Supplementary Information Guide for

Metagenomics-informed soil biogeochemical models projected less carbon loss in tropical soils in response to climate warming

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The SI files includes:

1. Song et al_SI.pdf
    a. Supplementary Methods
    Method S1. Projection of soil carbon dynamics in response to climate change
    Method S2. SOM analysis with Electrospray Ionization Fourier Transformed Ion Cyclotron Resonance Mass Spectrometry (ESI-FTICR MS)
    Method S3. A summary of the equations in the CoMEND model
    Method S4. Parameterization of the dynamic EFC allocation scheme for resource acquisition
    Method S5. Kinetic parameters in the CoMEND model.
    Method S6. Site-specific parameter optimization in the CoMEND model.
    Method S7. Initialization of soil pools in the CoMEND model.
    Method S8. Input data for the CoMEND model.
    b. Supplementary Equations
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    c. Supplementary Figures
    Fig. S1. Metagenomics-informed lignocellulose-containing soil organic matter (SOM) decomposition pathways and corresponding enzymes identified in the Panama soil samples, where EC refers to the Enzyme Classification number
    Fig. S2. Metagenomics-informed nitrogen (N)-containing SOM decomposition and mineralization pathways and corresponding enzymes identified in the Panama soil samples, where EC refers to the Enzyme Classification numbers.
    Fig S3. Metagenomics-informed P-containing SOM decomposition and mineralization pathways and corresponding enzymes identified in the Panama soil samples, where EC refers to the Enzyme Classification numbers.
    Fig. S4. Modeled and metagenomics-informed effect sizes of enzyme function groups (EFCs) between the control and P-fertilized soils. Here the effect size is defined as the $\log_2$ fold change of gene abundance of the EFC in the control plots relative to that in the P-fertilized soils. The error bar represents the standard deviation of metagenomics-informed effect size of each EFC. The filled symbols indicate that the difference of the EFC between the control soils and the P-fertilized soils is statistically significant (q-value <0.05). The Willmott index of agreement (WI) for all EFCs is 0.47 (P value <0.05), while the index (WI_{sig}) for EFCs with statistically significant effect size is 0.67 (P value <0.05). C_{EFC}, N_{EFC}, P_{EFC} are EFCs for decomposing lignocellulose-containing, N-containing, and P-containing SOM, respectively.
    Fig. S5. Effects of enzyme functional diversity of soil microbial communities on decomposition kinetics of enzyme functional classes (EFCs): (a-b) Activation energy (kJ/mol); (c-d) Potential EFC activity (Vd *E); and (e-f) Substrate affinity (K_m). Three

version of models were compared: $CoMEND_H$ included all metagenomics-informed 22 EFCs for SOM decomposition and thus represented high enzyme functional diversity. $CoMEND_M$ only included 15 EFCs for SOM decomposition and thus represented moderate functional diversity of microbial community. $CoMEND_L$ included 11 clusters of EFCs and represented low functional diversity of microbial community.

d. Supplementary Tables S1-S3
Table S1. Classification of soil enzyme functional groups (EFCs) in Panamanian soils.
Table S2. Classification of soil enzyme functional groups (EFCs) in Panamanian soils.
Table S3. Chemical components, representative molecular formula and C/N and C/P ratio of SOM pool.

e. Supplementary Notes
References cited in the SI

2. Supplementary Data S1 to S7

a. **Supplementary_Data_S1.xlsx: Supplementary Data S1.** Differential analysis of gene abundances of all detected enzymes in the Panama soil samples.
b. **Supplementary_Data_S2.xlsx: Supplementary Data S2.** EC numbers in soil enzyme function classes (EFCs) for organic matter decomposition and mineralization in the Gigante soil and differential analysis of gene abundances for each enzyme between P-deficient Control and P-fertilized soils.
c. **Supplementary_Data_S3.xlsx: Supplementary Data S3.** Microbial-activated (A), mineral-protected (M), and adsorbed (Q) soil organic matter (SOM) pools, inorganic N and P pools, and the corresponding soil enzyme functional groups (EFCs) that act on each pool in the CoMEND model.
d. **Supplementary_Data_S4.xlsx**: **Supplementary Data S4**. Kinetic parameters in the CoMEND model.
e. **Supplementary_Data_S5.xlsx**: **Supplementary Data S5**. Calibrated parameters in the CoMEND model.
f. **Supplementary_Data_S6.xlsx: Supplementary Data S6.** Non-calibrated parameters in the CoMEND model.
g. **Supplementary_Data_S7.xlsx: Supplementary Data S7.** Initial soil physical and chemical properties