Table S1. Principal component analysis (PCA) of indicators for soil erosion resistance function, water regulation function and ecological function.

Soil variables	Erosion resistance function
	PC1
K_r	**-0.924**
C	**0.995**
τ	**0.927**
φ	-0.701
% of Variance	79.79
Cumulative variance (%)	79.79

Soil variables	Water regulation function	
	PC1	PC2
θ_a	0.779	0.182
θ_v	**-0.978**	-0.198
M_a	-0.825	-0.488
M_e	0.351	**0.928**
NAP	-0.091	**-0.993**
K_s	**0.880**	0.223
θ_r	**-0.971**	-0.192
α	0.829	0.555
n	0.652	0.649
% of Variance	75.05	15.82
Cumulative variance (%)	75.05	90.87

Soil variables	Ecological function	
	PC1	PC2
G_r	**0.884**	0.429
E_r	**0.908**	0.239
B_m	**0.872**	0.395

R_l	**<u>0.860</u>**	0.484
ARD	0.322	**<u>0.927</u>**
FD_{rs}	0.288	**0.851**
PRA	0.719	0.679
PRA_b	0.750	0.648
RSA	0.719	0.679
V_r	0.466	0.813
R_{cn}	**<u>0.874</u>**	0.475
R_{nn}	**0.895**	0.406
R_{an}	**<u>0.891</u>**	0.349
R_{bp}	0.781	0.551
R_c	0.779	0.563
% of Variance	86.36	7.18
Cumulative variance (%)	86.36	93.54

Note: Bold values indicate high factor loadings; underlined values denote the indicators selected for sub-index construction.

K_r is the soil erodibility, C is the cohesive strength, τ is the critical shear stress, φ is the internal friction angle, θ_a is the available water content, θv is the volumetric water content, M_a *is the macropores,* M_e *is the mesopores,* NAP *is the non-active pores,* K_s *is the saturated hydraulic conductivity, θ_r is the residual water content, α is the reciprocal of soil air intake value in Van Genuchten model, n is the fitting parameter related to pore distribution in Van Genuchten model, G_r is the germination rate, E_r is the emergence rate, B is the biomass, R_l is the root length, ARD is the average root diameter, FD_{rs} is the fractal dimension of root system, PRA is the projected root area, PRA_b is the pixel-based root area, RSA is the root surface area, V_r is the root volume, R_{cn} is the root connectivity number, R_{nn} is the root node number, R_{an} is the root apices number, R_{bp} is the root branching points number and R_c is the root crossing number.*

Table S2. Scoring method, weight assignment, and calculation formulas for each functional index based on the full indicator dataset.

	Soil Parameter	Scoring curve	Weight	Equation
SFI_1	K_r	Less is better	0.498	$SFI_1 = 0.498K_r + 0.502\tau$
	τ	More is better	0.502	
SFI_2	θ_v	More is better	0.354	$SFI_2 = 0.354\theta_v + 0.293K_s + 0.353\mathrm{NAP}$
	K_s	Less is better	0.293	
	NAP	More is better	0.353	
SFI_3	G_r	More is better	0.201	$SFI_3 = 0.201G_r + 0.203R_l + 0.200ARD + 0.206R_{cn} + 0.190R_{an}$
	R_l	More is better	0.203	
	ARD	More is better	0.200	
	R_{cn}	More is better	0.206	
	R_{an}	More is better	0.190	

Note: SFI_1 is the soil erosion resistance function, SFI_2 is the soil water regulation function, SFI_3 is the soil ecological function, K_r is the soil erodibility, τ is the critical shear stress, θv is the volumetric water content, K_s is the saturated hydraulic conductivity, NAP is the non-active pores, G_r is the germination rate, R_l is the root length, ARD is the average root diameter, R_{cn} is the root connectivity number and R_{an} is the root apices number.

Table S3. Soil erosion resistance-related parameters under different PAM concentrations.

PAM (‰)	K_r (s m^{-1})	*C* (Kpa）	*τ* (Kpa)	*φ* (°)
0	0.032±0.001	6.502±0.002	7.317±0.001	31.879±0.002
1	0.026±0.001	10.655±0.005	10.767±0.002	31.203±0.003
3	0.014±0.001	12.355±0.005	10.455±0.003	30.837±0.005
5	0.012±0.001	13.122±0.002	10.564±0.002	30.965±0.001
7	0.007±0.001	13.562±0.002	11.830±0.002	31.588±0.001

Note: K_r is the soil erodibility, C is the cohesive strength, τ is the critical shear stress and φ is the internal friction angle.

Table S4. Soil water regulation-related parameters under different PAM concentrations.

PAM (‰)	θ_a (%)	θ_v (%)	M_a (%)	M_e (%)	NAP (%)	K_s (cm min^{-1})	θ_r (%)	A	n
0	28.439±0.315	16.715±0.004	4.552	37.726	57.722	0.307±0.001	5.092 ±0.812	17.069	1.323
1	28.738±0.292	19.349±0.233	5.695	29.733	64.572	0.171±0.001	5.904 ± 0.439	9.503	1.086
3	29.128±0.178	23.460±0.252	5.411	35.154	59.435	0.024±0.001	7.073 ± 0.248	9.245	1.069
5	26.739±0.397	26.463±0.298	6.13	33.121	60.742	0.013±0.001	7.565± 0.568	7.727	1.115
7	23.741±0.360	30.786±0.068	7.746	29.828	62.426	0.010±0.001	8.131 ± 0.372	3.222	1.026

Note: θ_a is the available water content, θ_v is the volumetric water content, M_a is the macropores, M_e is the mesopores, NAP is the non-active pores, K_s is the saturated hydraulic conductivity, θ_r is the residual water content, α is the reciprocal of soil air intake value in Van Genuchten model and n is the fitting parameter related to pore distribution in Van Genuchten model.

Table S5. Fitting parameters of SWCC at different PAM concentrations.

PAM (‰)	Fitting parameters			
	α	n	θ_r	R^2
0	17.069 ± 6.816	1.323 ± 0.161	5.092 ±0.812	0.999
1	9.5025± 7.527	1.086 ± 0.151	5.904 ± 0.439	0.996
3	9.245 ± 7.944	1.069 ± 0.154	7.073 ± 0.248	0.989
5	7.727 ± 7.126	1.115 ± 0.172	7.565± 0.568	0.989
7	3.222 ± 5.522	1.026 ± 0.161	8.131 ± 0.372	0.986

Note: α is the reciprocal of soil air intake value in Van Genuchten model., n is the fitting parameter related to pore distribution in Van Genuchten model and θ_r is the residual volume moisture conten

Table S6. Soil ecological function under different PAM concentrations.

PAM (‰)	G_r (%)	E_r (‰)	B (g)	R_l (cm)	ARD (cm)	FD_{rs}	PRA (cm^2)	PRA_b (cm^2)
0	31.000±7.937	15.000±10.557	887.129±388.168	93.270±14.808	0.190±0.041	1.108±0.074	2.281±0.984	2.442±0.929
1	50.333±11.590	21.667±2.309	1325.448±67.834	199.840±36.461	0.206±0.031	1.115±0.112	3.824±0.934	4.297±0.991
3	54.000±3.464	23.333±5.774	1838.312±258.864	215.579±19.577	0.233±0.054	1.248±0.035	5.019±0.643	5.483±0.558
5	5.333±1.528	1.000±1.000	60.714±57.478	48.124±9.038	0.184±0.027	1.162±0.029	1.370±0.445	1.431±0.455
7	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000

PAM (‰)	RSA (cm^2)	V_r (cm^3)	R_{cn}	R_{nn}	R_{an}	R_{bp}	R_c
0	7.167±3.092	0.054±0.043	355.667±26.026	395.667±38.850	249.667±42.619	126.000±5.292	13.000±5.568
1	12.014±2.936	0.077±0.043	677.667±67.486	909.000±130.150	655.333±167.888	184.000±20.664	19.333±1.528
3	15.767±2.019	0.123±0.042	783.667±81.206	990.667±182.138	760.000±215.571	255.000±73.014	30.000±6.928
5	4.305±1.398	0.043±0.019	107.500±21.500	157.000±18.000	128.000±6.000	26.000±11.000	2.000±1.000
7	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000	0.000±0.000

Note: G_r is the germination rate, E_r is the emergence rate, B is the biomass, R_l is the root length, ARD is the average root diameter, FD_{rs} is the fractal dimension of root system, PRA is the projected root area, PRA_b is the pixel-based root area, RSA is the root surface area, V_r is the root volume, R_{cn} is the root connectivity number, R_{nn} is the root node number, R_{an} is the root apices number, R_{bp} is the root branching points number and R_c is the root crossing numbe

Figure S1. Representative gully erosion features (a) and limited effectiveness of gully control measures (b) in granite-derived weathering mantles of subtropical southern China.



Figure S2. Experimental setup for measuring soil detachment rate.

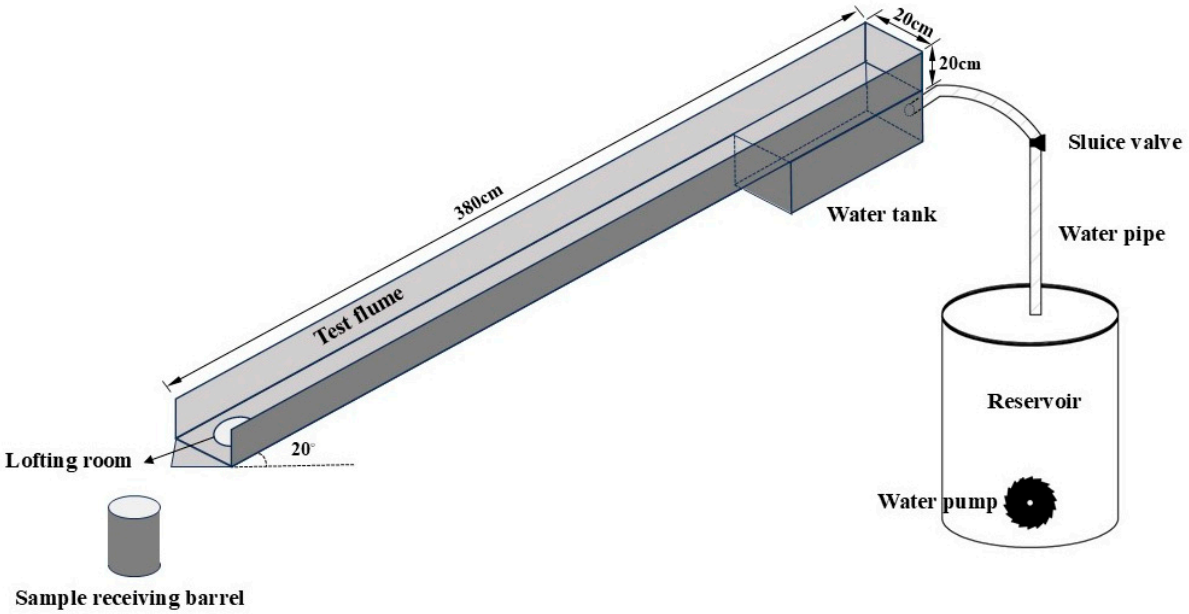


Figure S3. SEM image of soil mass under different PAM application amount.

