

Diagnostic de déficiences en soufre en production herbagère

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Introduction





Le soufre : élément essentiel pour la plante et l'animal



- Acides aminés soufrés (méthionine, cystine, cystéine)
 - Synthèse des protéines
 - Méthionine : synthèse de la lignine et chlorophylle
 - Vitamines (B8, B1)
 - Gluthation : anti-oxydant et précurseur de molécules qui interviennent dans la détoxification des ML
 - Sulpholipides :constituants des membranes cellulaires
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- 
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Effets d'une déficience en S sur le végétal (Mengel & Kirkby, 1982).

| Augmentation | Diminution |
|--|---|
| <p>Teneur en NO_3^- Rapport Norg/Sorg et Ntot/Stot Teneur en acides aminés non soufrés : surtout asparagine, glutamine et arginine. Symptômes chlorotiques</p> | <p>Teneur en sucre Teneur en acides aminés soufrés : méthionine et cystéine Teneur en S et SO_4^{2-} Croissance Taille des entre-nœuds chez le ray-grass anglais Teneur en protéines Teneur en soufre des protéines</p> |



Le soufre : élément polluant

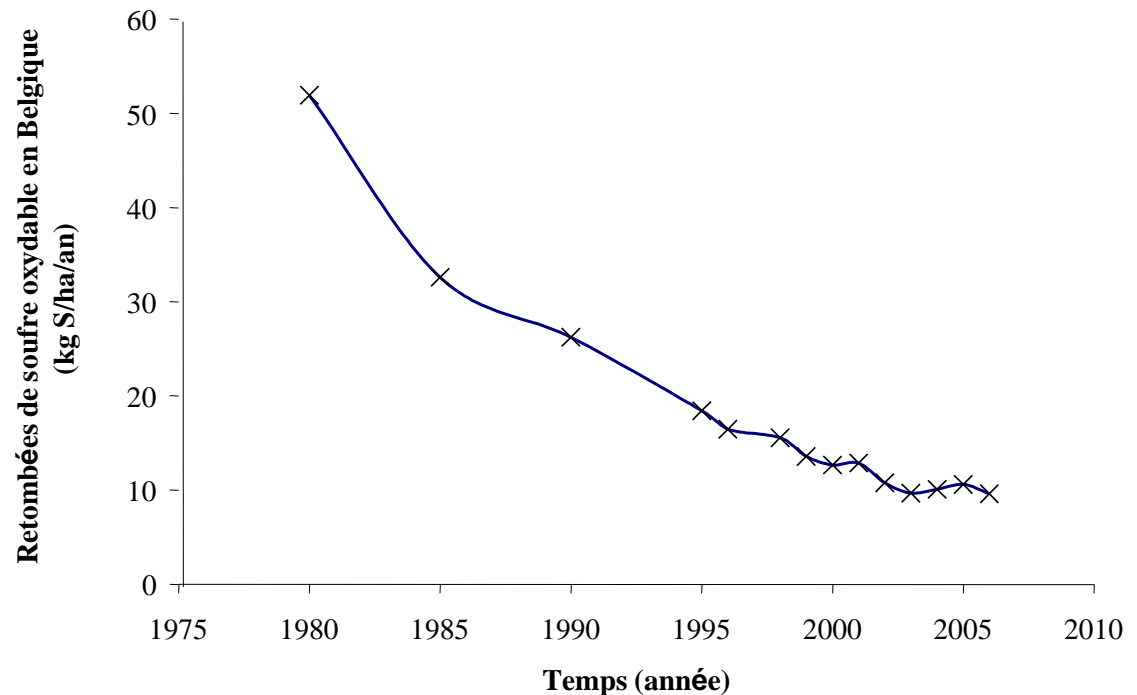
- Pluies acides

Combustion → SO₂ → pluies acide
Nox

- Directive européenne 80/779/CEE , protocole de Göteborg, 1999
→ diminution importante des émissions atmosphériques et donc des retombées

Depuis 30 ans :

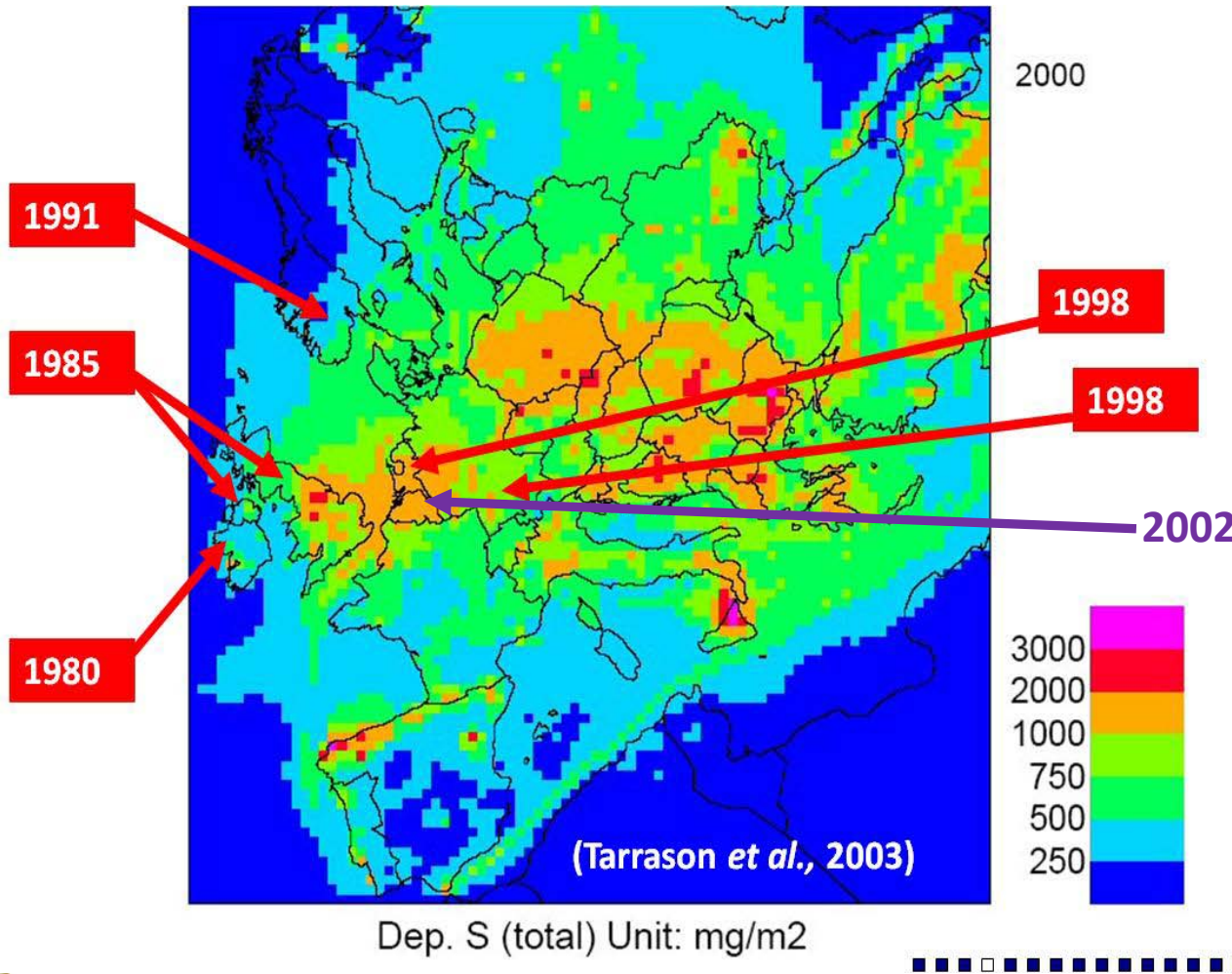
• 50 kg S/ha → 10kg S/ha



Un bilan généralement négatif sans apport d'engrais

| <i>Poste</i> | | <i>Kg S/ha/an</i> |
|--------------------------|------------------------------|-------------------|
| Entrée | Retombées atmosphériques (1) | 10 |
| | Sortie | |
| | Récolte du fourrage (2) : | 14 |
| | Pertes par lessivage (3) | 7 à 14 |
| Bilan (1)-(2)-(3) | | -11 à - 18 |

Des déficiences de plus en plus fréquentes



Les dates correspondent à des déficiences signalées en prairies (Zhao *et al.*, 2002; Mathot *et al.*, 2008)



Indicateur de déficience à l'aide d'analyses du végétal



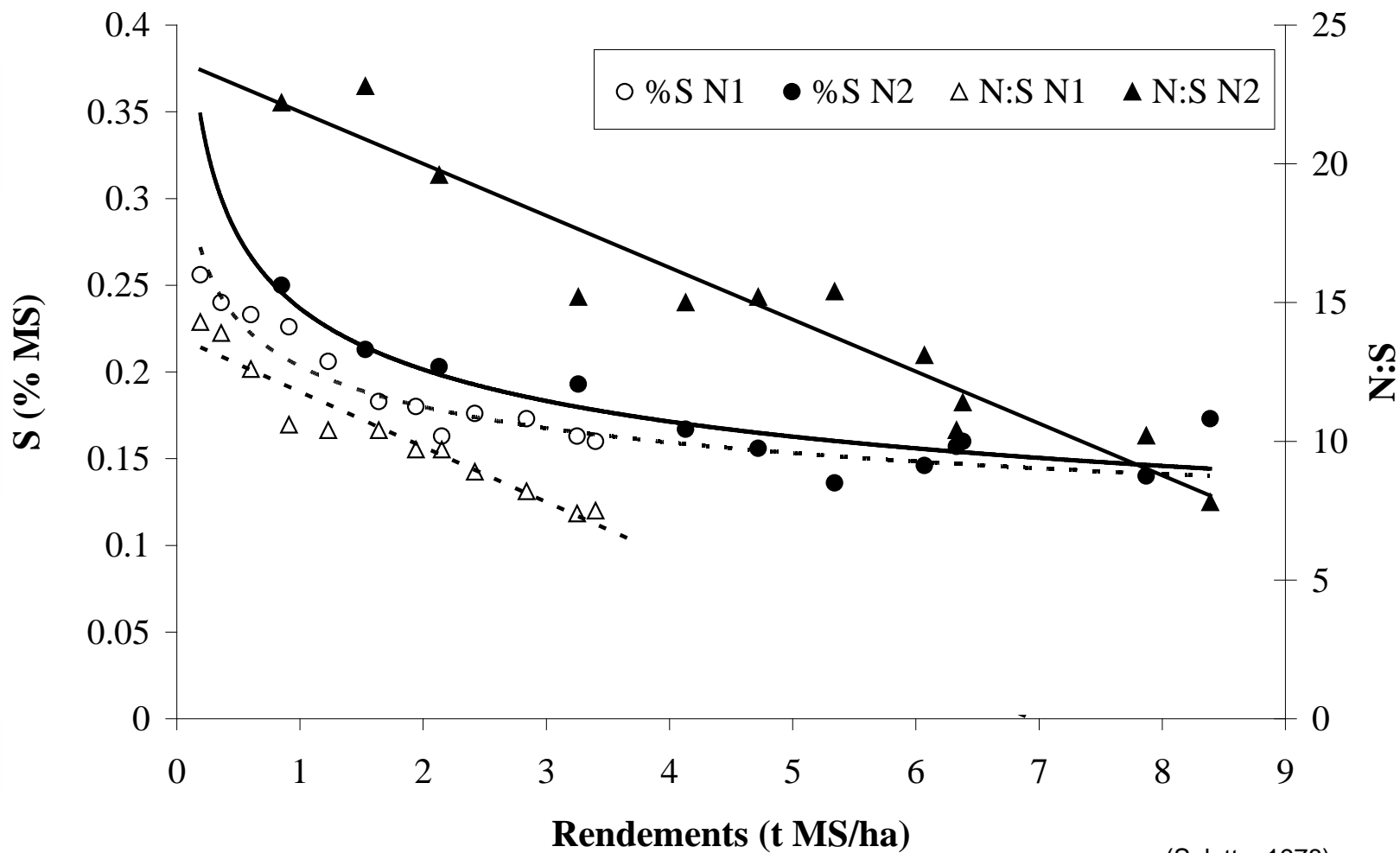
Généralement indicateur : teneur ou ratio fixe

| Date | Espèce | Type d'essai | Seuils critiques | | | | |
|----------------------|----------|--------------|------------------------|---------------------|-------------------|------------------------|--|
| | | | S_{tot} (% MS) | $S-SO_4$ (% MS) | $S-SO_4/S_{tot}$ | N_{tot}/S_{tot} | N_{org}/S_{org} |
| (1971) ¹ | Lp | Serre | 0,17-0,20 ⁺ | | | | |
| (1975) ² | Lp | Serre | 0,2 | | | 20/1-14/1 ⁻ | |
| (1976) ³ | Lm | Serre | 0,2-0,25 ⁺ | 0,03 ⁺ | | 20/1 | 15,3-15,5 ⁺ |
| (1986) ⁴ | Lm | Champs | 0,2 ⁻ | | 0,3 ⁺ | | |
| (1988) ⁵ | Tr | Serre | | | | 20/1-25/1 ⁻ | |
| (1989) ⁶ | Lp | Champs | | | | 15/1 | |
| (1989) ⁷ | Lp | Champs | 0,2 ⁺ | | | | |
| (1993) ⁸ | Lp et Tr | Champs | 0,28-0,35 | | | | |
| (1994) ⁹ | Lm | Champs | | | | | ⁻ varie en fonction du temps (coupes) |
| (1998) ¹⁰ | Lp | Champs | >0,2 ⁻ | >0,032 ⁻ | 0,33 ⁺ | | <15/1 ⁻ |

Légende : 1- Jones *et al.*, 1971. 2- Bolton *et al.*, 1975. 3- Eppendorfer, 1976. 4- Keer *et al.*, 1986. 5- Hern *et al.*, 1988. 6- Murphy & O'Donnell, 1989. 7- Klessa *et al.*, 1989. 8- Nguyen & Goh, 1993. 9- Morris *et al.*, 1994. 10- Chiy & Philips, 1998. **Lm** : *Lolium multiflorum*, **Lp** : *Lolium perenne*, **Tr** : *Trifolium repens* ; + indique que l'auteur trouve cet indice assez fiable, - indique que l'auteur trouve cet indice moins fiable.



Mais...



(Salette, 1978)

Source : essais en champs et conditions contrôlées + données de la littérature



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The Effects of Sulphur Application on Yield, Sulphur Content and N/S-Ratio of Grasses for Silage at Six Sites in Finland

Hahtonen, M. and Saarela, L. (Department of Plant Production, University of Helsinki, PO 27, FIN-00014 University of Helsinki, Finland and Agricultural Research Centre, Institute of Soil Science, FIN-31600 Jokioinen, Finland). The effects of sulphur application on yield, sulphur content and N/S-ratio of grasses for silage at six sites in Finland. Accepted January 18, 2005. *Acta Agric. Scand., Sect. B, Soil and Plant Sci.*, 48, 131-138, 2005. © 2005 Scandinavian University Press.

The effect of sulphur (S) fertilisation on forage production, sulphur content and N/S ratio of perennial timothy-meadow-grass (*Phleum pratense* L., *Festuca pratensis* Moench) and cocksfoot-dominant (*Dactylis glomerata* L.) swards sown for one to three years were measured under a stage-cutting regime at six sites in Finland. Soil sulphur status ranged from potassium-sulphate (the most) to good (organic soils). Forage growth responses to supplementary sulphur were small, inconsistent and statistically insignificant. The supplementary S-fertilisation increased the nitrogen content of forage and decreased N/S-ratio at all sites. However, even in low levels fertilized plots the average sulphur content was very widely below the 0.2% on a dry matter (DM) basis, which has been assumed to be an adequate concentration in several forage studies. High N/S ratios (>14) were seen. The sulphur content of DM depended more significantly on growth stage and grass species than on supplementary sulphur. According to the results of these experiments, NPKS fertilizers contain sufficient amounts of sulphur to ensure both a good quality and a high yield of grass silage.

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Key words: N/S-ratio, silage, grass, sulphur content

Introduction
In the 1970s several studies on sulphur fertilization of crop plants were conducted in Finland (Kortumäki, 1975; Eklund, 1977). In those studies positive effects of supplementary sulphur fertilization were found in northern Finland but, as a consequence of changes in the quantities of sulphur coming within the soil-plant-atmosphere system. During the last few decades the use of fertilizers containing little (1-4%) or no sulphur but

is not adequate for plant growth. However, it was emphasized that the role of sulphur in yield quantity and quality was of great importance. Since then the subject of sulphur fertilization has expanded as a consequence of changes in the quantities of sulphur coming within the soil-plant-atmosphere system. During the last few decades the use of fertilizers containing little (1-4%) or no sulphur but

The effect of sulphur nutrition on the efficiency of nitrogen use in two contrasting grassland soils

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SUMMARY
The effect of sulphur (S) application on the efficiency of nitrogen (N) use was investigated using pot experiments on two contrasting soil types. Nitrogen was applied at 200 and 450 kg N/ha per year with and without 30 kg S/ha. An 115 kg N/ha rate was used. Over three consecutive annual sward cuts for 2 years, measurements were made of herbage dry matter, the yield of N and S in herbage and losses of N and S by leaching and N by denitrification.
Herbage dry matter and N yields were significantly increased by the application of S at the high N level at the study from site (Hales). At the clay from site (Great Close) the application of S had no significant effect on herbage dry matter or N yields. At Hales, the pattern of response through the year was not the same in the 2 years studied, although in both, the effect of S was significant at third cut at high N. Deficiency was suggested by the N/S ratio of herbage on the plots without S, especially at first cut, and at later cuts of Hales. Nitrate leaching was reduced by S at Hales by 72% and 58% with high N in 1997 and 1998, respectively, and by 10% and 3% on the low N treatments in 1997 and 1998, respectively. Application of S at high N at Hales reduced the peak concentration of nitrate-N in leachate from 27 mg N/l to 9 mg N/l. At Great Close, application of S had no significant effect on the amount or peak concentration of nitrate-N leached. The improvement in efficiency reported at Hales suggest that on permeable soils receiving high levels of N, the application of S could have a large effect on nitrate leaching and its associated environmental impact.

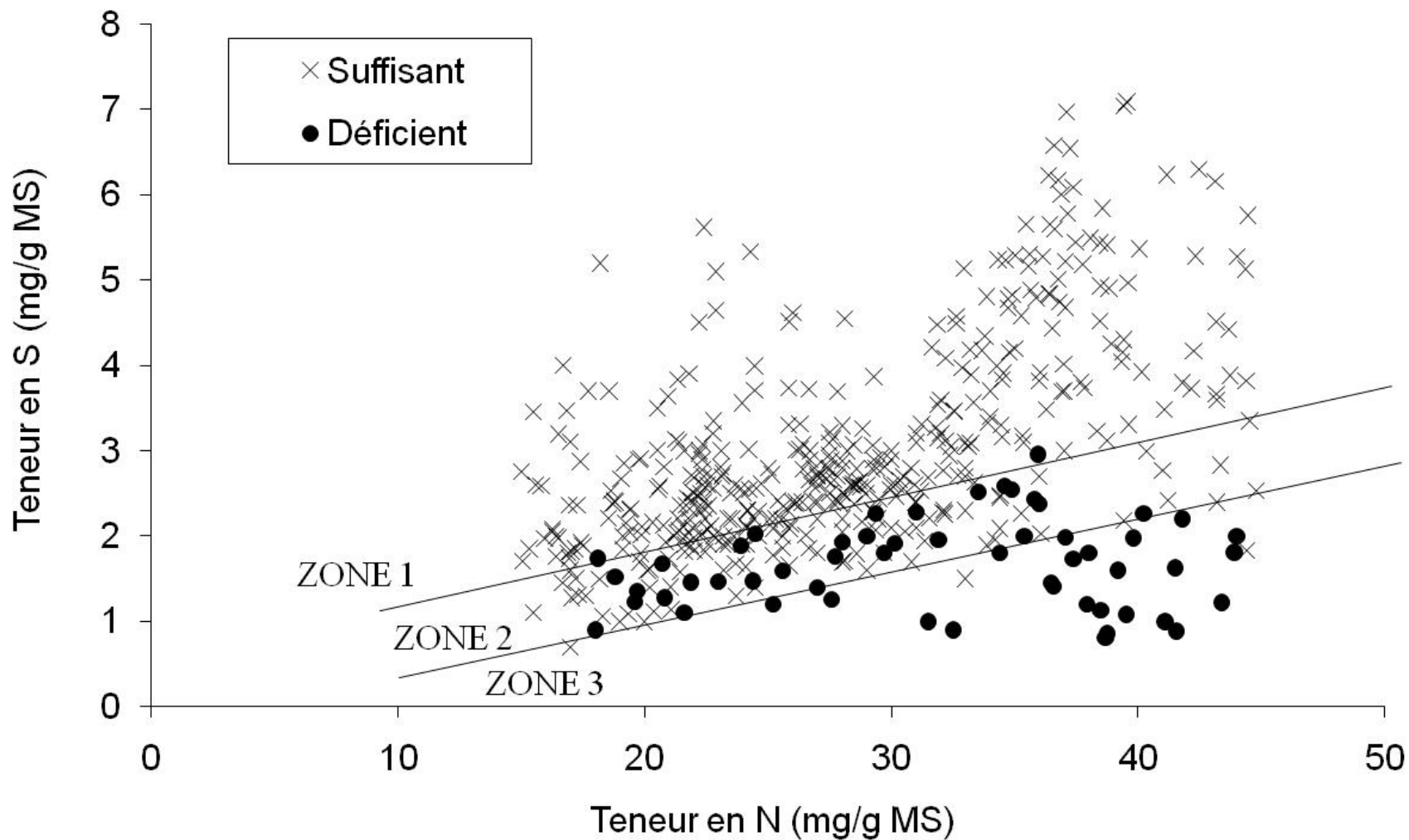
INTRODUCTION
The sulphur (S) requirement of intensively managed grassland has in the past been met by inputs from the atmosphere and fertilizer. Industrial pollution control measures have resulted in a decline in SO₂ emissions since its peak in the early 1970s. Campbell & Smith (1996) estimate that since the peak, emissions have halved, with inputs of S to land have decreased by at least five amounts. It is estimated that three-quarters of the British land area now receives less than 20 kg S/ha, which is smaller than the S requirement of low to great grass crops (McGrath & Zhao 1995). In areas in which atmospheric input of S represents an important source, much of it is deposited in winter months, when roots are inactive (Oen et al. 1987). Supply of S is also being reduced by a change in preferred fertilizer type to high ammonia fertilizer from ammonium sulphate (24% S) and single superphosphate (12.7% S) to ammonium nitrate (0% S).
Sulphur is a constituent of plant proteins, and protein-N:protein-S and organic N:organic S ratios are nearly constant (Dijkshoorn et al. 1960). It is therefore predictable that an increase in use of N will increase the demand for S, which, if not met, will result in S deficiency. The improvement in efficiency reported at Hales suggest that on permeable soils receiving high levels of N, the application of S could have a large effect on nitrate leaching and its associated environmental impact.

Après tri (rendement, teneur en N et % trèfle; Duru et Thélier huché, 1997) : Déficient : 59, suffisant : 816

| Source | Type of experiment and origin ^a | Number of site | Sward species | Number of data | |
|----------------------------|--|-----------------|---|----------------|------------|
| | | | | Def | Suf |
| Bolton et al., 1976 | Pot experiment | / | Lp ¹ | 7 | 38 |
| Brown et al., 2000 | Field (UK) | 2 | Lp | 2 | 9 |
| Eppendorfer, 1976 | Pot experiment | / | Lm ² | 7 | 80 |
| Hahtonen and Saarela, 1995 | Field (Fin) | 6 ^a | Pp ³ , Dg ⁴ and Fp ⁵ | 0 | 80 |
| Kowalenko, 2004 | Field (Can) | 1 ^b | Dg, Lp, Fa ⁶ , Tp ⁷ and Tr ⁸ | 3 | 15 |
| Mathot et al., 2005 | Pot experiment | / | Lp | 12 | 79 |
| Mathot et al., 2008 | Field (Bel) | 8 | Lp and Lm | 14 | 366 |
| Mertens, 2005 | Field (Bel) | 2 | Lp | 2 | 49 |
| Morris et al., 1994 | Field (USA) | 1 | Lm | 0 | 54 |
| Murphy et al., 2002 | Field (Irl) | 1 ^b | Lp and Tr | 2 | 4 |
| Stevens and Watson, 1986 | Field (N-Irl) | 20 ^c | n.c. | 10 | 42 |
| Total | | | | 59 | 816 |

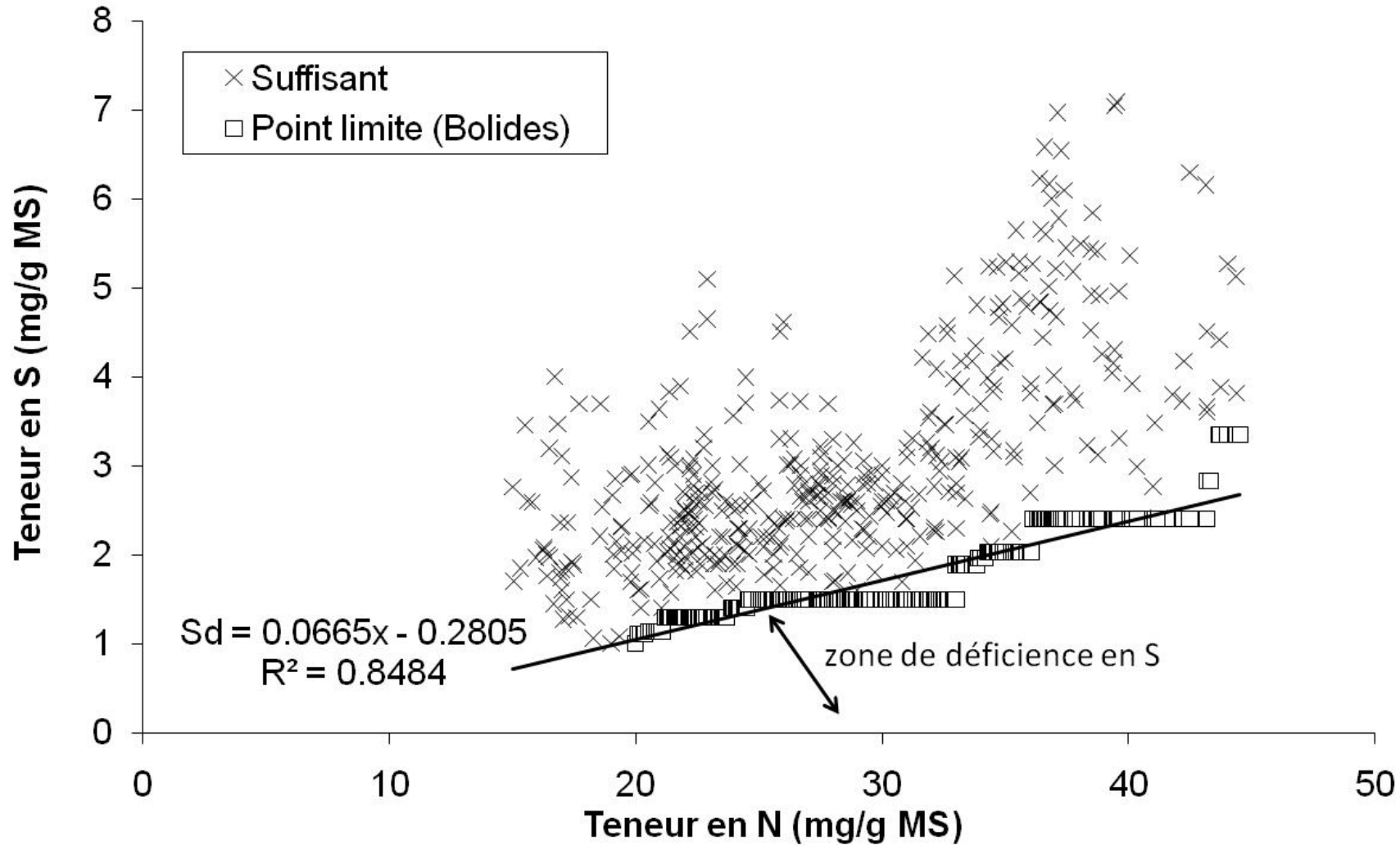


Principe : diviser en 3 zones



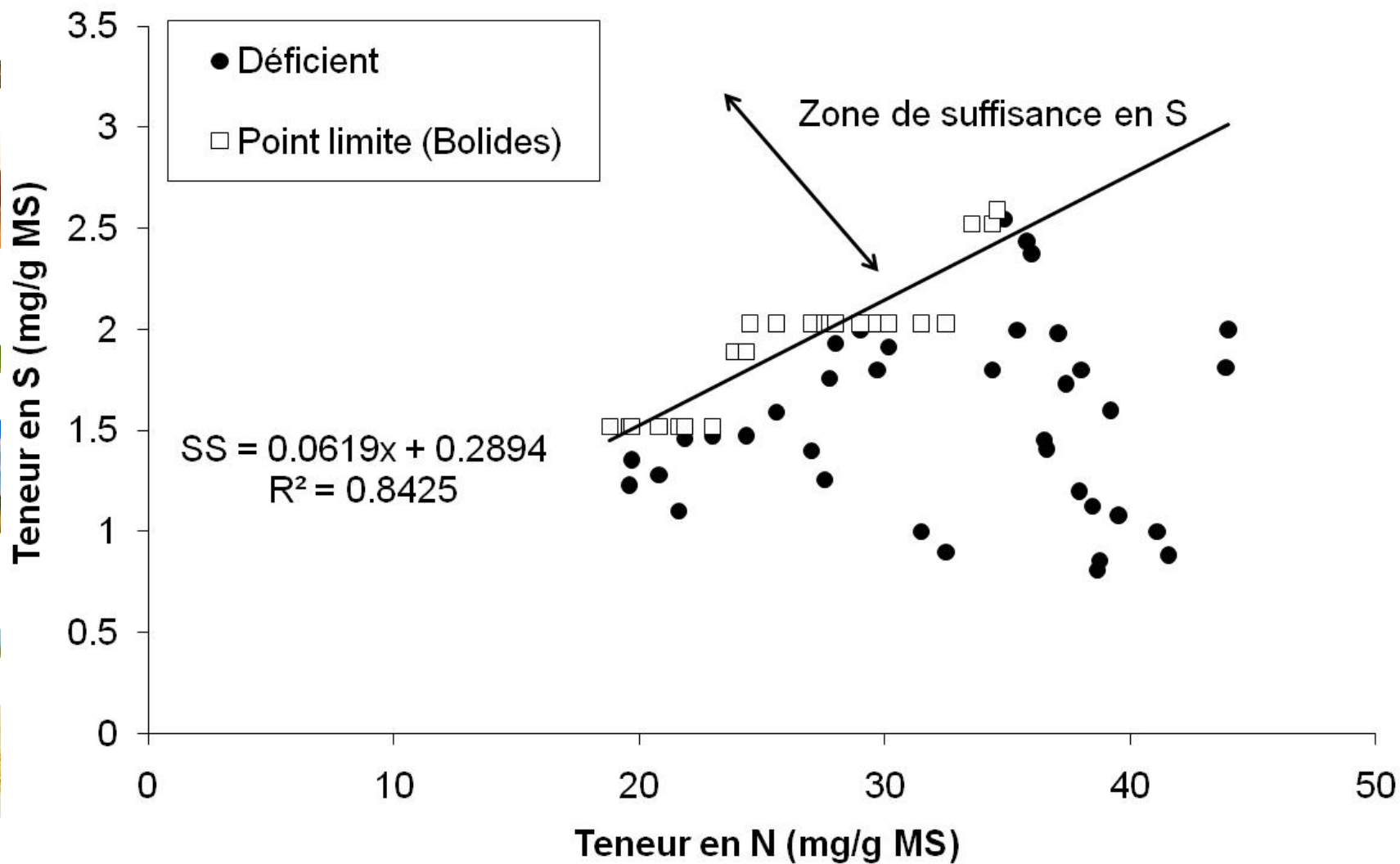


Boundary lines (Schnug et al., 1996) sur suffisant => en dessous =

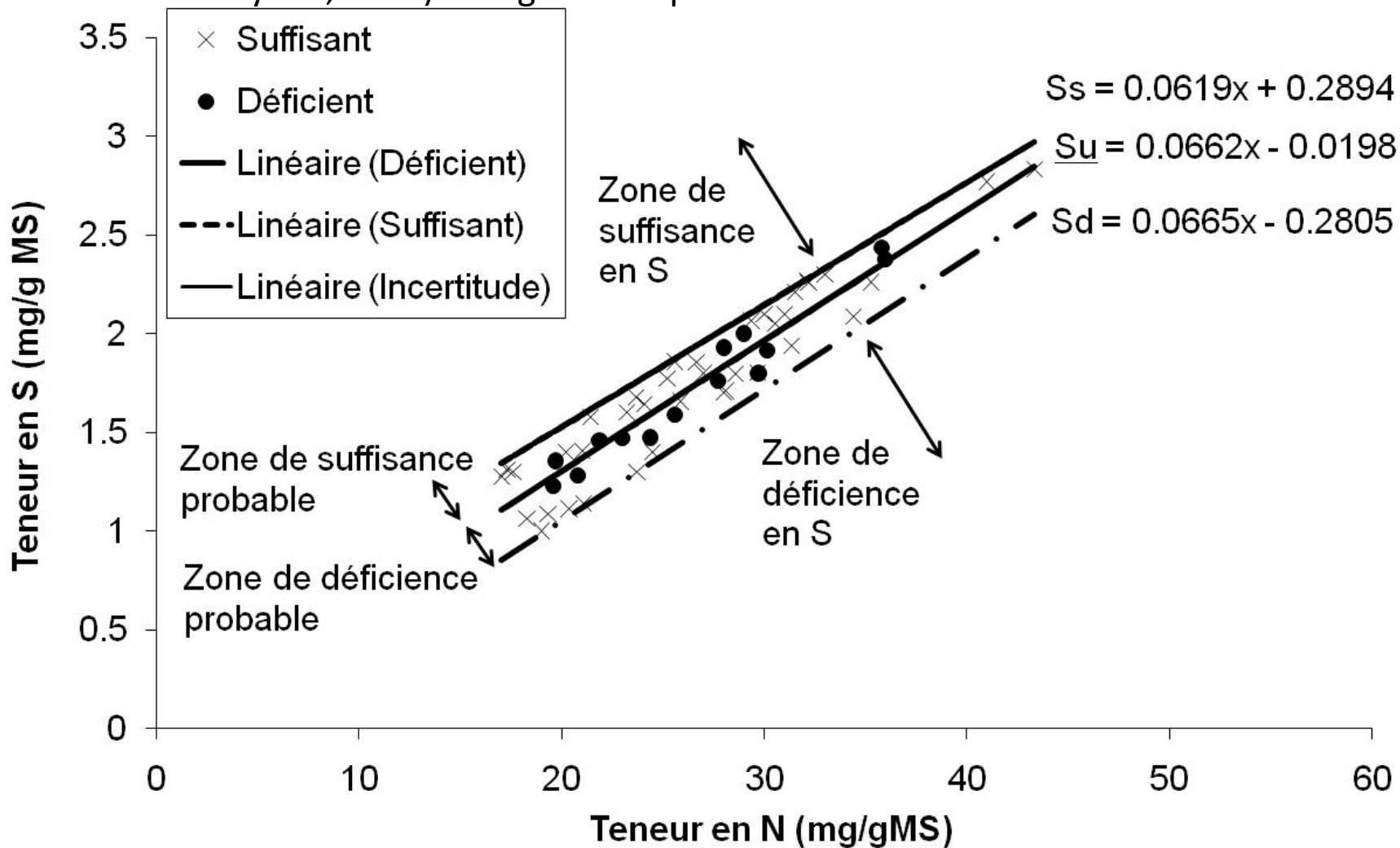




Boundary lines (Schnug et al., 1996) sur déficient => au dessous =



Au milieu = incertitude => Analyses discriminante (Dagnelie, 1975 et Systat, 1998) => Ligne de séparation des déficients et suffisants

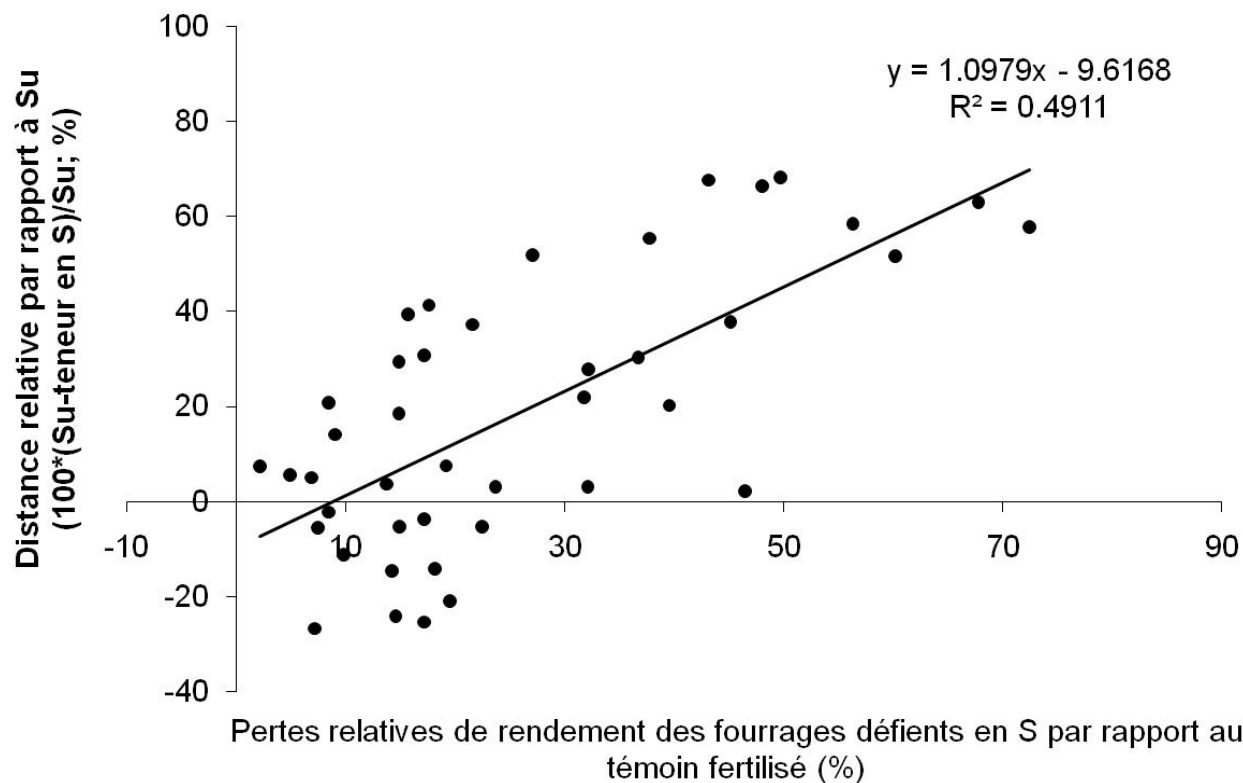


=> 3 équations et 5 zones

Table 2

Critical linear relationships for diagnosing sulphur nutritional status of grasses.

| Zones | Diagnostic | Critical relationships | Equation determination |
|----------------|---|--------------------------------------|------------------------|
| 1. Sufficiency | S > S _s , certainly sufficient | S _s = 0.0619 × N + 0.2894 | Boundary line 2 |
| 2. Uncertainty | S _s > S > S _u , probably sufficient S _u > S > S _d , probably deficient | S _u = 0.0662 × N - 0.0198 | Discriminant analysis |
| 3. Deficiency | S _d > S, Certainly deficient | S _d = 0.0665 × N - 0.2805 | Boundary line 1 |

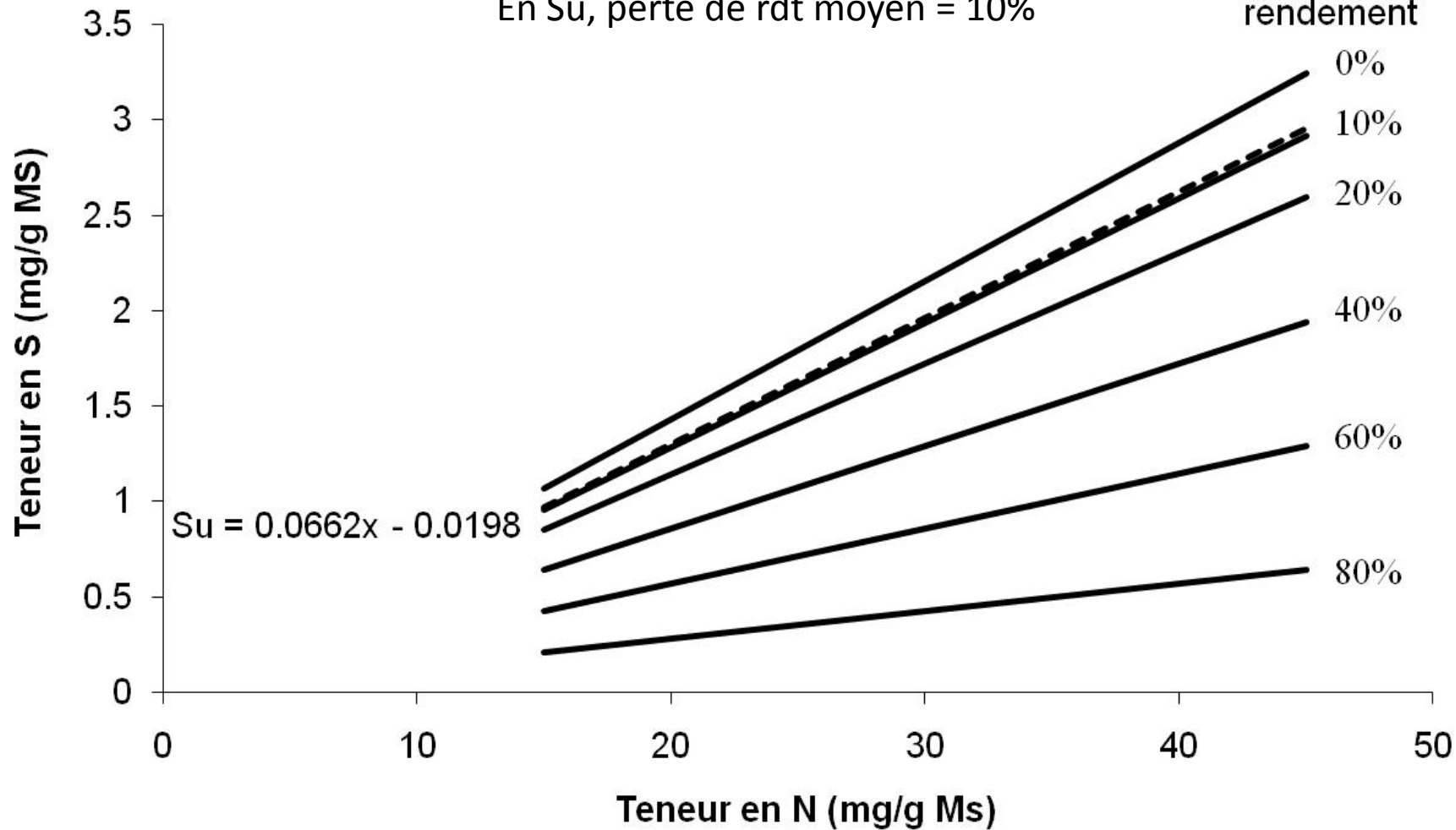


Mathot, non publié



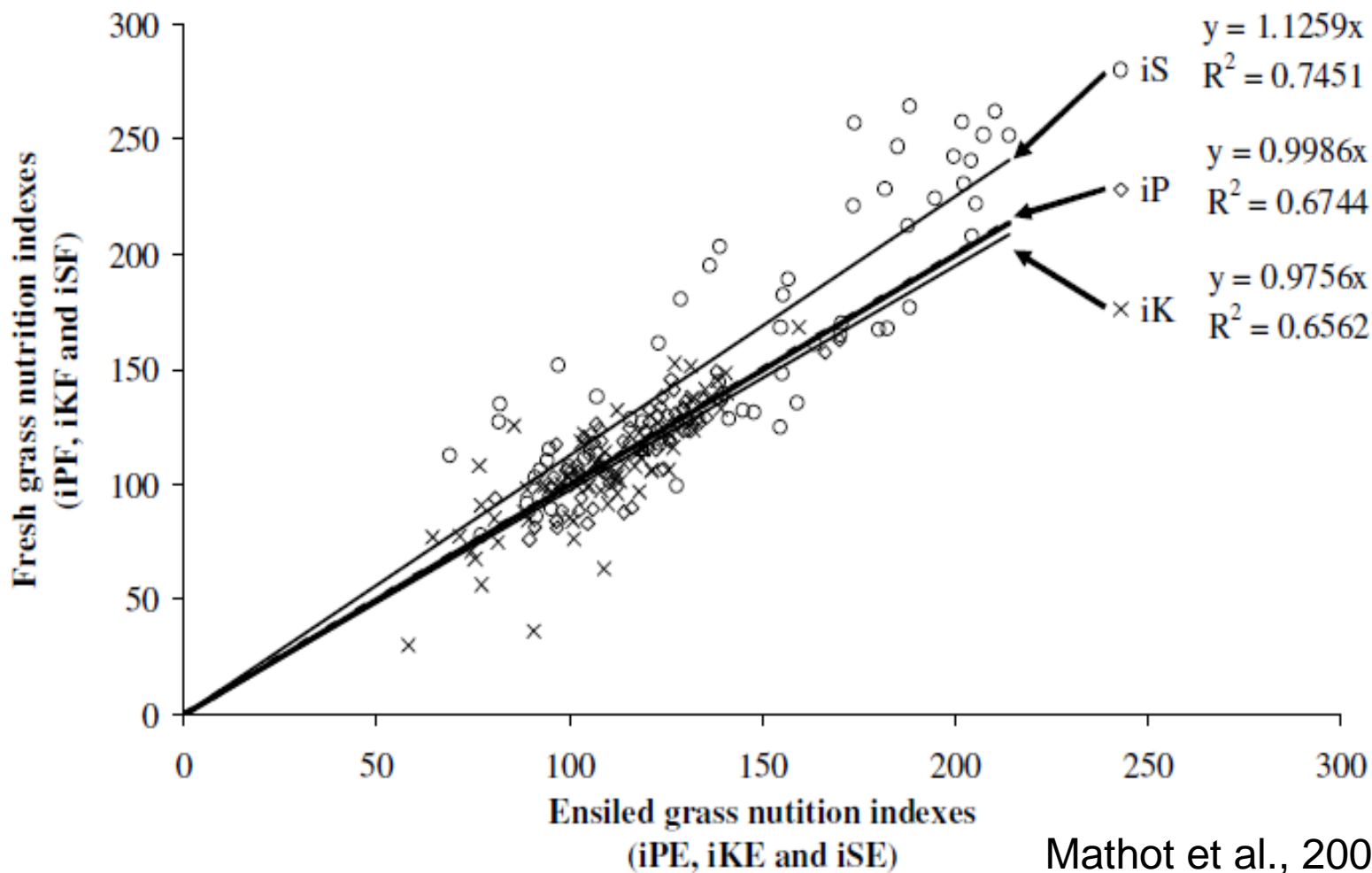
Courbes d'équi-déficiences.
En Su, perte de rdt moyen = 10%

Perte de rendement



Mathot, non publié

Et si herbe ensilée?





Conclusions





- Validation
- Rapide, large échelle
- Attention aux quelques conditions d'utilisation (rendement, % trèfle, stress...)
- Applicable sur les fourrages conservés (Mathot et al., 2009)
- Mise en œuvre pour des aperçus à l'échelle régionale (voir poster)