



*Supplement of*

## **Soil health approaches to assess the impacts of no-tillage with agricultural terraces in southern Brazil**

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## Supplementary material

**Table S1.** Methods used in the analyses of the soil health indicators within the database, along with their corresponding references.

Indicators	Methods	References
Clay	Granulometric analysis	Gee and Or (2002)
Silt	Granulometric analysis	Gee and Or (2002)
Sand	Granulometric analysis	Gee and Or (2002)
Bulk Density (BD)	Cylinder with undisturbed soil sample	Teixeira et al., 2017
Total Porosity (TP)	Cylinder with undisturbed soil sample	Teixeira et al., 2017
Macroporosity (Macro)	Macro = TP - Micro	Teixeira et al., 2017
Microporosity (Micro)	Cylinder with undisturbed soil sample in tension table of 6 kPa	Teixeira et al., 2017
Field Capacity (FC)	Cylinder with undisturbed soil sample in tension table of 6 kPa	Teixeira et al., 2017
Permanent Wilting Point (PWP)	Measured at -1500 kPa using WP4 dew point potentiometer	
Plant Available Water (PAW)	PAW = FC - PWP	Teixeira et al., 2017
Soil Water Storage Capacity (SWSC)	SWSC = FC / PT	Reynolds et al. (2007)
Soil Aeration Capacity (SAC)	SAC = 1-SWSC	Reynolds et al. (2007)
Soil Penetration Resistance (SPR)	By field penetrometer	Bowen (1981)
pH <sub>H2O</sub>	Soil:water ratio of 2.5:1	Pavan et al., 1992
pH <sub>CaCl2</sub>	Soil:Solution ratio 2.5:1	Pavan et al., 1992
Exchangeable Aluminum (Al)	KCl extraction and NaOH titration	Pavan et al., 1992
Potential Acidity (H+Al)	SMP buffer	Pavan et al., 1992
Available Phosphorous (P)	Mehlich-I extraction method and measured by absorption molecular spectrometry	Pavan et al., 1992
Exchangeable Potassium (K)	Mehlich-I extraction method and flame photometry	Pavan et al., 1992
Exchangeable Calcium (Ca)	KCl extraction and EDTA titration	Pavan et al., 1992
Exchangeable Magnesium (Mg)	KCl extraction and EDTA titration	Pavan et al., 1992
Cation Exchange Capacity (CEC)	Sum of Ca+Mg+K+H+Al	Pavan et al., 1992

Cation Exchange Capacity at pH 7.0 (CEC <sub>pH7.0</sub> )	Sum of SB + Al		Pavan et al., 1992
Sum of bases (SB)	(Ca+Mg+K)		Pavan et al., 1992
Base saturation (BS)	[(Ca+Mg+K)/CEC]*100		Pavan et al., 1992
Organic Carbon (OC)	Walkley-Black method		Pavan et al., 1992
Organic Matter (SOM)	OC x 1.72 = SOM		Pavan et al., 1992
Microbial Carbon Biomass (MCB)	Chloroform-fumigation method	extraction	Vance et al. (1987)
β-glucosidase Activity (BG)	P-method		Tabatabai et al. (1982) adapted by Eivazi e Tabatabai (1988)
Arylsulfatase Activity (A)	P-method		Tabatabai and Bremmer (1970)

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5 **Table S2.** Soil health indicators and scoring curves for SMAF.

Indicator	Class Factor	Characteristic	Class Factor of the present study
Organic Matter	1	Soil Taxonomic suborders with high organic matter content: Aquands; Aquods; Aquox; Fibrists; Folists; Hemists; Histels; Saprist; Turbels	4
	2	Soil Taxonomic suborders: Albolls; Aquepts; Aquerts; Aquolls; Aquults; Borolls; Cryolls; Humods; Humults; Rendolls; Udands; Udolls; Ustands; Usterts; Ustolls; Xererts; Xerolls	
	3	Soil Taxonomic suborders: Andepts; Anthrepts; Aqualfs; Aquents; Boralfs; Cryalfs; Cryands; Cryerts; Cryods; Orthels; Udalfs; Ustalfs; Vitrand; Xeralfs	
	4	Soil Taxonomic suborders with low organic matter content: Arents; Argids; Calcids; Cambids; Cryepts; Cryids; Durids; Fluents; Gypsids; Ochrepts; Orthents; Orthids; Orthods; Orthox; Perox; Psamments; Salids; Torrands; Torrerts; Torrox; Topepts; Udepts; Udults; Umbrepts; Ustepts; Ustox; Ustults; Xerands; Xerepts; Xerents; Xerults	
Texture	1	Sand, loamy sand, or sandy loam (with < 8% clay)	2 and 4
	2	Sandy loam (with >8% clay)	
	3	Silt loam, silt	
	4	Sandy clay, clay loam, silty clay loam, silty clay, or clay (with <60% clay)	
	5	Clay, with > 60% clay	
Climate	1	hi/hi->=170° days and >=550ppt	1 which is hot and humid
	2	hi/lo->=170° days and <550ppt	climate, ≥ 170-degree
	3	lo/hi-<170° days and >=550ppt	days and ≥ 550 mm
	4	lo/lo-<170° days and <550ppt	average annual precipitation, used for all locations

Season	1	Spring	3: soil samples were collected in fall.
	2	Summer	
	3	Fall	
	4	Winter	
Fe <sub>2</sub> O <sub>3</sub>	1	Ultisols	2
	2	All other suborders	
Mineralogy	1	Smectitic	3 (1:1 clay and Fe and Al oxides)
	2	Glassy	
	3	Others	
Slope	1	0 to 2% slope	3 and 4
	2	2 to 5% slope	
	3	5 to 9 % slope	
	4	9 to 15% slope	
	5	more than 15% slope	
Weathering	1	calc - calc rxn class	2 (oxisols, highly weathered soils)
	2	hi - ultisols, oxisols, acidic orchepts, (quartzipsamments, ultic Alfisols)	
	3	Slightly - all others	
P Method	1	Mehlich 1	1
	2	Mehlich 3	
	3	Bray	
	4	Olsen	
	5	Resin	
	6	Iron oxide strip	

**Table S3.** Median, 1st quartile and 3rd quartile values of the soil's physical, chemical and biological indicators assessed in no-till (NT) and no-till with terraces (NT+T) in 2020, 2021 and 2022.

Soil Indicator	2020			2021			2022		
	NT	NT+T	Significance	NT	NT+T	Significance	NT	NT+T	Significance
	Median [Q1-Q3]	Median [Q1-Q3]		Median [Q1-Q3]	Median [Q1-Q3]		Median [Q1-Q3]	Median [Q1-Q3]	
BD (Mg dm <sup>-3</sup> )	1.31 [1.23-1.39]	1.31 [1.23-1.39]	ns	1.23 [1.15-1.31]	1.27 [1.20-1.33]	ns	1.48 [1.39-1.55]	1.46 [1.38-1.55]	ns
TP (m <sup>3</sup> m <sup>-3</sup> )	0.49 [0.46-0.52]	0.49 [0.45-0.51]	ns	0.53 [0.50-0.55]	0.53 [0.49-0.55]	ns	0.49 [0.45-0.52]	0.50 [0.46-0.54]	*
SPR (MPa)	0.91 [0.72-1.16]	1.22 [0.84-1.28]	*	1.09 [0.88-1.27]	1.34 [0.99-1.71]	**	0.77 [0.67-0.95]	1.22 [0.95-1.38]	***
SWSC	0.71 [0.62-0.76]	0.72 [0.69-0.80]	*	0.53 [0.49-0.60]	0.60 [0.53-0.67]	**	0.72 [0.69-0.77]	0.72 [0.69-0.80]	ns
pH <sub>CaCl2</sub>	5.18 [4.73-5.43]	5.10 [4.77-5.34]	ns	5.56 [5.24-5.82]	4.89 [4.69-5.16]	***	5.11 [4.96-5.24]	5.01 [4.75-5.17]	*
pH <sub>H2O</sub>	6.02 [5.47 - 6.19]	5.92 [5.56 - 6.21]	ns	5.40 [5.18 - 5.65]	5.54 [5.30 - 5.92]	ns	5.48 [5.26-5.61]	5.26 [5.15 - 5.40]	***
H+Al (cmol <sub>c</sub> dm <sup>-3</sup> )	5.41 [4.46 - 7.42]	5.37 [4.69 - 6.43]	ns	6.05 [5.50 - 6.94]	6.32 [4.98 - 7.15]	ns	5.47 [4.52 - 6.81]	6.05 [5.06 - 7.10]	ns
Al (cmol <sub>c</sub> dm <sup>-3</sup> )	0.05 [0.01 - 0.11]	0.06 [0.02 - 0.10]	ns	0.35 [0.30 - 0.61]	0.32 [0.18 - 0.45]	ns	0.04 [0.00 - 0.18]	0.05 [0.00 - 0.15]	ns
P (mg dm <sup>-3</sup> )	50.6 [32.2-72.7]	36.90 [24.2-46.8]	**	25.1 [15.3-38.7]	17.1 [12.6-26.4]	*	17.7 [11.9-30.2]	17.9 [11.5-32.3]	ns
K (cmol <sub>c</sub> dm <sup>-3</sup> )	0.56 [0.47-0.71]	0.65 [0.53-0.87]	*	0.22 [0.18-0.27]	0.26 [0.20-0.31]	**	0.38 [0.32-0.45]	0.35 [0.28-0.44]	ns
Ca (cmol <sub>c</sub> dm <sup>-3</sup> )	3.78 [3.16-4.44]	3.34 [2.94-3.62]	**	3.03 [2.47-3.30]	3.07 [2.08-3.49]	ns	2.74 [2.41-3.95]	2.84 [2.52-3.38]	ns
Mg (cmol <sub>c</sub> dm <sup>-3</sup> )	1.09 [0.63 - 1.67]	1.03 [0.78 - 1.35]	ns	0.59 [0.47 - 0.69]	0.74 [0.59 - 1.17]	***	0.74 [0.52 - 1.20]	0.82 [0.64 - 1.23]	ns
CEC (cmol <sub>c</sub> dm <sup>-3</sup> )	5.53 [4.73 - 6.44]	5.11 [4.44 - 5.82]	*	3.52 [2.81 - 4.14]	4.43 [3.42 - 5.19]	***	3.90 [3.51 - 5.52]	4.19 [3.77 - 4.75]	ns
CEC <sub>pH7.0</sub> (cmol <sub>c</sub> dm <sup>-3</sup> )	11.3 [10.5-12.9]	10.9 [9.77-11.5]	**	10.3 [9.57-10.9]	10.3 [9.52-11.1]	ns	9.89 [9.00-10.8]	10.2 [9.61-11.1]	ns
SB	5.45	5.06	ns	3.75	3.92	ns	3.78	4.14	ns

( $\text{cmol}_c \text{ dm}^{-3}$ )	[4.64 – 6.42]	[4.37 – 5.77]		[3.37 – 4.27]	[3.02 – 4.97]		[3.37 – 5.51]	[3.59 – 4.75]	
BS	48.5	47.5	ns	41.2	37.0	ns	43.1	40.5	ns
(%)	[41.9-58.9]	[43.2-54.4]		[34.4-50.4]	[31.6-48.4]		[36.6-52.5]	[34.0-46.8]	
OC	22.2	20.9	***	19.1	19.8	ns	18.9	21.0	***
( $\text{g dm}^{-3}$ )	[21.8-22.5]	[19.6-21.7]		[17.5-21.6]	[18.1-21.2]		[16.2-20.7]	[20.3-22.9]	
SOM	38.20	35.90	***	32.90	34.10	ns	32.50	36.10	***
( $\text{g dm}^{-3}$ )	[37.60 – 38.60]	[33.70 – 37.30]		[30.00 – 37.20]	[31.10 – 36.40]		[27.90 – 35.50]	[34.90 – 39.30]	
MBC	230.17	325.54	***	439.42	392.97	ns	593.46	465.05	***
( $\text{mg kg}^{-1}$ )	[176.0-295.0]	[216.0-422.0]		[205.0-460.0]	[280.0-447.0]		[577.0-613.0]	[426.0-524.0]	
BG	85.8	101.0	***	69.6	47.4	***	94.1	137.0	***
( $\text{mg kg}^{-1} \text{ h}^{-1}$ )	[76.2-706.0]	[92.4-107]		[56.4-86.5]	[46.2-48.9]		[53.9-141.0]	[117.0-191.0]	
A	73.1	49.4	***	54.9	42.6	***	66.0	65.9	ns
( $\text{mg } p\text{-nitrophenol kg}^{-1} \text{ soil h}^{-1}$ )	[49.7-92.8]	[46.5-54.6]		[45.6-77.5]	[39.5-45.7]		[45.1-71.9]	[62.7-66.9]	

10 BD: Bulk Density; TP: Total Porosity; SPR: Soil Penetration Resistance; SWSC: Soil Water Storage Capacity; H+Al: Potential Acidity; Al: Exchangeable Aluminum; P: Available Phosphorous; K: Exchangeable Potassium; Ca: Exchangeable Calcium; Mg: Exchangeable Magnesium; CEC: Cation Exchange Capacity; CECpH7.0: Cation Exchange Capacity at pH 7.0; SB: Sum of bases; BS: Base saturation; OC: Organic Carbon; SOM: Organic Matter; MBC: Microbial Carbon Biomass; BG: Beta-glucosidase Activity; A: Arylsulfatase Activity; Asterisks indicate statistically significant differences between treatment medians according to the Wilcoxon test at the 1% (\*\*\*), 5% (\*\*), and 10% (\*) significance levels; ns: not significant. Medians are based on thirty-six replicates.

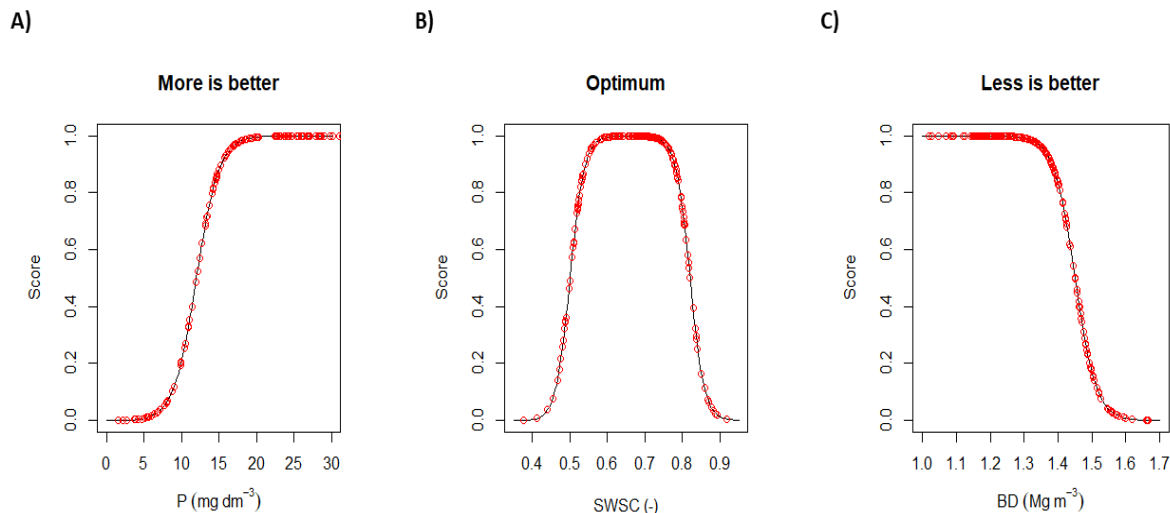
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**Table S4.** Results of principal component analysis (PCA)

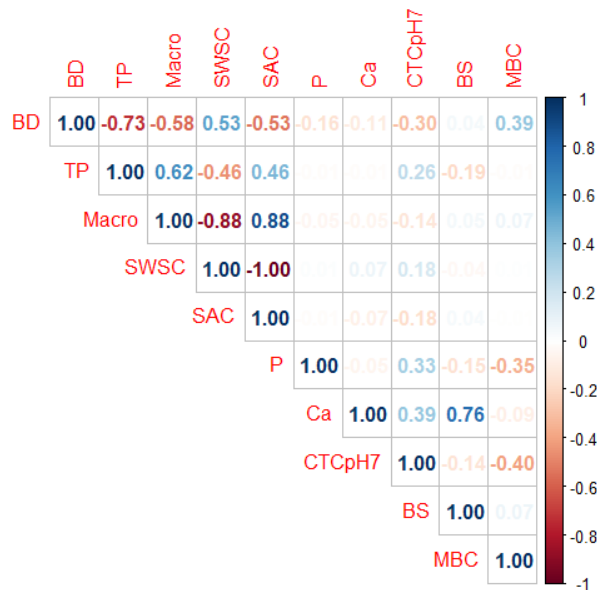
	Principal components analysis (PCA)					
	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalues	4.937	3.727	2.630	1.619	1.426	0.984
Variance (%)	24.684	18.633	13.152	8.095	7.131	4.922
Cumulative (%)	24.684	43.316	56.469	64.564	71.695	76.616
BD	0.427	-0.480	<b><u>0.638</u></b>	-0.019	0.118	-0.106
TP	-0.288	0.534	-0.438	0.014	<b><u>-0.619</u></b>	0.010
Macro	<b><u>-0.868</u></b>	0.282	-0.098	-0.137	-0.220	-0.052
Micro	0.770	0.164	-0.294	0.178	-0.317	0.071
PAW	0.768	-0.081	-0.200	0.021	-0.412	0.021
SWSC	<b><u>0.921</u></b>	-0.295	0.049	0.084	0.023	-0.013
SAC	<b><u>-0.921</u></b>	0.295	-0.049	-0.084	-0.023	0.013
SPR	0.083	0.318	0.115	0.272	0.211	-0.631
pH <sub>CaCl2</sub>	-0.619	-0.591	-0.071	0.164	-0.046	0.041
P	0.091	0.022	-0.254	<b><u>-0.728</u></b>	0.237	0.200
K	0.300	-0.371	-0.418	-0.319	0.129	0.243
Al	0.217	0.737	0.081	-0.010	0.164	-0.085
Ca	-0.068	-0.573	<b><u>-0.640</u></b>	0.300	-0.009	-0.080
Mg	-0.416	-0.617	-0.208	0.113	0.080	-0.105
CEC <sub>pH7.0</sub>	0.331	0.223	<b><u>-0.689</u></b>	-0.015	0.080	-0.075
BS	-0.297	<b><u>-0.825</u></b>	-0.323	0.217	0.010	-0.032
OC	0.152	-0.008	-0.500	-0.239	-0.017	-0.554
MBC	-0.104	-0.211	0.505	0.185	<b><u>-0.562</u></b>	0.035
BG	0.230	-0.359	0.231	-0.448	-0.491	-0.196
A	-0.203	-0.425	0.191	-0.615	-0.124	-0.296

Abbreviations, according to Supplementary Table 3.

The underlined values indicate the indicators selected to compose the SHI\_PCA and the underlined ones are those selected by the PCA.



**Figure S1.** Representative scoring curves used to standardize soil health indicators.



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**Figure S2.** Spearman correlation matrix for the physical, chemical and biological indicators pre-selected by PCA. The correlations considered for analysis were those with  $r \geq 0.80$  within each PC.

## References

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Bowen, H. D.: Alleviating mechanical impedance, in: Arkin, G. F. and Taylor, H. M. (Eds.), *Modifying the Root Environment to Reduce Crop Stress*, American Society of Agricultural Engineers, St. Joseph, 21–57, ISBN 0-916150-40-2, 1981.

Eivazi, F. and Tabatabai, M. A.: Glucosidases and galactosidases in soils, *Soil Biol. Biochem.*, 20, 601–606, [https://doi.org/10.1016/0038-0717\(88\)90141-1](https://doi.org/10.1016/0038-0717(88)90141-1), 1988.

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- Gee, G. W. and Or, D.: Particle-size analysis, in: *Methods of Soil Analysis. Part 4. Physical Methods*, edited by: Dane, J. H. and Topp, G. C., American Society of America, Madison, 255–289, ISBN: 9780891188933, <https://doi.org/10.2136/sssabookser5.4>, 2002.
- Reynolds, W. D., Drury, C. F., Yang, X. M., Fox, C. A., Tan, C. S., and Zhang, T. Q.: Land management effects on the near-surface physical quality of a clay loam soil, *Soil Till. Res.*, 96, 316–330, <https://doi.org/10.1016/j.still.2007.07.003>, 2007.
- 40 Pavan, M. A., Bloch, M. de F., Zempulski, H. da C., Miyazawa, M., and Zocoler, D. C.: *Manual de análise química de solo e controle de qualidade*, IAPAR, Circular Técnica 76, Londrina, 38 pp., ISSN 0100-3356, 1992.
- Tabatabai, M. A. and Bremner, J. M.: Assay of urease activity in soils, *Soil Biol. Biochem.*, 4, 479–487, [https://doi.org/10.1016/0038-0717\(72\)90064-8](https://doi.org/10.1016/0038-0717(72)90064-8), 1972.
- 45 Teixeira, P. C., Donagemma, G. K., Fontana, A., and Teixeira, W. G. (Eds.): *Manual de Métodos de Análise de Solo*, 3rd ed., rev. e ampl., Embrapa, Brasília, DF, 574 pp., ISBN 978-85-7035-771-7, 2017.