

*La spectroscopie infrarouge, une approche alternative
pour évaluer l'effet des pratiques agricoles sur les
propriétés de rétention en eau du sol*

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Contexte

- Travail du sol peut affecter significativement plusieurs caractéristiques du sol, tels que les propriétés de rétention en eau, la température du sol, ainsi que les processus d'infiltration et d'évapotranspiration.
- Méthodes d'analyses conventionnelles des propriétés des sols, longues et coûteuses. La spectroscopie Vis-PIR a démontré son potentiel pour l'estimation rapide de plusieurs propriétés du sol.

Objectif

- Evaluer l'efficacité et la robustesse de l'indice spectral SWSI (Soltani et al., 2019) pour estimer les impacts à moyen terme (5 ans) du travail du sol conventionnel (CT) et du travail du sol superficiel (ST), combinés à deux apports de fertilisants (minéral, organique), sur les propriétés de rétention en eau du sol.

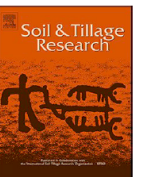
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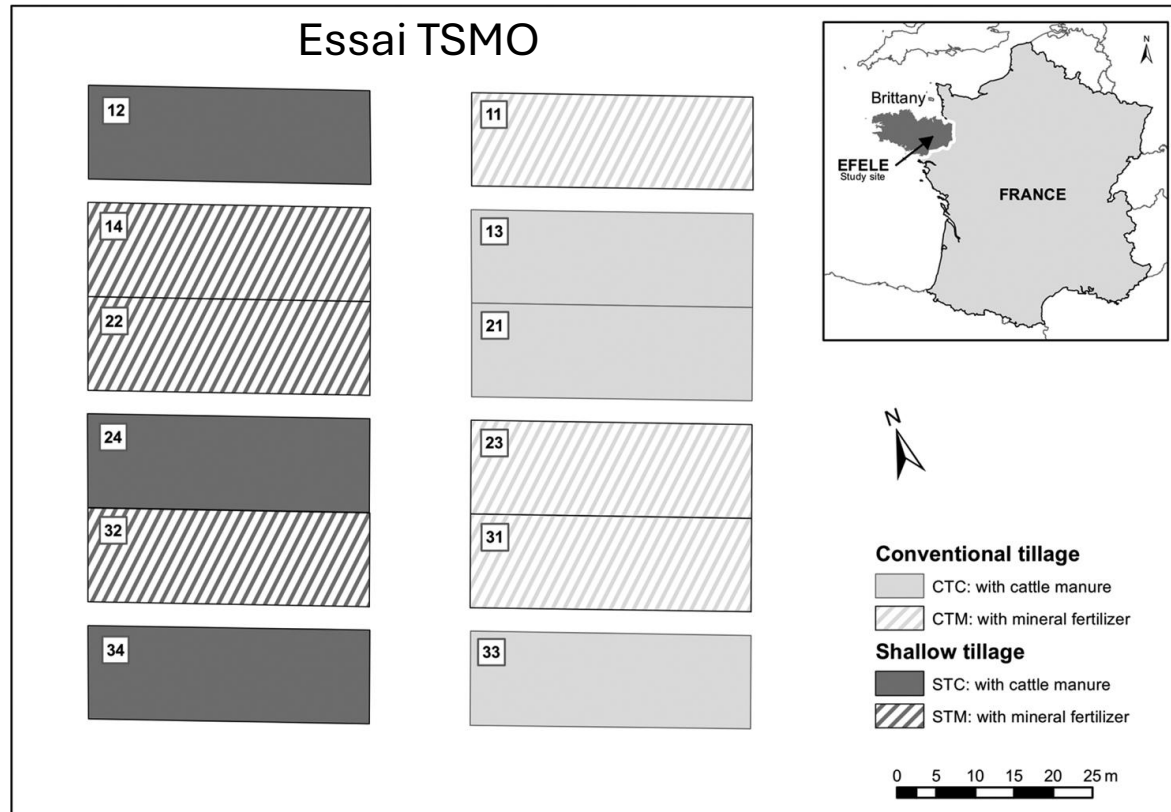


Relevance of a near infrared spectral index for assessing tillage and fertilization effects on soil water retention

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Site experimental et systemes de travail du sol

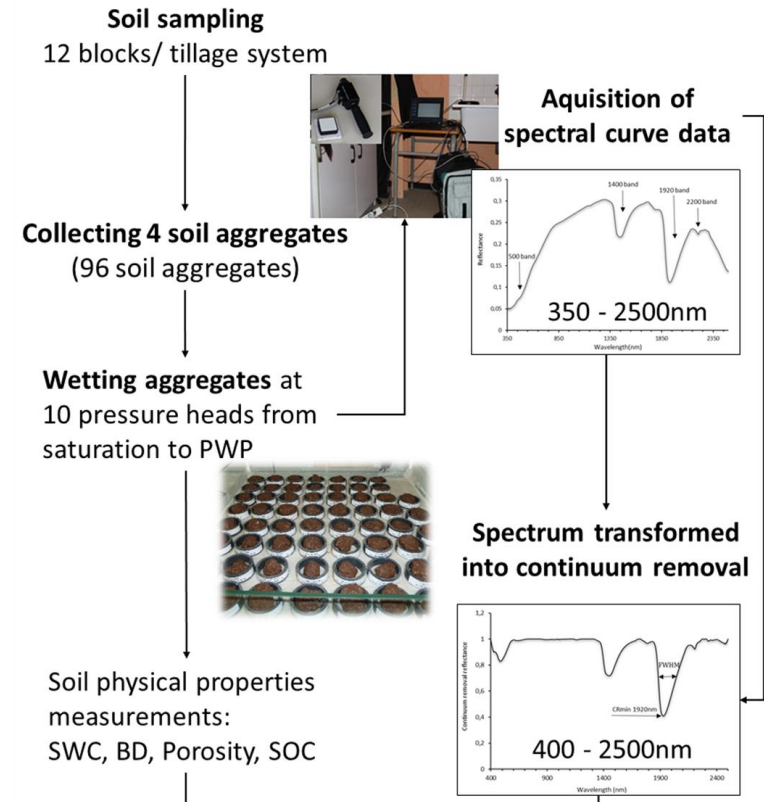


- Le dispositif expérimental conçu selon un plan en split-plot avec deux types de travail du sol, ST et CT, chacun combiné à 2 types d'apports, minéral et fumier de bovin.

Echantillonnage du sol :

- Blocs de sol non remaniés prélevés à deux profondeurs, 0–15 cm et 15–25 cm, à deux dates différentes : février 2012 (T0, état initial) et mars 2017.
- Campagnes de prélèvement conduites avant le travail du sol

Work flow



Statistical analyses

- Pearson correlation matrix
- Analysis of variance (ANOVA)
- Fisher's least significant difference (LSD) test

Soil water spectral index (SWSI)

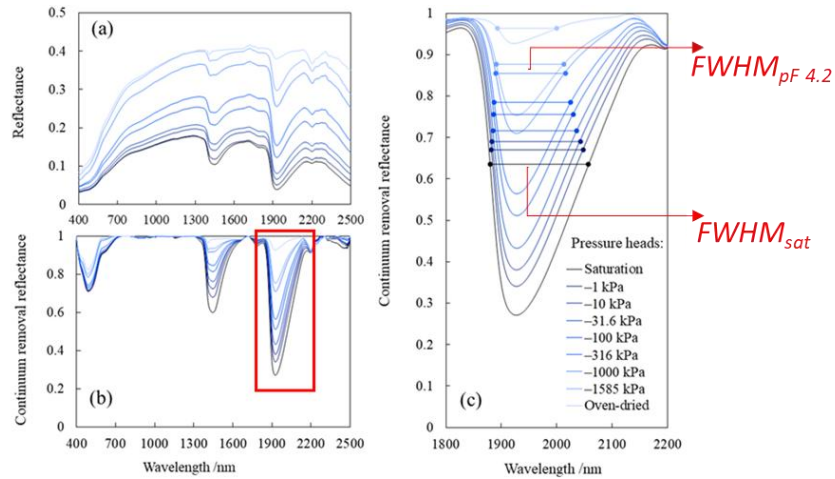


Fig. 2. Soil spectral reflectance according to pressure heads: (a) reflectance spectra, (b) continuum removal and (c) absorption band near 1920 nm (Soltani et al. 2019).

● Topsoil ○ Subsoil

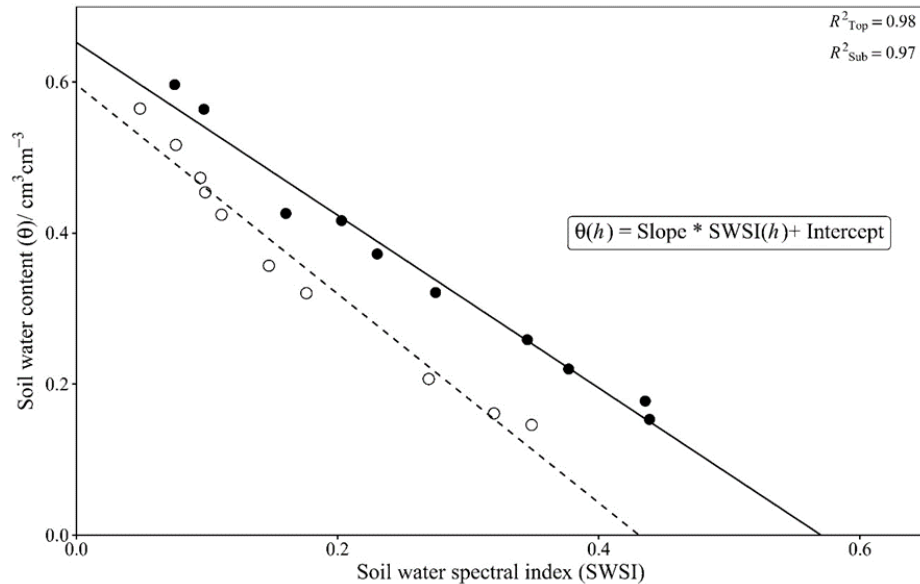


Fig. 3. Volumetric soil water content as a function of the soil water spectral index (SWSI) for selected soil samples from the topsoil and subsoil.

$$SWSI_{pFi} = 1 - \frac{FWHM_{pFi}}{FWHM_{sat}}$$

(Soltani et al., 2019)

$$\theta \text{ (cm}^3/\text{cm}^3\text{)} = \text{Slope} * \text{SWSI} + \text{Intercept}$$

- **Slope and intercept** significantly correlated with soil **texture and SOC**
- **Slope** directly related to **SWR**
- **Intercept** = theoretical value of θ_s

Résultats

Effet sur la teneur en CO du sol et la Da

Table 1
Results of two-way ANOVA with depth and fertilization as fixed effects on soil organic carbon content and bulk density under conventional and shallow tillage.

Source of variation	Degrees of freedom	Soil organic carbon content				Bulk density			
		Sum of squares	Mean squares	<i>F ratio</i>	<i>P</i>	Sum of squares	Mean squares	<i>F ratio</i>	<i>P</i>
	Conventional tillage (CT)								
Depth	1	2.574	2.5742	10.323	0.0048	0.002558	0.002558	1.704	0.20821
Fertilizer	2	1.14	0.5701	2.286	0.1304	0.023558	0.011779	7.847	0.00354
D*F	2	0.13	0.0651	0.261	0.7732	0.000049	0.000024	0.016	0.98396
Residuals	18	4.488	0.2494			0.02702	0.001501		
Total	23	8.332	3.4588			0.053185	0.015862		
	Shallow tillage (ST)								
Depth	1	9.375	9.375	84.144	3.31E-08	0.00151	0.001513	0.857	0.367
Fertilizer	2	1.241	0.62	5.568	0.0131	0.00683	0.003414	1.934	0.173
D*F	2	5.501	2.75	24.686	6.94E-06	0.00462	0.002311	1.309	0.294
Residuals	18	2.005	0.111			0.03177	0.001765		
Total	23	18.122	12.856			0.04473	0.009003		

Table 2
The effect of agricultural practices on soil bulk density and soil organic carbon content at depths of 0–15 cm and 15–25 cm, compared to the initial state (T0). The T0 values are averaged for all 6 plots, while the values for each treatment are averaged for its 3 plots.

	Conventional tillage			Shallow tillage		
	T0	CTM	CTC	T0	STM	STC
Soil organic carbon content (g kg ⁻¹)						
0-15 cm	11.0 (0.2) ^{a,a}	10.8 (0.2) ^{a,a}	11.5 (0.3) ^{a,a}	10.4 (0.2) ^{c,a}	11.3 (0.2) ^{b,a}	12.1 (0.2) ^{a,a}
15-25 cm	10.3 (0.3) ^{a,b}	10.4 (0.2) ^{a,a}	10.8 (0.3) ^{a,a}	10.1 (0.1) ^{a,a}	9.4 (0.2) ^{b,b}	9.6 (0.1) ^{b,b}
Bulk density						
0-15 cm	1.56 (0.02) ^{a,a}	1.62 (0.01) ^{a,a}	1.62 (0.02) ^{a,a}	1.58 (0.01) ^{a,a}	1.61 (0.02) ^{a,a}	1.59 (0.03) ^{a,a}
15-25 cm	1.54 (0.02) ^{a,a}	1.60 (0.02) ^{a,a}	1.59 (0.00) ^{a,a}	1.55 (0.02) ^{a,a}	1.57 (0.02) ^{a,a}	1.62 (0.04) ^{a,a}

Effet sur la retention en eau du sol

Table 3

The effects of depth and fertilization treatments on soil water content (SWC) and water holding capacity (WHC) at three pressure heads (near saturation (−3.2 kPa), field capacity (−31.6 kPa) and permanent wilting point (−1585 kPa)), compared to the initial state (T0) under conventional and shallow tillage.

Matric potential (kPa)	Conventional tillage (CT)			Shallow tillage (ST)		
	T0	CTM	CTC	T0	STM	STC
0-15 cm						
SWC (cm ³ cm ^{−3})						
−3.2	0.432 (0.005) ^a	0.446 (0.011) ^a	0.439 (0.009) ^a	0.432 (0.004) ^a	0.448 (0.010) ^a	0.440 (0.011) ^a
−31.6	0.376 (0.008) ^a	0.383 (0.008) ^a	0.391 (0.006) ^a	0.373 (0.006) ^a	0.369 (0.006) ^a	0.380 (0.012) ^a
−1585	0.114 (0.001) ^b	0.122 (0.002) ^a	0.114 (0.002) ^b	0.113 (0.001) ^{ab}	0.110 (0.004) ^b	0.121 (0.004) ^a
WHC (mm) *						
−31.6 to −1585	26.2 (0.8) ^a	26.1 (0.8) ^a	27.6 (0.7) ^a	26.0 (0.7) ^a	25.9 (0.7) ^a	26.0 (1.4) ^a
15-25 cm						
SWC (cm ³ cm ^{−3})						
−3.2	0.430 (0.006) ^b	0.442 (0.011) ^b	0.470 (0.008) ^a	0.431 (0.005) ^a	0.450 (0.011) ^a	0.429 (0.012) ^a
−31.6	0.362 (0.008) ^b	0.378 (0.008) ^b	0.415 (0.004) ^a	0.370 (0.007) ^a	0.366 (0.008) ^a	0.355 (0.006) ^a
−1585	0.115 (0.001) ^a	0.121 (0.005) ^a	0.117 (0.002) ^a	0.116 (0.002) ^a	0.107 (0.001) ^b	0.120 (0.004) ^a
WHC (mm) *						
−31.6 to −1585	24.8 (0.9) ^b	25.6 (0.8) ^b	29.8 (0.4) ^a	25.4 (0.8) ^{ab}	25.9 (0.8) ^a	23.5 (0.7) ^b

Notes: Values with different letters are significantly different ($P < 0.05$) according to ANOVA. Values with the same letter within each row are not significantly different according to the probability of mean differences at $\alpha = 0.05$ with Fisher's least significant difference test. Standard errors of means are indicated in parentheses. STM is shallow tillage with mineral fertilizer; STC is shallow tillage with cattle manure; CTM is conventional tillage with mineral fertilizer and CTC is conventional tillage with cattle manure.

* WHC was calculated for a standard thickness of 10 cm.

Effet sur la distribution porale

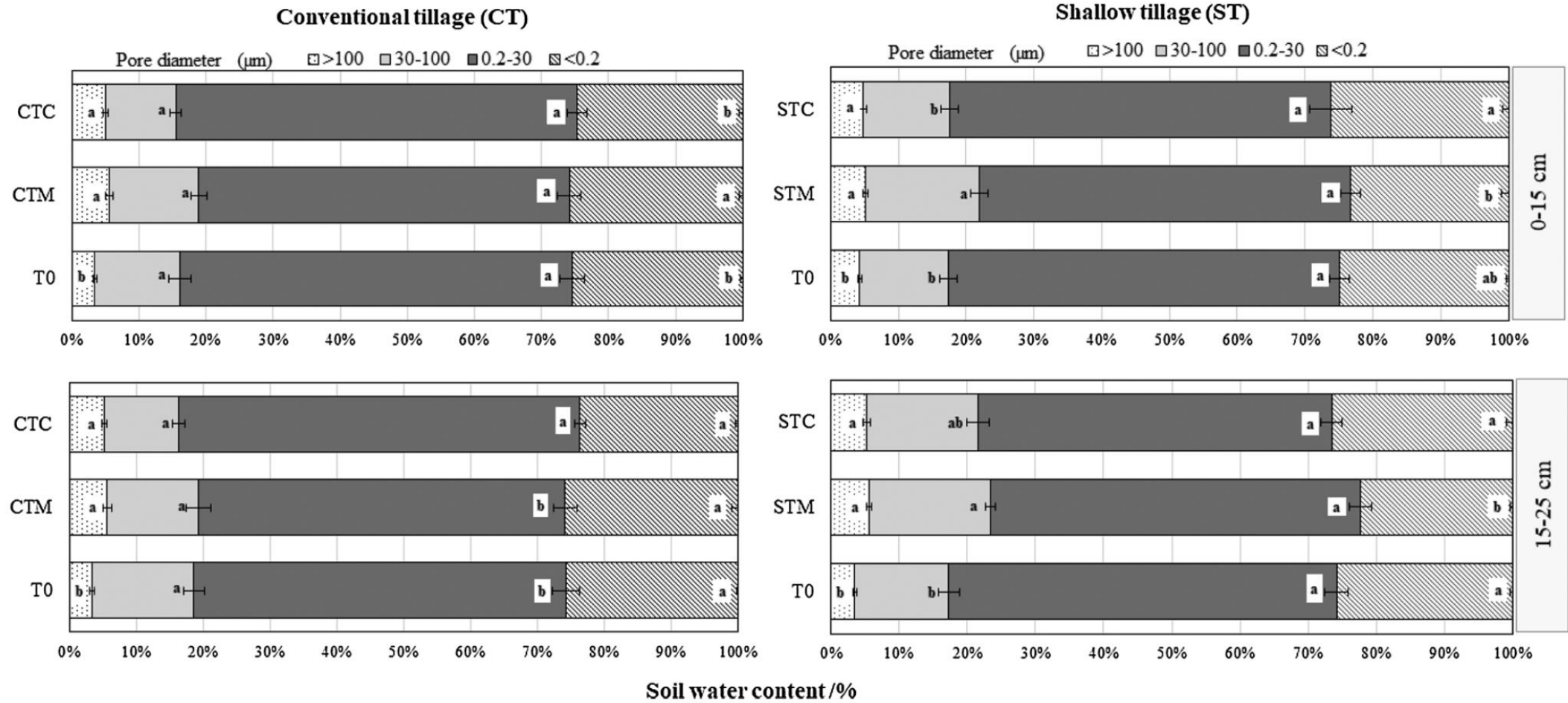


Fig. 3. Pore-size distribution of soil samples at two depths at the initial state (T0) and under four treatments: STM, shallow tillage with mineral fertilizer; STC, shallow tillage with cattle manure; CTM, conventional tillage with mineral fertilizer; CTC, conventional tillage with cattle manure. Error bars indicate 1 standard error. Values with different letters are significantly different ($P < 0.05$) according to ANOVA.

Effet sur AvS et Intercept

Table 5

Results of two-way ANOVA of the intercept and absolute value of the slope (AvS) of the relationship between the soil water spectral index and soil water content with depth and fertilization as fixed effects under mineral and organic fertilization.

Source of variation	Degrees of freedom	Intercept (cm ³ cm ⁻³)				AvS			
		Sum of squares	Mean squares	<i>F ratio</i>	<i>P</i>	Sum of squares	Mean squares	<i>F ratio</i>	<i>P</i>
	Conventional tillage								
Depth	1	0.00598	0.005981	4.512	0.0368	0.0012	0.00118	0.118	0.732
Fertilizer	2	0.0121	0.006048	4.563	0.0134	0.0261	0.013074	1.311	0.275
D*F	2	0.00205	0.001026	0.774	0.4646	0.0389	0.019449	1.95	0.149
Residuals	78	0.10339	0.001326			0.7779	0.009973		
Total	83	0.12352	0.014381			0.8441	0.043676		
	Shallow tillage								
Depth	1	0.00017	0.0001701	0.106	7.46E-01	0.0004	0.000399	0.046	0.831
Fertilizer	2	0.00306	0.0015315	0.952	0.39	0.0151	0.007552	0.867	0.424
D*F	2	0.00029	0.0001433	0.089	9.15E-01	0.0297	0.01485	1.706	0.188
Residuals	78	0.12549	0.0016088			0.679	0.008705		
Total	83	0.12901	0.0034537			0.7242	0.031506		

Table 6

Pearson correlation matrix of the absolute value of the slope (AvS) and intercept of the relationship between the soil water spectral index and soil water content and soil properties [soil organic carbon (SOC) content, bulk density (BD), water holding capacity (WHC), and the Dexter index of soil physical quality (S_{Dexter})].

	AvS	Intercept	SOC	BD	WHC	S _{Dexter}
AvS	1.00					
Intercept	0.80***	1.00				
SOC	0.07	0.12	1.00			
BD	-0.09	-0.18	-0.06	1.00		
WHC	0.62***	0.64***	0.27*	-0.09	1.00	
S _{Dexter}	0.39**	0.34**	0.21*	-0.25*	0.74***	1.00

Plan (Intercept, AvS) pour évaluer les effets du travail du sol et de la fertilisation

Intercept $\nearrow$ $\rightarrow$ Quantité maximale d'eau que le sol peut contenir $\nearrow$

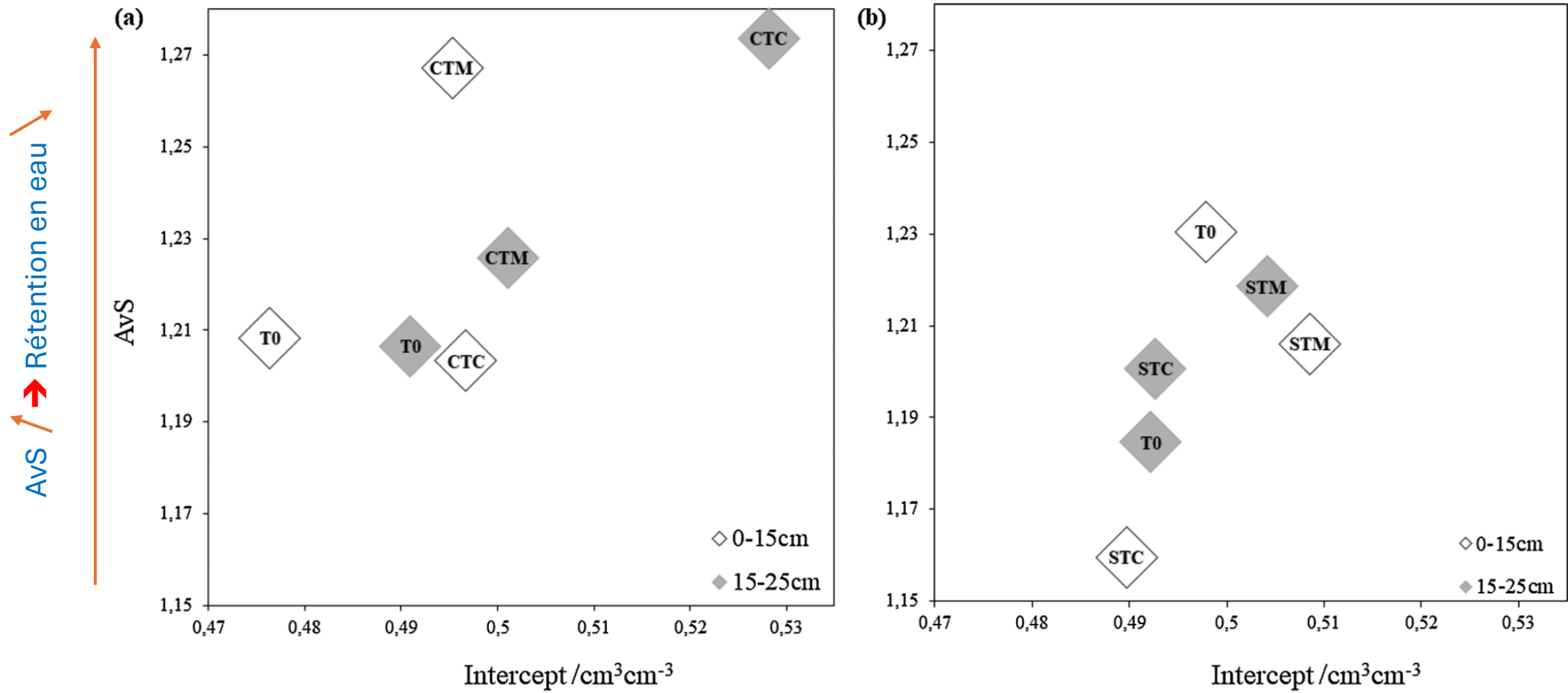


Fig. 6. Mean intercept vs. mean absolute value of the slope (AvS) of the relationship between the soil water spectral index and soil water content at the initial state (T0) and under four treatments at two depths (0–15 and 15–25 cm). STM is shallow tillage with mineral fertilizer; STC is shallow tillage with cattle manure; CTM is conventional tillage with mineral fertilizer and CTC is conventional tillage with cattle manure.

Conclusion

- Cinq années de travail du sol combiné à une fertilisation minérale et organique ont significativement affecté les propriétés de rétention en eau du sol ;
 - CT a généralement eu un effet plus positif que T0. Effet plus marqué avec CTC qu'avec CTM à la profondeur 15-25 cm.
 - ST effet plus négatif qu'à T0 et l'apport de fumier de bovin n'a pas permis une amélioration significative en comparaison à STM et T0.
- Globalement, la fertilisation n'a eu aucun effet significatif sur les propriétés du sol qui influencent directement la rétention en eau du sol. Néanmoins, le fumier de bovin a joué un rôle important dans l'amélioration de la qualité des sols travaillés ;
- AvS et Intercept pertinent pour étudier les effets du type de travail du sol et du type de fertilisation sur les propriétés de rétention en eau du sol et sur la qualité structurale du sol ;
- Représentation dans le plan (Intercept, AvS) offre un moyen de synthétiser et d'évaluer les impacts des pratiques agricoles sur ces propriétés ;
 - Une augmentation de l'Intercept et de l'AvS était généralement associée à une amélioration de la qualité des sols.
- Spectroscopie PIR une approche alternative prometteuse pour évaluer les propriétés de rétention en eau du sol et la qualité structurale du sol.