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Soil Research

Supplementary Material

Soil capacity to biomass production in sandy loam soils following cover crop farming systems in tropical conditions in the Northeast region of Brazil

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Online Material

Supplementary Table S1 Monthly rainfall (mm) and mean air temperature (ºC) data from the experimental sites in Areia, Paraiba, Brazil (July 2014 to December 2019). Data were obtained online: http://www.inmet.gov.br

Year	Climate variable	July	August	September	October	November	December
2014	Temp (ºC)	18.6	18.0	20.5	20.9	22.1	22.9
	Rainfall (mm)	160.8	110.4	60.5	15.1	1.3	0.9
2015	Temp (ºC)	20.8	20.1	21.3	21.9	22.5	23.4
	Rainfall (mm)	250.8	131.1	55.8	21.1	2.7	3.9
2016	Temp (ºC)	21.5	21.9	22.5	22.1	22.8	23.1
	Rainfall (mm)	150.8	139.8	97.6	27.8	0.0	13.5
2017	Temp (ºC)	21.3	22.6	22.9	23.4	24.1	24.0
	Rainfall (mm)	130.4	160.5	88.3	43.1	22.1	61.8
2018	Temp (ºC)	22.0	22.6	23.4	24.1	25.0	26.0
	Rainfall (mm)	90.8	27.3	30.8	19.3	13.1	3.0
2019	Temp (ºC)	20.2	20.0	21.8	22.3	23.0	23.9
	Rainfall (mm)	275.8	120.8	58.9	59.9	4.5	9.3

Supplementary Table S2 Mean values of soil chemical properties as affected by green manure practice over 6 consecutive years in a Tropical Regosols, Areia, Paraiba, Brazil.

Green manure	2014	2015	2016	2017	2018	2019
	Soil pH H_2O 1:2.5 v:v					
B. decumbens	4.95 (0.01)	5.11 (0.02)	5.26 (0.03)	5.31 (0.02)	5.45 (0.01)	5.60 (0.02)
C. ensiformis	4.99 (0.02)	5.06 (0.04)	5.13 (0.01)	5.24 (0.03)	5.41 (0.02)	5.30 (0.02)
C. juncea	5.00 (0.01)	5.14 (0.01)	5.21 (0.02)	5.30 (0.01)	5.36 (0.02)	5.40 (0.01)
C. ochroleuca	4.98 (0.03)	5.10 (0.01)	5.20 (0.04)	5.25 (0.01)	5.30 (0.03)	5.40 (0.02)
C. spectabilis	5.01 (0.02)	5.07 (0.02)	5.17 (0.05)	5.23 (0.02)	5.33 (0.01)	5.40 (0.03)
D. lablab	4.90 (0.01)	4.96 (0.03)	5.14 (0.01)	5.30 (0.03)	5.38 (0.01)	5.40 (0.02)
M. pruriens	4.97 (0.09)	4.99 (0.01)	5.05 (0.02)	5.09 (0.01)	5.28 (0.02)	5.10 (0.02)
N. wightii	5.05 (0.04)	5.10 (0.01)	5.19 (0.03)	5.23 (0.01)	5.37 (0.02)	5.20 (0.01)
P. glaucum	4.96 (0.06)	5.02 (0.02)	5.12 (0.01)	5.23 (0.01)	5.35 (0.01)	5.50 (0.02)
S. aterrimum	5.02 (0.03)	5.09 (0.03)	5.11 (0.01)	5.23 (0.02)	5.37 (0.01)	5.20 (0.02)
Green manure	*Exchangeable Mg ($cmol_c\ kg^{-1}$)*					
B. decumbens	1.41 (0.03)	1.29 (0.02)	1.19 (0.04)	1.10 (0.02)	1.25 (0.01)	0.80 (0.02)
C. ensiformis	1.34 (0.01)	1.26 (0.01)	1.17 (0.03)	1.13 (0.02)	1.09 (0.02)	0.80 (0.02)

C. juncea	1.35 (0.02)	1.29 (0.01)	1.20 (0.01)	1.12 (0.03)	1.11 (0.04)	0.80 (0.02)
C. ochroleuca	1.39 (0.02)	1.24 (0.03)	1.20 (0.02)	1.09 (0.02)	1.03 (0.02)	1.00 (0.03)
C. spectabilis	1.40 (0.04)	1.30 (0.02)	1.21 (0.02)	1.09 (0.01)	1.00 (0.01)	1.00 (0.03)
D. lablab	1.42 (0.01)	1.28 (0.01)	1.15 (0.03)	1.08 (0.01)	1.07 (0.03)	0.90 (0.02)
M. pruriens	1.43 (0.02)	1.37 (0.03)	1.31 (0.01)	1.25 (0.03)	0.98 (0.03)	1.20 (0.04)
N. wightii	1.25 (0.01)	1.24 (0.01)	1.20 (0.05)	1.19 (0.02)	1.13 (0.02)	1.00 (0.02)
P. glaucum	1.31 (0.02)	1.26 (0.02)	1.19 (0.01)	1.13 (0.04)	1.07 (0.02)	0.90 (0.02)
S. aterrimum	1.43 (0.02)	1.32 (0.02)	1.29 (0.02)	1.21 (0.03)	1.21 (0.02)	1.30 (0.01)
Green manure	$H^{+}+Al^{3+}$ *(cmol$_c$ kg^{-1})*					
B. decumbens	4.91 (0.19)	3.45 (0.03)	3.12 (0.03)	2.98 (0.01)	2.75 (0.01)	2.34 (0.02)
C. ensiformis	4.76 (0.01)	3.23 (0.01)	3.00 (0.03)	2.91 (0.01)	2.82 (0.02)	2.39 (0.02)
C. juncea	4.99 (0.01)	4.02 (0.03)	3.87 (0.19)	3.01 (0.01)	2.82 (0.01)	2.38 (0.01)
C. ochroleuca	4.65 (0.01)	3.97 (0.19)	3.04 (0.02)	2.87 (0.01)	2.55 (0.19)	2.10 (0.19)
C. spectabilis	4.00 (0.01)	3.41 (0.19)	3.25 (0.02)	3.11 (0.02)	3.09 (0.01)	2.79 (0.03)
D. lablab	5.33 (0.03)	4.56 (0.02)	3.21 (0.02)	2.92 (0.03)	2.81 (0.03)	2.39 (0.03)
M. pruriens	5.55 (0.03)	5.01 (0.02)	4.71 (0.19)	3.54 (0.02)	2.97 (0.02)	2.57 (0.01)
N. wightii	5.00 (0.02)	4.50 (0.02)	3.76 (0.03)	3.56 (0.01)	3.01 (0.19)	2.64 (0.01)
P. glaucum	5.01 (0.02)	4.98 (0.01)	4.11 (0.03)	3.17 (0.19)	2.95 (0.02)	2.53 (0.01)
S. aterrimum	5.37 (0.02)	5.21 (0.01)	4.49 (0.19)	4.01 (0.02)	3.31 (0.02)	2.93 (0.01)
Green manure	*Exchangeable Al (cmolc kg^{-1})*					
B. decumbens	0.25 (0.01)	0.20 (0.03)	0.15 (0.02)	0.10 (0.02)	0.07 (0.01)	0.07 (0.01)
C. ensiformis	0.24 (0.03)	0.21 (0.01)	0.18 (0.01)	0.11 (0.01)	0.08 (0.03)	0.09 (0.03)
C. juncea	0.23 (0.01)	0.19 (0.01)	0.14 (0.01)	0.09 (0.01)	0.08 (0.01)	0.07 (0.02)
C. ochroleuca	0.22 (0.01)	0.16 (0.02)	0.13 (0.02)	0.12 (0.01)	0.09 (0.01)	0.11 (0.02)
C. spectabilis	0.21 (0.02)	0.15 (0.01)	0.12 (0.02)	0.11 (0.03)	0.10 (0.02)	0.10 (0.01)
D. lablab	0.26 (0.02)	0.19 (0.02)	0.16 (0.02)	0.13 (0.03)	0.08 (0.03)	0.07 (0.03)
M. pruriens	0.25 (0.03)	0.17 (0.01)	0.15 (0.02)	0.12 (0.02)	0.10 (0.01)	0.12 (0.03)
N. wightii	0.28 (0.01)	0.22 (0.03)	0.17 (0.01)	0.14 (0.01)	0.09 (0.01)	0.09 (0.01)
P. glaucum	0.27 (0.01)	0.21 (0.03)	0.16 (0.01)	0.12 (0.03)	0.09 (0.02)	0.10 (0.01)
S. aterrimum	0.26 (0.03)	0.23 (0.01)	0.18 (0.01)	0.15 (0.02)	0.10 (0.02)	0.11 (0.01)
Green manure	*Soil organic carbon (g kg^{-1})*					
B. decumbens	10.20 (1.79)	12.10 (0.98)	12.50 (1.10)	12.56 (0.92)	11.23 (0.85)	17.90 (0.17)
C. ensiformis	12.00 (0.92)	14.20 (1.73)	15.80 (1.23)	15.10 (1.10)	12.35 (1.12)	18.00 (0.10)
C. juncea	11.24 (0.27)	14.10 (0.92)	14.42 (0.58)	14.02 (0.36)	12.80 (1.12)	17.30 (0.14)

C. ochroleuca	11.37 (1.18)	14.51 (0.93)	14.79 (0.89)	14.33 (0.62)	13.45 (0.53)	11.82 (0.10)
C. spectabilis	12.77 (0.39)	14.73 (0.17)	15.00 (0.18)	14.62 (0.25)	11.78 (0.21)	12.75 (0.19)
D. lablab	9.75 (0.39)	11.71 (0.29)	12.02 (0.31)	11.87 (0.17)	9.80 (0.25)	15.75 (0.23)
M. pruriens	12.49 (0.27)	14.44 (0.28)	15.10 (0.19)	14.51 (0.19)	13.51 (0.13)	12.84 (0.10)
N. wightii	11.80 (0.25)	13.70 (0.21)	13.80 (0.19)	13.40 (0.31)	11.12 (0.33)	16.70 (0.26)
P. glaucum	11.52 (0.35)	13.76 (0.30)	13.98 (0.28)	14.03 (0.09)	12.19 (0.27)	18.40 (0.10)
S. aterrimum	12.13 (0.41)	14.55 (0.39)	15.06 (0.87)	15.03 (0.18)	19.82 (0.91)	12.89 (1.04)

Standard error in parentheses.

Within each column (studied year), same small letters represent no significant differences by Bonferroni's test ($p < 0.05$)

Supplementary Table S3 Mean values of soil physical properties as affected by green manure practice over 6 consecutive years in a Tropical Regosols, Areia, Paraiba, Brazil.

Soil physical properties	2014	2019
Bulk Density (g cm^{-3})	1.11 (0.01)	1.07 (0.02)
Geometric mean diameter (mm)	2.49 (0.04)	2.45 (0.02)
Weighted average diameter (mm)	2.96 (0.03)	2.90 (0.05)
Soil macroporosity (mm^3 mm^{-3})	9.86 (0.15)	10.02 (0.18)
Soil microporosity (mm^3 mm^{-3})	37.05 (2.34)	33.19 (4.51)
Sand (g kg^{-1})	365.94 (11.01)	365.00 (10.04)
Silt (g kg^{-1})	405.31 (9.31)	406.32 (8.78)
Clay (g kg^{-1})	228.75 (2.33)	228.68 (4.59)

Standard error in parentheses.

Supplementary Table S4 Polynomial regression to estimate soil capacity to biomass production rate (SC_k) of green manure practice over 6 consecutive years in a Tropical Regosols, Areia, Paraiba, Brazil.

Green manure	Polynomial regression	R^2	*p- value*
B. decumbens	SC_k (years^{-1}) = $0.006x^2 - 24.25x + 24437$	0.99	$p < 0.001$
C. ensiformis	SC_k (years^{-1}) = $0.0155x^2 - 62.67x + 62180$	0.99	$p < 0.001$
C. juncea	SC_k (years^{-1}) = $0.0035x^2 - 14.22x + 14332$	0.99	$p < 0.001$
C. ochroleuca	SC_k (years^{-1}) = $-0.0028x^2 + 11.20x - 11293$	0.99	$p < 0.001$
C. spectabilis	SC_k (years^{-1}) = $0.0241x^2 - 97.05x + 97829$	0.99	$p < 0.001$
D. lablab	SC_k (years^{-1}) = $0.0214x^2 - 86.17x + 86851$	0.99	$p < 0.001$
M. pruriens	SC_k (years^{-1}) = $0.0159x^{2} - 64.21x + 64722$	0.99	$p < 0.001$
N. wightii	SC_k (years^{-1}) = $-0.0063x^2 + 25.27x + 25453$	0.99	$p < 0.001$
P. glaucum	SC_k (years^{-1}) = $0.0018x^{2} - 7.29x + 7355.7$	0.99	$p < 0.001$
S. aterrimum	SC_k (years^{-1}) = $0.0178x^2 - 71.58x + 71147$	0.99	$p < 0.001$

"x" represents the number of years using the green manure practice with a specific plant species

Online resources 2: Calculating SC by PCA-LSF-SQIw approach:

1) First go creating a matrix considering attributes from soil factors (e.g., pH, nitrogen, bulk density, moisture, etc.), plant (e.g., biomass, root density, yield, etc.).
2) Then, insert the matrix in R using an ".csv" file extension, and the script:

   data<-read.table(file.choose(),header=T,sep=";",dec=",")
3) Next, install the packages "ape" and "vegan" using the scripts: library(ape) and library(vegan), respectively.
4) Now, create the SC base using the script:

   SC<-data[,xi:xf]

   Note that the xi and xf into the script means the initial and final columns correspondent to the evaluated attributes into the matrix.
5) Before starting the analysis transform all database using "ape" package using the scrip:

   SClog<-decostand(SC,"log")

   It will correct possible asymmetries into the database.
6) Now, run a regular PCA analysis using the script:

   SC.pca<-rda(SClog[,1:9], scale=T)
7) Check the PCA values using the script:

   summary(SC.pca).
8) Then, we are ready to check the p-value of each attribute used to create the SC using the described scripts:

   nmds.env<-envfit(SC.pca, SClog[,xi:xf])

   nmds.env.
9) All the attributes presented a p-value < 0.001. So, we can use all of them into the SC.
10) We start creating the SC using the proportion explained by each principal component.
11) In our example, we have the follow SC formula:

   $SC = (53.94 * PC1) \pm (27.37 * PC2) \pm (5.43 * PC3) \pm (3.17 * PC4) \pm (2.15 * PC5) \pm (1.73 * PC6) \pm 6.22$

   Now, we have six components explaining 93.78% of our SC. We will consider the other 6.22 as correction factor (cf) because they present a low importance into the index and their importance will be our cf into the formula.
12) Then, check the best attributes to put into the formula. To do that we must choose the attributes that present the highest values.
13) Now, we put the best attributes into the formula:

   $SC = (53.94 \times N - Root) + (27.37 \times N - P) + (5.43 \times N - Shoot) + (3.17 \times N - Ca^{2+}) + (2.15 \times N - K^{+}) + (1.73 \times N - SOC\ stock) + 6.22$
14) Finally, we must calculate the normalized values of each attribute. To do this, we must divide the mean of each attribute by their scores.
15) To interpret the SC values, we must consider that the SC ranges from -1000 to +1000 that corresponds to negative and positive values of soil quality, respectively. Within each category (positive or negative), we must find four categories of soil quality (high SC (well-conserved soil or natural ecosystem): values ranging from 750 to 1000; average SC (organic farming systems or

agroforestry systems: values ranging from 450 to 749.9; low SC (conventional farming based on monocropping systems: values ranging from 175 to 439.9; and very-low SC (degraded areas): values ranging from -1000.0 to 174.9.

16) Within the very-low SC, we can find five categories of levels of soil degradation: level 1 (values ranging from -110.0 to 174.9); level 2 (-400.0 to -110.1); level 3 (-600.0 to -400.1); level 4 (-800.0 to -600.1); level 5 (-1000.0 to -800.1).

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