputs...) and the farm (crop sequences, herd and waste management…) and also at the innovative scale of territories (structure of the landscape mosaics, spatial planning...). Integrated models dealing with the nitrogen cascade within landscapes (resp. larger territories) are developed and/or used under task 2 (resp. task 3) to quantify nitrogen flows and losses to the environment. Models developed under task 2 are calibrated and evaluated from data inventoried and measured on the experimental sites of the project (task 4). These sites are located in Brittany, Parisian Basin and southwest of France. They are characterized by a wide range and variability of nitrogen flows due to differences in agro-pedo-climatic conditions. Scenarios and models are then applied to the sites and territories to quantify nitrogen flows and losses within the sites and larger territories. The ESCAPADE project associates research actors (basic and applied) and actors of the agricultural development (technical institutes, cooperatives, local actors). Partners are from various disciplines (biophysics, biogeochemistry, agronomy, socio-economy, mathematics/statistics, computer science).
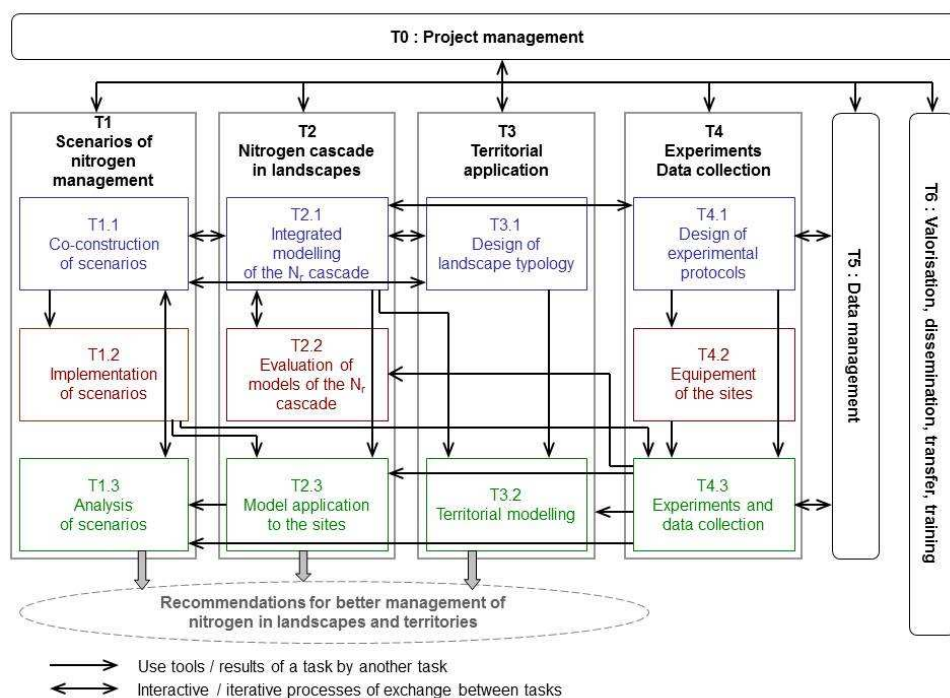

Figure 2. Structure of the ESCAPADE project.

Results and discussion

The expected results are: i) production, evaluation and interpretation of scenarios for nitrogen management in territories, ii) production of knowledge and reliable tools (models, databases) to quantify the nitrogen cascade in territories, iii) strengthening multidisciplinary partnerships between research and development, iv) co-construction of innovative solutions to reduce nitrogen losses in the environment or adapt production systems.

Conclusions, acknowledgements

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POTENTIAL EMISSIONS OF NITROUS OXIDE FROM VINEYARD SOIL: SIMULATION OF RAIN AND FERTILIZATION EVENTS UNDER CONTROLLED CONDITIONS

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1. Background and Objectives

Of global anthropogenic emissions of greenhouse gases, agriculture accounts for about 60% of nitrous oxide (N_2O) (Smith *et al.*, 2007). Globally, agricultural N_2O emissions have increased by nearly 17% from 1990 to 2005. N_2O emissions are linked to management practices and biogeochemical soil properties. Agricultural practices influence in different ways the soil properties and the biological processes occurring in soil as nitrogen (N) mineralization. The objectives of the study were to determine the potential emissions of N_2O in Champagne vineyard soil under different cultural practices and to provide a better understanding of the mechanisms behind N_2O emissions to improve mitigation strategies.

2. Materials and Methods

This study was conducted in a vineyard of 0.5 ha in Champagne Ardennes region in Northeast France (Montbré, 49°11'N, 4°02'E). The soil is of brown limestone and comprised of 20.8% clay, 46.0% silt and 33.2% sand with a pH_{H2O} of 7.6. In 1988, it was planted in vines and a field trial started from 1991 with four different managements in the alleys between grapevine rows. These were (1) control treatment with bare soil inter-rows, (2) organic N fertilizer with inter-rows receiving 51 kg N/ha/yr of dry-pellet form, (3) conifers bark applied every three years at rate 150 m^3/ha and (4) grass-covering treatment with bluegrass inter-rows and bare soil and 50 kg N/ha/yr (ammonitrate 33%) under rows. During the spring of 2012, soil samples were collected for the 0-5 cm and the 5-25 cm layers, sieved through a 4-mm mesh-size sieve and stored at 4°C. At the beginning of the experimentation, soil was repacked into PVC columns of 15.4 cm in diameter and 30 cm of height, with a bulk density close to field density. The experiment (with 3 replicates per treatment) was conducted in a climate chamber at 20°C. Rains were applied with deionized water with rain simulators, which consisted of capillary tubes (inner diameter 0.5 mm), equally distributed over the surface of a column (186 cm²). Columns received a total of 5 rains with 4 to 19 mm of water applied at 12mm/h intensity (Fig. 1). "Fertilization" was realized by the application of KNO_3 solution on the column surface at a rate equivalent to 15 kgN/ha. We used quantum cascade laser absorption spectroscopy (QCLAS) for the measurement of soil-derived N_2O emissions (Mappé-Fogaing *et al.*, 2012; Köster *et al.*, 2013). Some biogeochemical soil variables were measured at the beginning and the end of the experiment.

3. Results and Discussion

Soil moisture, total N and carbon (C) and microbial biomass C distinguished clearly the 4 treatments after 21 years of different agronomic practices (Table 1). Soils of control and organic N fertilizer treatments were characterized by low water holding capacity and low N and C organic content. Conversely, grass and bark treatments enhanced water retention properties and soil organic matter content with high contents of total N, C and microbial biomass, especially in the 0-5 cm soil layer.

N_2O emissions followed the same hierarchy than the soil variables with soil-induced N_2O emissions ranking as control<organic N<grass-covering<conifers bark (Fig. 2). Control and organic N treatments responded to rain and nitrate applications with low or none N_2O emissions. In spite of high content of C and N in soil of the grass treatment, soil did not emitted N_2O in initial conditions or after water application but responded in N_2O emissions only after the addition of water and nitrate together. Soil of conifers bark treatment was the only treatment with high N_2O emissions, up to 0.11 µgN/m²/s in response to the addition of water and nitrate together. N_2O emissions triggered around four hours after simulation events and lasted about 48 hours with a peak emission after about 9 hours.

Table 1. Soil variables of the four treatments in the 0-5 and 5-25 cm layers at the beginning and end of the experiment: soil moisture for wilting point (WP) of 3, contents of organic carbon (C), total nitrogen (N), C/N ratio, microbial biomass C, dissolved organic C (DOC), nitrate (NO_3^-) and ammonium (NH_4^+).

| Treatment | Soil layer (cm) | Beginning of the experiment | | | | | End of the experiment | | | |
		Moisture (WP=3)	Organic C (g/kg)	Total N (g/kg)	C/N	Microbial biomass (mg C/kg)	DOC (mg C/kg)	NO_3^- (mg N/kg)	NH_4^+ (mg N/kg)	Microbial biomass (mg C/kg)
Control	0-5	16%	20	1.2	16	68	13	68	0.4	306
	5-25	18%	13	1.0	14	31	-	27	0.4	-
Organic N fertilizer	0-5	18%	24	1.5	16	92	15	61	0.5	373
	5-25	18%	17	1.1	16	31	-	32	0.4	-
Grass-covering	0-5	29%	44	3.1	14	363	88	85	12	1050
	5-25	20%	21	1.4	15	65	-	4	3.4	-
Conifers bark	0-5	41%	104	3.4	31	622	34	117	0.6	911
	5-25	21%	20	1.1	18	43	-	43	0.5	-

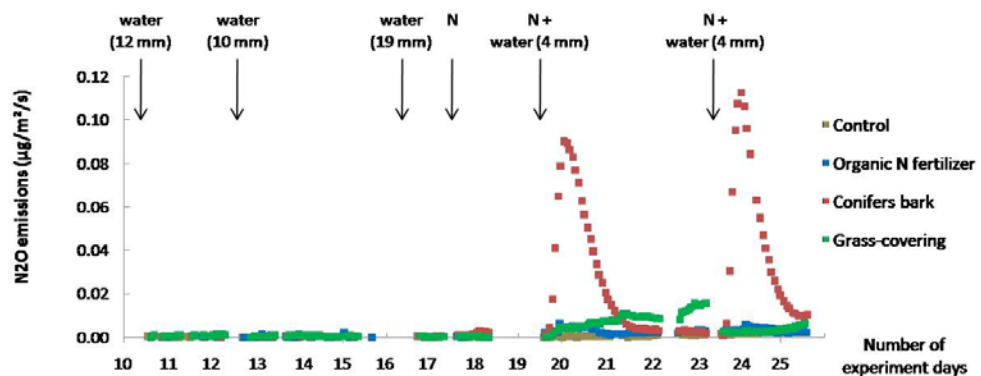Fig. 1. Column of soil under rain simulator

Fig. 2. Mean of the soil-derived N_2O emissions (n=3) from the four treatments of vineyard soil. Times of water and N additions are indicated with arrows.

4. Conclusions

Potential of N_2O emission was high in vineyards soil especially if conditions of accumulation of organic matter, high availability of nitrate and saturation of water in soil were met. In the study, these conditions were found in the soil under conifers bark management during 21 years, after addition of water and nitrate simulating possible field conditions.

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Nitrogen mineralization of sugarbeet vinasses in interaction with catch crops

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1. Background and objectives

Adequate nitrogen (N) fertilization is essential for sugar beet crop management, because excess N decreases sugar rate and extractable sugar. In France, the N balance sheet method is widely used to forecast N fertilizer requirements of sugar beet crop (Machet et al 2007). The balance is made on the inorganic N pool in the soil rooting zone, during the growth cycle of crops; it enables to determine the amount of N-fertilizer necessary to fit soil N supplies to crop requirements. Soil N supplies take into account the N contribution of organic products and catch crops. In many cases, before establishment of sugar beet crop, various organic products are spread, particularly vinasses and mandatory introduction of catch crops bounded to the regulation. Vinasses are coproducts from sugar refinery. They are used as organic fertilizer for the conventional and biological cultures and meet the criteria of the NF standard U42-001-2. The objective of this study was to estimate the N effect of vinasse in interaction with catch crops, in field conditions on annual experiments. The results allowed to test the decision-making tool AzoFert® in conditions of vinasses application and presence of catch crops in winter.

2. Materials and Methods

Field experiments were set up each year between 2005 and 2013 in northern France. Soils are deep loamy soils with high water content. The climatic contexts and cultural systems are similar. In all situations, the preceding crop is winter wheat with buried straw. The five different experimental treatments (with four randomized replicates) are:

- Control treatment without vinasse and with or without a catch crop
- Spreading of vinasse in August after winter wheat harvest, followed or not by a catch crop
- Spreading of vinasse in spring before sugar beet sowing

Vinasses are spread at a mean rate of 3.3 t.ha^{-1}. Total N content is 22 kg N ton^{-1} vinasse (equivalent to 73 kg N ha^{-1}). Catch crop is a white mustard, *Sinapsis alba,* sowed just after wheat harvest. Sugar beet is sowed in March.

For each treatment, N response curve is set up, with 0 (control), 40, 80, 120 and 160 kg N ha^{-1} as ammonium nitrate. Optimal N rate is determined as the lower rate which allows to reach the statistically highest sugar yield.

The changes in soil nitrate and ammonium are followed at different dates (August, November and February) until 120 cm depth (four layers of 30 cm). Catch crops are sampled each year, in November, before their burying in the soil by ploughing. Dry matter and nitrogen (N) and carbon (C) contents are determined on above and below-ground biomasses. In October, sugar beet crop is sampled on control treatments, to determine N and C contents in the tops and roots. Roots yield, sugar content, sugar yield and qualitative criteria on roots as glucose and alpha-amino N are determined after harvesting on every treatment.

3.Results and Discussion

Residual mineral N in the soil **a**fter wheat harvest is on average 34 kg N ha^{-1}. Between August and November, evolution of the mineral N pool is similar in the plots with catch crops, with or without spreading of vinasse. The amount of mineral N decreases to reach a minimal value, on average 17 kg N ha^{-1}, at time the catch crop is destroyed. In the control treatments without catch crop, mineral N pool is higher than in the control treatments with catch crops. During autumn, the extra mineral N due to vinasse addition is on average 11 % of vinasse-N applied with a high variability between the years (0 to 27 %). At the end of winter, mineral amounts increase because N supplies (mineralization of soil OM, wheat residues, catch crop residues and vinasse) are higher than N leaching losses. This increase is more important in treatments with catch crops. In bare soils treatments (without catch crop in autumn), leaching losses are similar with or without vinasse addition, about 14 kg N ha^{-1} and a concentration of water drainage at 90 cm depth of 60 mg N l^{-1}. With a catch crop, N leaching losses reach 3 kg N ha^{-1} and the N concentration in water is calculated with Burns model at 14 mg N l^{-1} (Justes et al 2012).
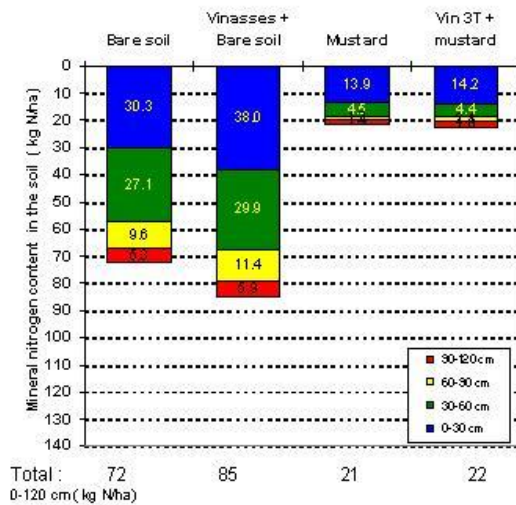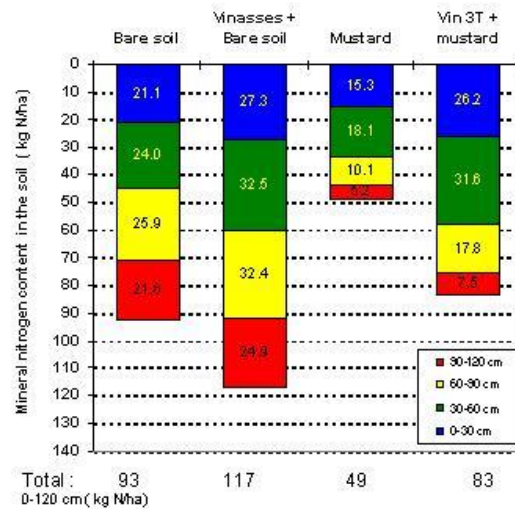
Figure 1 : Evolution of Nitrogen soil contents for different treatments between the beginning and the end of winter

The mean aerial biomass of the catch crops is 1.7 t DM ha^{-1} in treatments without vinasse compared to 2.3 t DM ha-1 with vinasse. Catch crop N is 40 and 59 kg N ha^{-1} without or with vinasse, respectively, representing an apparent recovery of vinasse-N by catch crop of , on average, 20 % added N (3 % to 28 % depending of the year).

The apparent recovery of vinasse-N by sugar beet crop, measured on the control treatment (withouth mineral fertilization), reach 56 % added N (SD = 20) and 49 % added N (SD = 30) for August and spring vinasse spreadings, respectively. N response curves show that the N optimal doses measured on the experiments agree with the rate of fertilization proposed by the decision-making tool AzoFert®.

4.Conclusions

The experiments set up during the period 2005-2012 allow to build up a significant database on N fertilization management of sugar beet crops. It contributes to a better knowledge of the dynamics of N in response to different scenario of vinasse spreading and intercrop management, particularly the establishment of catch crops. These results contribute to improve the relevance of AzoFert® tool for the N fertilization of sugar beet crops.

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AZOFERT® : A DYNAMIC DECISION SUPPORT TOOL FOR FERTILIZER N ADVICE ADAPTED FOR ORGANIC PRODUCTS AND CATCH CROPS

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1.   Background and objectives

The increasing demand for high quality crops (protein content of cereals, technological quality of sugar beet, nitrate rate of vegetables) and protection of the environment (minimising nitrate leaching and gaseous losses) on the one hand, the evolution of agricultural practises with increasing and diversification of organic applications on the other hand, require an adaptation of reasoning and a rigorous management of the N fertilization, as well as an evaluation of environmental impacts.

2.Materials and Methods

AzoFert® is based on a complete inorganic N balance sheet. The following equation is used to predict fertiliser-N rates, expressing that the variation of soil inorganic N between opening and close of balance sheet equals the difference between N inputs and outputs :

Rf – Ri = (Mn + X + Ap + Fns + Fs + Ir) – (Pf – Pi + Ix + Gx + Lx + Gs + Ls)
With Mn = Mh + Mr + Ma + Mci + Mp

Rf : soil inorganic N at close of balance sheet (at harvest), **Ri** : soil inorganic N at opening of balance sheet (end of winter for winter crops, sowing for spring crops), **Mn** : net mineralization from humus (**Mh**), crop residues (**Mr**), organic products (**Ma**), catch crops (**Mci**) and meadow (**Mp**) residues, **X** : amount of fertilizer N, **Ap** : N wet deposition, **Fns** : non symbiotic fixation, **Fs** : symbiotic fixation, **Ir** : N irrigation contribution, **Pf** : total N uptake by crop at close of balance sheet, **Pi** : N uptake by crop at opening of balance sheet, **Ix** : fertilizer N immobilised, **Gx** : fertilizer N lost as gas, **Lx** : fertilizer N lost by leaching, **Gs** : soil inorganic N lost as gas, **Ls** : soil inorganic N lost by leaching between opening and close of balance sheet

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AzoFert® integrates a dynamic simulation of soil N supplies. At the opening of the balance sheet (end of winter for winter crops, at sowing for spring crops), the soil inorganic N pool is measured at the rooting depth. In order to take into account the various contributions of crop residues, catch crops and organic products previously applied to the residual mineral N (varying with climate and characteristics of added organic matter), the decomposition of the different organic sources are simulated (using observed climatic data) from harvest of the previous crop, until the opening of the balance sheet. Decomposition is expressed over time using a "normalized time", based on temperature (T) and soil moisture (W) functions :

Normalized time $_{(day\ i,\ day\ j)} = \Sigma_{ij}\ f(T) * g(W)$

Normalized time takes into account climatic variations and determines a potential rate of decomposition. From the opening of the balance sheet to the harvest of the crop, the subsequent net contribution of the organic residues or wastes and the net mineralisation of the humified organic matter are simulated using normalised days calculated from the past years mean climatic data of the area.

3. Results and Discussion

The decay of crop residues and organic amendments in the soil results in net mineralization or net immobilization of soil nitrogen. Each crop residue and organic product is characterised by a specific kinetic curve of decomposition according to N and C. The decay rate of these products depends on the nature of organic residues (chemical characteristics and C:N ratio) and temperature and moisture soil conditions (Nicolardot et al., 2001). AzoFert® estimates the direct effect of organic product or catch crop, using the curve of decomposition

Transposition in AzoFert® software is shown for vinasses and mustard catch crops residues, as indicated on figure 1.Thanks to this transposition in real time, it is possible to determine the mineralized part of products before the measure of soil mineral N pool at opening balance sheet, and the part which will be mineralized between soil mineral N measure and harvest (direct effect).

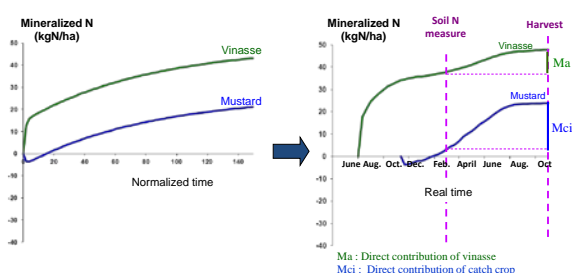Table 1 : Results of N annual experiments on sugar beet in the same farm

Figure 1 : Curve of N decomposition in normalized and real time

Experiment site	Soil inorganic N end of winter	Humus mineralisation	AzoFert dose	Optimal dose
	Kg N /ha	Kg N/ha	Kg N/ha	Kg N/ha
Fieffes 1992	58	112	87	80
Fieffes 1993	79	131	0	0
Fieffes 1994	37	104	110	120
Fieffes 1995	33	84	165	180
Fieffes 1996	62	70	170	140
Fieffes 1997	99	139	40	0

Deep loamy soils with frequent applications of organic products

A validation work was carried out by French Technical Institute for Sugar Beet (ITB) in order to test N recommendations. In the same farm, in deep loamy soils with frequent applications of organic products, there were annual (from 1992 to 1997) experiments on sugar beet, in order to know the optimal dose (table 1). Optimal dose varies a lot, from 0 to 180 kg N ha^{-1}, and AzoFert recommendation is close to optimal dose.

4. Conclusions

AzoFert® constitutes a decision support tool for fertilizer N advice based on a dynamic version of the predictive balance sheet method. The introduction of a dynamic simulation of soil N supplies allows its application to a larger range of cultural situations and pedoclimates. The integration of real data characterising the climate, soil type and cultivation practices leads to a significant improvement of N recommendations accuracy at field scale, especially with organic products and catch crops.

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INTERACTIONS BETWEEN THE CHEMICAL QUALITY OF CROP RESIDUES AND THEIR LOCATION IN THE SOIL: HOW NITROGEN AVAILABILITY CONTROLS MINERALIZATION OF C AND N?

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1. Background and Objectives

Nitrogen (N) availability can control the kinetics of decomposition of plant residues and the net mineralization of N in soils, due to the high microbial N requirements during decomposition (e.g., Recous et al., 1995). In field conditions, overall N availability for decomposers depend on the soil mineral N content, the amount and type of plant residue, and particularly their tissue N content (i.e. C:N ratio) and the location of plant residues (incorporated or at the soil surface, as in no-tilled systems). Indeed initial residues N content can be a good predictor of the net N mineralization during decomposition. However, the studies in field experiments or laboratory incubations aimed at varying the availability of N during decomposition (either by adding N to soil, or by varying type of plant residues) showed inconsistent effects on decomposition. Therefore, the aim of our study was to investigate for a range of crop residues, the effect of the availability of N and location on the C and N mineralization. The availability of N was manipulated by varying the initial quality of the residues, the residues placement, and the supply of mineral N to the soil.

2. Materials and Methods

The shoots of ten species of plants were collected at flowering and harvest for cover crops and main crops species, respectively, and characterized chemically (Table 1). The residues were dried at 40°C and leaves and stems were cut into pieces of 1 cm length. Mixture of leaves and stems were prepared with a ratio leaf:stem similar to the ratio in dry biomass observed in field. The soil used was a Typic Hapludalf collected from the 0–10-cm layer. Two initial soil mineral N concentrations were used, i.e. 9 mg N kg^{-1} dry soil (low N availability; 9N) and 77 mg N kg^{-1} dry soil (high N availability; 77N), obtained by adding KNO_3-N prior to incubation. The residues added at a rate of 0.6 g dry matter (DM) per pot (equivalent to a basis of 5.0 g DM kg^{-1} dry soil) were applied either on the surface (S) of soil samples or incorporated into the soil (I). C mineralization was assessed by quantifying continuous CO_2 release using NaOH trapping, at 2, 4, 7, 10, 14, 21, 28, 35, 50, 70, 90 and 120 days after start of incubation. The soil mineral N content was measured destructively, at day 0 and at 7, 14, 21, 35, 63, 90 and 120 days of incubation.

Table 1. Initial composition of the crop residues

Species	SOL[a]	HEM	CEL	LIG	C	N	Csw	Nsw	POL	C:N
	g kg^{-1} DM									
Soybean	349	122	386	143	450	11.7	94	10.5	21.7	38
Maize	141	323	469	67	452	4.3	46	3.5	6.4	105
Sunflower	322	79	485	114	428	9.6	84	8.0	37.4	45
Gray mucuna	464	119	318	99	451	29.4	168	7.1	21.4	15
Showy rattlebox	417	90	408	84	445	22.4	45	7.4	23.5	20
Black oat	290	246	417	47	447	12.2	104	10.4	15.2	37
Vetch	571	88	272	69	453	35.2	219	19.3	26.3	13
Wheat	326	257	356	61	437	4.9	94	4.3	24.5	89
Oilseed rape	394	152	359	95	421	19.1	60	15.0	14.8	22
Barley	271	260	407	62	441	5.3	109	4.7	12.1	83

[a] SOL = Soluble fraction (Van Soest); HEM = Hemicellulose; CEL = Cellulose; LIG = Lignin; C = Total carbon; N = Total nitrogen; Csw = Water-soluble carbon; Nsw = Water-soluble nitrogen; POL = Soluble polyphenols.

3. Results and Discussion

The type of residues did modify significantly the kinetics and rates of C and N mineralization in soil (not shown) as expected, and strongly interacted with soil mineral N availability and localization. For example, the residue of wheat (Fig. 1a) showed +6% (S) and +8% (I) C-CO_2 evolved with high soil mineral N (77N) compared to low soil mineral N (9N). For rape residues (Fig. 1c) there was no significant difference in C-CO_2 evolved whatever the soil N treatment and the residue location. This indicates that the increase of soil mineral N for high C:N wheat residues removed a N limitation of decomposition while the initial availability of N was sufficient for rapeseed residue for its optimal decomposition. Regarding soil N dynamics, we observed with wheat (Fig. 1b) that net immobilization of soil N was all the more important that the availability of N increased, with the following ranking: I-77N> I-9N> S-77N> S-9N. For oilseed rape residues (Fig. 1d), it is noticeable how N mineralization was strongly influenced by residue location: residues decomposing at the soil surface induced net mineralization of N compared to incorporated residues. The amount of mineral N in soil (9N or 77N) also influenced the net N mineralization. These results suggest that microorganisms had more efficient use of N (immobilized N by gram of decomposed C) and/or lower N requirements when residues were left on the surface due to shift in microbial populations with surface decomposition.
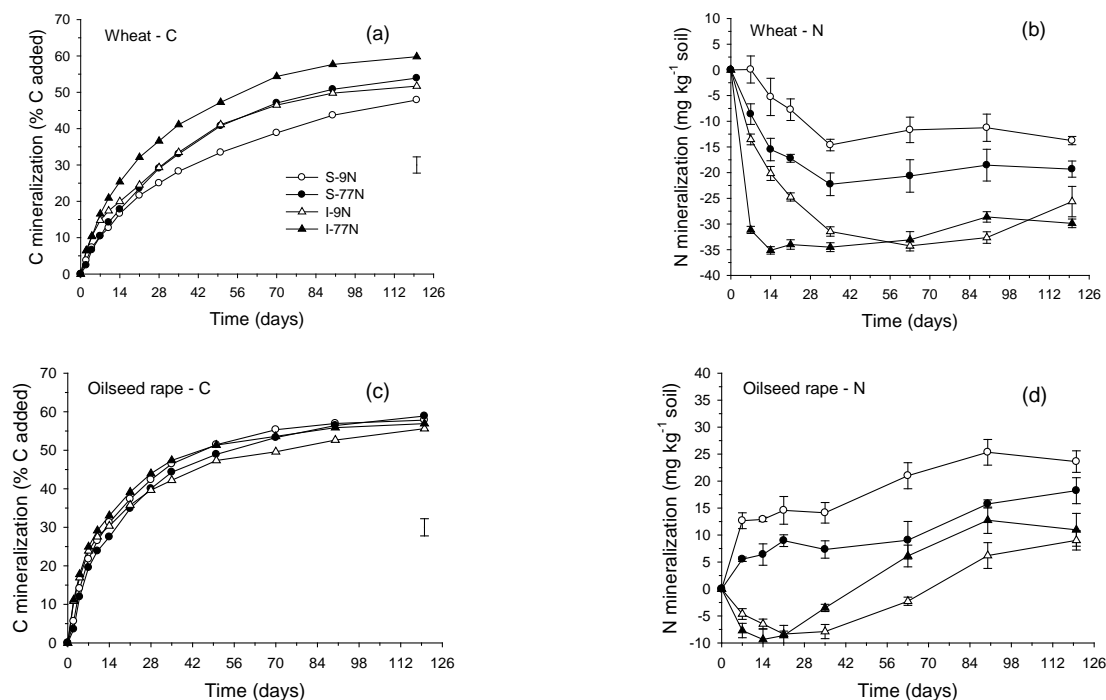
Figure 1. Cumulative CO_2 mineralization (a, c) and net changes in soil mineral N contents (b, d) of the wheat and oilseed rape residues during decomposition in soil at 25°C during 120 days. Bars are minimum significant difference between treatments at 120 days ($P<0.05$) (a, c) and standard deviation values ($n=3$) (b, d).

4. Conclusion, Acknowledgements and References

The results indicate that the effects of soil-N and residue-N availability on C and N mineralization are strongly dependent of the location and type of residue in the soil.

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PART OF GRASSLAND IN LEY-ARABLE ROTATIONS IS A PROXY FOR PREDICTING LONG TERM SOIL ORGANIC MATTER DYNAMICS

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1. Background and Objectives

Ley-arable rotations, common in dairy systems, have for long been known to ensure good productivity, facilitate control of weeds and diseases, and limit the decrease of soil organic matter (SOM) frequently observed in permanent arable land (Conijn *et al*., 2002). This paper deals with the long term effect on SOM of rotations widely differing in the ratio grass/grass+crops (G/G+C), to answer the following questions : how does the G/G+C ratio affects SOM ? Which combination could ensure carbon storage ? Can we predict SOM dynamics with a simple model previously evaluated for arable crops ?

2. Material and Methods

Fodder ley-arable rotations were studied in a 27 years experiment set up in west Brittany, France, on a loamy sand and slightly acidic soil in oceanic conditions (1110 mm, 11.8°C). Eight of them combine maize (silage) with grass (cut): continuous maize, maize/*Lolium multiflorum L.* for 6 or 18 months, maize/*Lolium perenne L.* for 3.5 years, permanent *Lp* and *Festuca arundinacea L.*. The other rotations were biennial, including maize and *L.multiflorum* as a catch crop after wheat, barley or grain legumes (details in Simon, 1992). Their G/G+C ratio, calculated as relative duration of both crops, varied from 0 to 1.

The top soil (0-25 cm) was sampled 7 times during the 27 years and analysed for total N (Kjeldahl or Dumas) and C (Dumas). Soil density was measured at the beginning and end of the trial.

Data were used to test the AMG model (Andriulo *et al*, 1999) which simulates the evolution of humified OM on an annual time step, assuming that SOM consists in a stable and an active pool. Its parameters are the initial size of the active fraction, the annual C input, the humification rate of fresh residues and the mineralisation rate of the active fraction. Amounts of annual C inputs derived from above and below ground plant residues, slurry and rhizodeposits to soil were estimated from literature (e.g. Nguyen, 2003, Whitehead et al. 1990) or measured data.

3. Results and Discussion

Final soil status

After nearly 30 years of constant practices, the amounts of C and N stocks had decreased from 3% (permanent grass) to 30% (continuous maize) as shown in figure 1a (observed data). Initial Soil Organic Carbon was 88 (+-3) t C.ha^{-1} while final SOC varied from 65 to 85 t C.ha^{-1} for mono-maize and permanent grass respectively. We could thus determine 4 groups for modelling approach varying with their G/G+C ratio, to know 0, 0.56, 0.76 and > O.9 for G1, G2, G3 and G4 respectively. Used values for C inputs were (all in t C.ha^{-1}.yr^{-1}): 0.77 (grass and slurry, C3 inputs) and 1.82 (maize, C4 inputs) for G1, 1.82 (C3) and 1.82 (C4) for G2, 3.50 (C3) and 0.88 (C4) for G3 and 3.96 (C3) and 0.43 (C4) for G4 (Vertès et Mary, 2007).

Figure 1: Effects of the grass/grass+crop ratio on a) long term SOM evolution in a ley-arable rotations trial and b) optimal mean annual C inputs
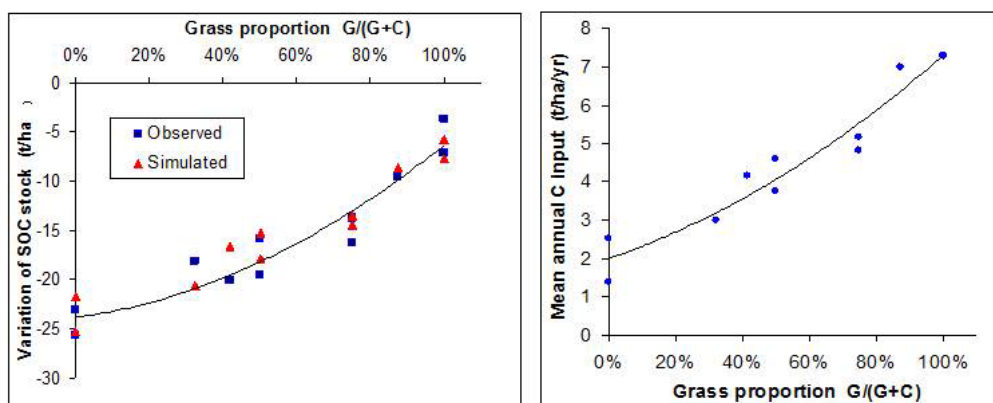
Long term SOC dynamics

The simulation was run first using the standard parameters calibrated with arable crops (Saffih and Mary, 2007). The model simulated a decrease in all situations and provided satisfactory simulation of the evolution of SOC in rotations dominated by crops (G/G+C < 0.6), but overestimated (about 11%) the SOC decrease in grass dominated rotations (Vertès et Mary 2007). The C inputs from grasslands were then calculated to obtain a good simulation of SOM dynamics in all cases (figure 1a), that led to optimal values of about 7 t C ha^{-1} yr^{-1} (figure 1b) for grass, corresponding to the highest values reported in the literature (e.g. Paustian *et al.*, 1990; Personneni *et al.*, 1995).

In our experimental conditions, a large decrease of SOM was observed in arable rotations and even permanent grassland hardly ensured SOC stability. The two main factors explaining this result are i) the high initial OM content, that favours high mineralisation rates, as assessed by measurement in incubated soils at the end of the experiment (data not shown) and ii) the lower C restitutions in cut compared to grazed grasslands, where about 75 to 95% of ingested organic matter returns to soil as dung (and urine). Final SOM status was consistent with statistical local references (Simon et al., 1992) for common rotations, where a similar decline was observed, especially in soils with high initial SOM content.

The AMG model was able to simulate satisfactory the SOC evolution in crop dominated rotations, and predicted that SOC is not at equilibrium after nearly 30 years of constant agricultural practices. The large uncertainties about C inputs from grassland may explain why the model overestimated SOM decline in grass dominated rotations: reliable data are crucial to evaluate simulation models predicting SOC changes, including the transitions from arable crops to grasslands and reverse. Finally changes in SOM quality (data not shown) led to predict that C and N mineralization rates should be more than proportional to total C and N content of soil (Accoe et al.,2004).

5. Conclusions and perspectives

The G/G+C ratio was shown a good proxy to explain observed long term SOM dynamics and could be used in SOM evolution modelling and determination of optimum combinations. Though no net carbon (or nitrogen) storage was observed neither modelled in the experimental conditions, hierarchy between rotations based on this ratio was in agreement with main conclusions in literature (Soussana et al., 2010) on the positive effect of grasslands on SOM dynamics.

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