

Supporting Information

Table S1. Pearson correlations of values of geochemical properties in ferromanganese nodules.

Table S2. Pearson correlations of values of geochemical properties in surrounding soils.

Table S3. Alpha diversity indices of ferromanganese nodules and surrounding soil.

Table S4. Microbial composition of ferromanganese nodules at order level.

Table S5. Microbial composition of surrounding soil at order level.

Table S6. Pearson correlations of values of weathering indices with microbial composition.

Fig. S1. Representative images of ferromanganese nodules from a sugarcane field and a paddy field.

Fig. S2. XRD spectra of ferromanganese nodules.

Fig. S3. Relative abundance of selected microbial taxa in the ferromanganese nodules and surrounding soil from sugarcane field and paddy field.

Table S1. Pearson correlations of values of geochemical properties in ferromanganese nodules.

	Fe _d	Mn _d	Fe _o	Fe _p	Fe(III)	Fe(II)	Total Fe	Total Mn	Total Mg	Total Ca	Total K	Total P	OM	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃
Fe _d	1															
Mn _d	-.484	1														
Fe _o	-.035	-.098	1													
Fe _p	-.160	-.183	-.268	1												
Fe(III)	.135	-.185	.128	-.156	1											
Fe(II)	-.130	.295	.219	-.098	.522	1										
Total Fe	.130	-.487	.117	-.550	.126	-.167	1									
Total Mn	-.631*	.975**	-.083	-.095	-.169	.293	-.511	1								
Total Mg	-.711**	.798**	-.118	.169	-.170	.196	-.552	.893**	1							
Total Ca	-.099	.163	.100	-.311	.275	.632*	.165	.187	.166	1						
Total K	-.738**	.755**	-.185	.283	-.135	.189	-.614*	.864**	.978**	.154	1					
Total P	-.388	.602*	.474	-.480	.059	.463	.047	.580*	.353	.220	.234	1				
OM	-.490	.663*	.119	-.482	-.393	.070	-.022	.699**	.653*	.277	.538	.547	1			
Fe ₂ O ₃	.130	-.487	.117	-.550	.126	-.167	1.000**	-.511	-.552	.165	-.614*	.047	-.022	1		
SiO ₂	.591*	-.730**	.294	-.128	.358	.035	.436	-.810**	-.936**	-.089	-.891**	-.231	-.711**	.436	1	
Al ₂ O ₃	-.144	.670*	.088	-.272	-.154	.135	-.468	.642*	.520	-.113	.422	.560*	.565*	-.468	-.472	1

* $P < 0.05$; ** $P < 0.01$.

Table S2. Pearson correlations of values of geochemical properties in surrounding soils.

	Fe _d	Mn _d	Fe _o	Fe _p	Fe(III)	Fe(II)	Total Fe	Total Mn	Total Mg	Total Ca	Total K	Total P	OM	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	pH
Fe _d	1																
Mn _d	-.699**	1															
Fe _o	-.565*	.667*	1														
Fe _p	-.511	.362	.870**	1													
Fe(III)	-.609*	.885**	.632*	.314	1												
Fe(II)	-.449	.838**	.782**	.428	.922**	1											
Total Fe	.705**	-.288	-.448	-.501	-.195	-.143	1										
Total Mn	-.784**	.969**	.678*	.439	.810**	.737**	-.370	1									
Total Mg	-.392	.330	-.015	.051	.064	-.096	.056	.434	1								
Total Ca	-.486	.828**	.508	.174	.886**	.838**	-.153	.769**	1.000	1							
Total K	.158	-.154	-.463	-.336	-.355	-.486	.462	-.056	.772**	-.394	1						
Total P	.138	.306	.510	.227	.472	.705**	.033	.139	-.688**	.523	-.724**	1					
OM	-.030	.434	.725**	.453	.486	.759**	-.071	.300	-.415	.417	-.657*	.858**	1				
Fe ₂ O ₃	.705**	-.288	-.447	-.500	-.195	-.143	1.000**	-.369	.056	-.152	.462	.034	-.069	1			
SiO ₂	-.901**	.822**	.583*	.432	.707**	.556*	-.502	.893**	.502	.608*	-.025	-.079	.106	-.502	1		
Al ₂ O ₃	.800**	-.861**	-.741**	-.507	-.703**	-.681*	.446	-.932**	-.370	-.649*	.081	-.116	-.329	.446	-.857**	1	
pH	-.824**	.722**	.806**	.663*	.614*	.618*	-.696**	.793**	.095	.605*	-.401	.239	.399	-.696**	.847**	-.857**	1

* $P < 0.05$; ** $P < 0.01$.

Table S3. Alpha diversity indices of ferromanganese nodules and surrounding soil.

	Ferromanganese Nodules			Surrounding Soil		
	PD	chao1	Observed species	PD	chao1	Observed species
Sugarcane samples						
20 cm	187	3942	1733	192	4682	1753
40 cm	253	6579	2267	253	6402	2299
60 cm	229	5725	2110	244	6319	2224
80 cm	242	5970	2125	251	6792	2233
Paddy samples						
20 cm	102	2520	941	242	6631	2137
40 cm	187	2515	1586	245	6372	2182
60 cm	212	3073	1781	240	6089	1999
80 cm	193	4659	1745	236	6052	1898
100 cm	137	3270	1354	190	4553	1569
120 cm	157	3799	1269	217	3853	1896
140 cm	167	2337	1395	231	4382	2018
160 cm	99	1782	753	199	3790	1870
180 cm	125	2189	1013	178	3690	1669

Table S4. Microbial composition of ferromanganese nodules at order level *.

Taxon	Paddy field samples									Sugarcane field samples			
	0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	100-120 cm	120-140 cm	140-160 cm	160-180 cm	0-20 cm	20-40 cm	40-60 cm	60-80 cm
Acidobacteriaceae	4.05%	4.16%	2.20%	1.56%	13.50%	4.95%	3.76%	4.16%	2.18%	3.30%	4.63%	5.07%	3.83%
Actinomycetales	1.99%	1.91%	1.42%	0.93%	0.55%	1.83%	2.04%	2.01%	1.58%	1.34%	1.74%	2.25%	2.08%
Caldilineales	2.12%	2.42%	2.35%	1.52%	1.04%	2.27%	2.64%	2.91%	2.48%	0.91%	2.01%	1.96%	2.28%
Veillonellaceae	4.62%	4.19%	4.06%	2.02%	0.79%	3.73%	2.65%	3.26%	3.46%	4.25%	4.22%	4.79%	4.29%
Hyphomicrobiaceae	1.17%	1.24%	1.08%	0.93%	0.80%	1.65%	1.37%	1.66%	1.88%	0.34%	0.81%	0.87%	0.68%
Rhodospirillaceae	0.98%	1.01%	0.20%	0.63%	0.36%	1.26%	1.09%	0.95%	1.07%	1.11%	1.38%	1.61%	1.58%
Comamonadaceae	3.74%	3.44%	4.55%	5.18%	1.84%	3.40%	2.04%	2.53%	4.73%	6.78%	3.70%	4.70%	4.10%
Burkholderiales Incertae sedis 5	0.74%	0.82%	2.40%	2.65%	0.50%	1.33%	0.91%	1.25%	2.89%	1.30%	0.85%	0.92%	0.93%
Oxalobacteraceae	1.08%	1.13%	4.16%	4.55%	0.58%	0.75%	1.50%	1.35%	2.38%	1.16%	0.75%	0.87%	0.81%
Neisseriaceae	1.36%	1.17%	2.50%	1.64%	0.45%	1.49%	0.90%	0.85%	2.01%	1.61%	0.87%	1.44%	1.17%
Rhodocyclaceae	9.00%	7.28%	10.7%	12.3%	2.70%	5.04%	4.53%	6.41%	10.4%	12.1%	7.05%	10.3%	9.51%
Geobacteraceae	3.88%	4.23%	3.28%	4.76%	1.12%	3.28%	3.18%	1.99%	4.43%	3.93%	4.47%	4.59%	4.62%
Cystobacterineae	1.19%	1.05%	0.64%	0.63%	1.43%	1.09%	0.83%	1.42%	1.07%	0.95%	1.32%	1.40%	1.33%
Pseudomonadaceae	2.86%	2.36%	1.47%	2.23%	0.50%	0.99%	1.75%	0.33%	1.21%	1.98%	3.11%	2.05%	3.42%
Verrucomicrobiales Subdivision 3	2.13%	2.26%	2.20%	2.32%	2.10%	1.98%	2.44%	1.21%	2.05%	0.64%	1.63%	0.89%	1.76%

* Microbial species with relative abundance larger than 1% are listed.

Table S5. Microbial composition of surrounding soil at order level *.

Taxon	Paddy field samples									Sugarcane field			
	0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	100-120 cm	120-140 cm	140-160 cm	160-180 cm	0-20 cm	20-40 cm	40-60 cm	60-80 cm
Acidobacteriaceae	40.5%	5.16%	5.65%	3.49%	2.48%	20.8%	5.38%	28.7%	1.15%	5.40%	5.00%	4.28%	3.91%
Actinomycetales	2.54%	2.93%	2.29%	2.25%	2.07%	1.58%	3.24%	0.96%	0.97%	3.87%	1.98%	1.74%	1.67%
Crenotrichaceae	8.00%	0.24%	0.25%	0.07%	0.28%	0.26%	0.14%	0.20%	0.07%	1.85%	0.80%	0.74%	0.61%
Caldilineales	0.13%	2.17%	1.60%	1.17%	2.97%	1.67%	1.16%	0.14%	1.36%	0.70%	2.01%	1.83%	1.95%
Veillonellaceae	0.07%	3.76%	2.44%	2.80%	7.45%	1.32%	2.23%	0.54%	4.83%	0.89%	4.14%	4.64%	2.91%
Rhodospirillaceae	0.00%	1.53%	2.01%	0.95%	0.77%	0.53%	1.65%	0.06%	1.51%	0.36%	1.54%	1.42%	1.14%
Burkholderiaceae	1.17%	0.80%	0.95%	2.84%	0.50%	1.28%	2.04%	0.56%	2.64%	0.32%	0.89%	1.17%	0.75%
Comamonadaceae	2.38%	3.93%	3.32%	7.47%	1.78%	3.43%	5.23%	0.79%	7.07%	3.08%	3.88%	4.15%	5.53%
Burkholderiales Incertae sedis 5	0.56%	2.36%	1.72%	4.73%	0.50%	2.11%	2.85%	0.32%	4.34%	1.22%	0.76%	0.76%	1.05%
Oxalobacteraceae	3.82%	0.98%	1.21%	1.27%	2.53%	2.68%	1.05%	0.46%	2.91%	0.32%	0.60%	0.64%	0.51%
Rhodocyclaceae	0.54%	4.52%	3.13%	10.9%	7.67%	6.82%	5.58%	1.33%	12.2%	3.04%	6.93%	8.34%	8.94%
Geobacteraceae	0.07%	4.41%	2.90%	4.53%	2.62%	2.42%	2.57%	0.32%	4.47%	4.03%	3.80%	4.17%	3.38%
Moraxellaceae	0.06%	2.14%	2.41%	7.66%	0.18%	2.29%	4.13%	0.66%	5.78%	0.14%	0.85%	0.71%	0.59%
Pseudomonadaceae	0.13%	2.32%	2.39%	2.71%	0.61%	1.10%	1.31%	0.41%	3.30%	0.67%	2.81%	3.17%	2.46%
Verrucomicrobiales Subdivision 3	0.69%	1.32%	1.38%	1.21%	4.46%	1.63%	0.49%	6.02%	1.72%	1.26%	1.65%	1.81%	1.83%

* Microbial species with relative abundance larger than 1% are listed.

Table S6 .Pearson correlations of values of weathering indices with microbial composition.

	Fe ₂ O ₃	SiO ₂	Al ₂ O ₃	SiO ₂ /Al ₂ O ₃	Al ₂ O ₃ /Fe ₂ O ₃	SiO ₂ /(Al ₂ O ₃ +Fe ₂ O ₃)
Ferromanganese						
Nodules						
Acidobacteriales	-.087	-.395	.088	-.321	.086	-.394
Actinobacteridae	.533	.151	-.132	.197	-.356	.005
Sphingobacteriales	-.069	.104	-.190	.145	.098	.164
Caldilineae	.0617	.208	.123	.074	.046	.17
Chloroplast	-.056	.182	.242	.061	.219	.157
Clostridiales	.071	.388	.023	.243	-.019	.367
Rhizobiales	.455	.302	-.125	.294	-.301	.178
Rhodospirillales	-.026	-.138	.342	-.242	.243	-.191
Burkholderiales	-.466	-.174	.146	-.195	.343	-.047
Rhodocyclales	-.219	.168	-.012	.108	.113	.247
Desulfuromonales	.135	.45	-.193	.416	-.174	.452
Myxococcales	.629*	.700**	-.490	.731**	-.630*	.596*
Pseudomonadales	-.456	-.244	.365	-.326	.486	-.161
Verrucomicrobiales	.172	-.098	-.106	-.0200	-.165	-.141
Surrounding						
Soil						
Acidobacteriales	-.199	.123	.075	-.009	.156	.035
Actinobacteridae	.366	-.308	.319	-.194	.211	-.270
Sphingobacteriales	-.125	-.207	.120	-.064	.186	-.103
Caldilineae	.161	.043	.086	-.019	.041	-.026
Chloroplast	-.137	-.100	.055	.050	.108	.005
Clostridiales	.152	-.314	.161	-.079	.113	-.163
Rhizobiales	.435	.260	-.159	.185	-.340	.157
Rhodospirillales	.563*	-.703**	.557*	-.531	.400	-.623*
Burkholderiales	-.085	.044	-.242	.100	-.232	.115
Rhodocyclales	.028	-.160	-.107	.036	-.128	-.007
Desulfuromonales	.255	-.387	.154	-.142	.072	-.225
Myxococcales	.260	-.305	.476	-.266	.417	-.318
Pseudomonadales	.156	-.294	-.031	-.012	-.087	-.097
Verrucomicrobiales	-.342	.472	-.423	.406	-.333	.444

P* < 0.05; *P* < 0.01.

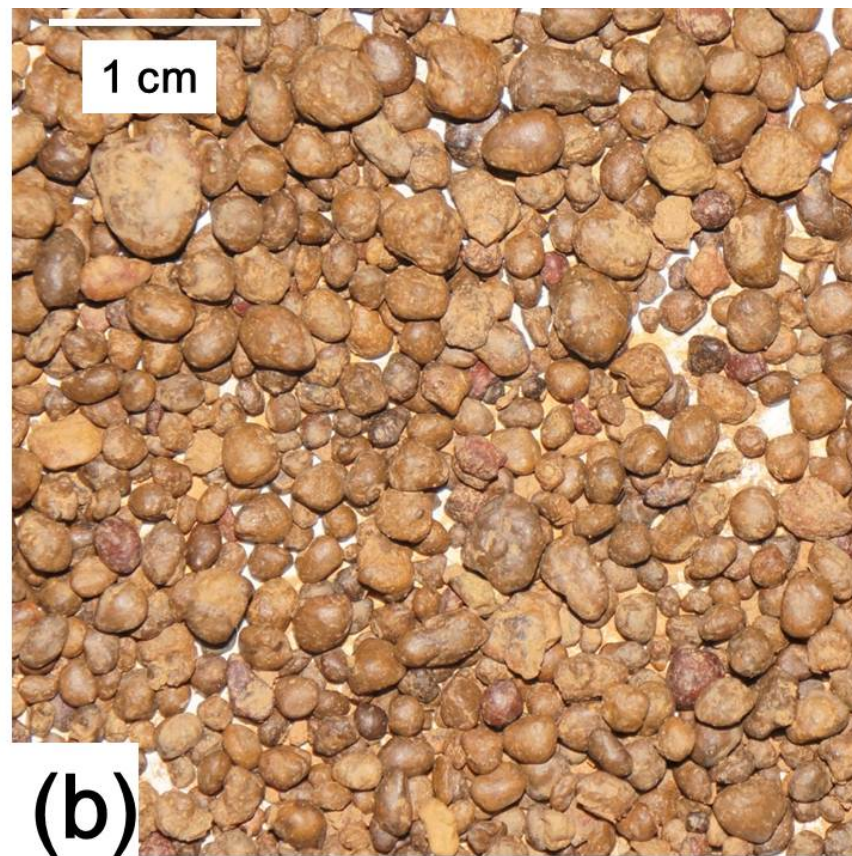
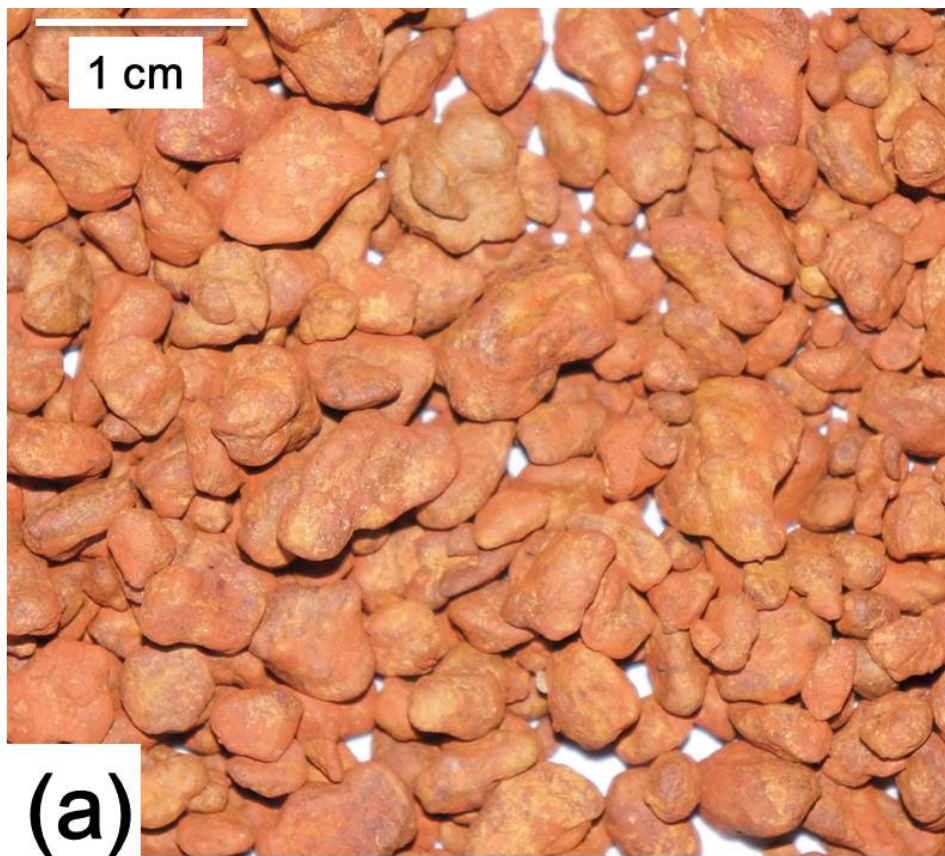


Fig. S1. Representative images of ferromanganese nodules from sugarcane field (a) and paddy field (b).

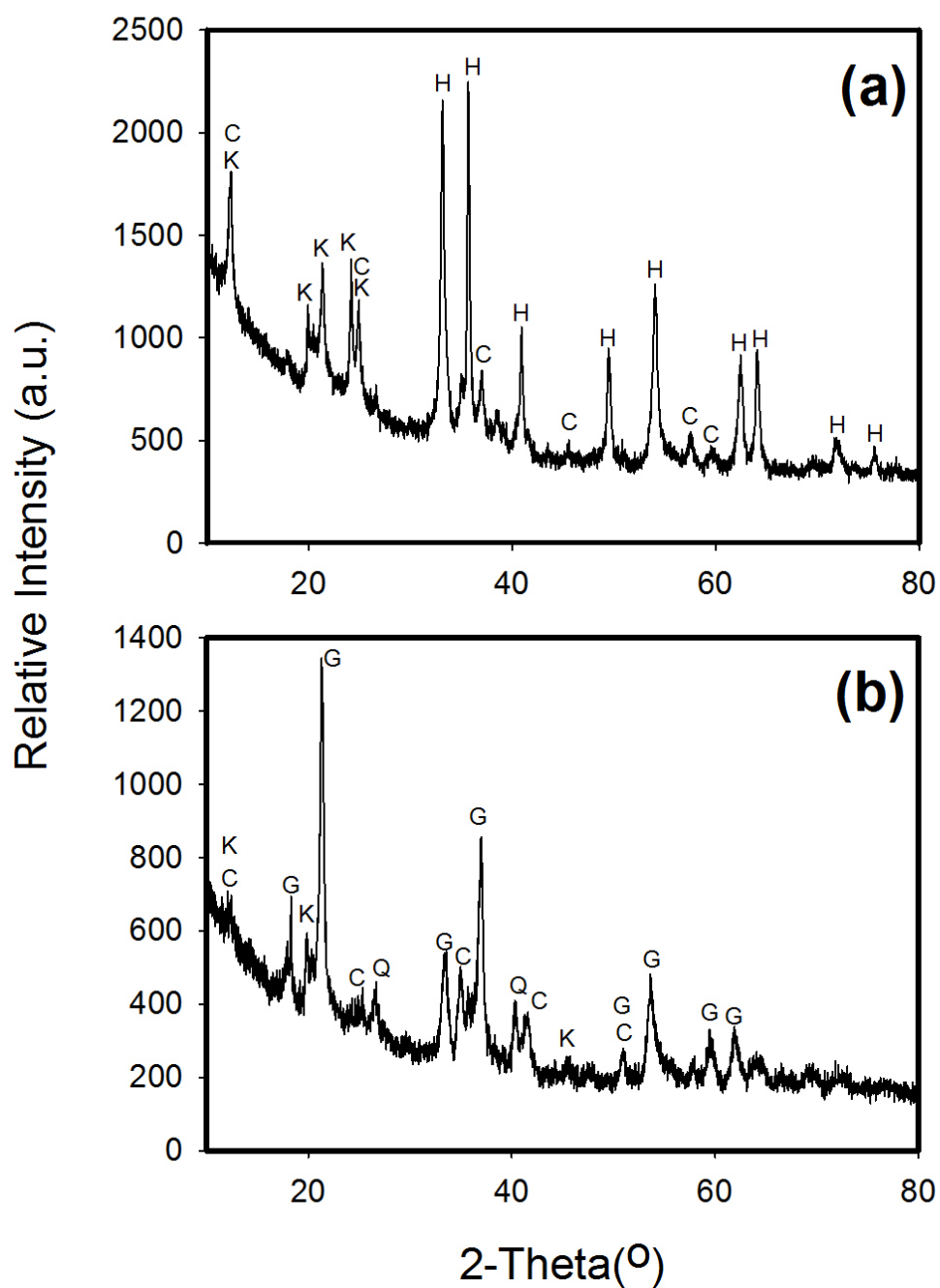


Fig. S2. XRD spectra of ferromanganese nodules, showing the mineralogical divergence of the FMNs from sugarcane field (a) and paddy field (b). C: Cronstedtite; G: Geothite; H: Hematite; K: Kaolinite; Q: Quartz.

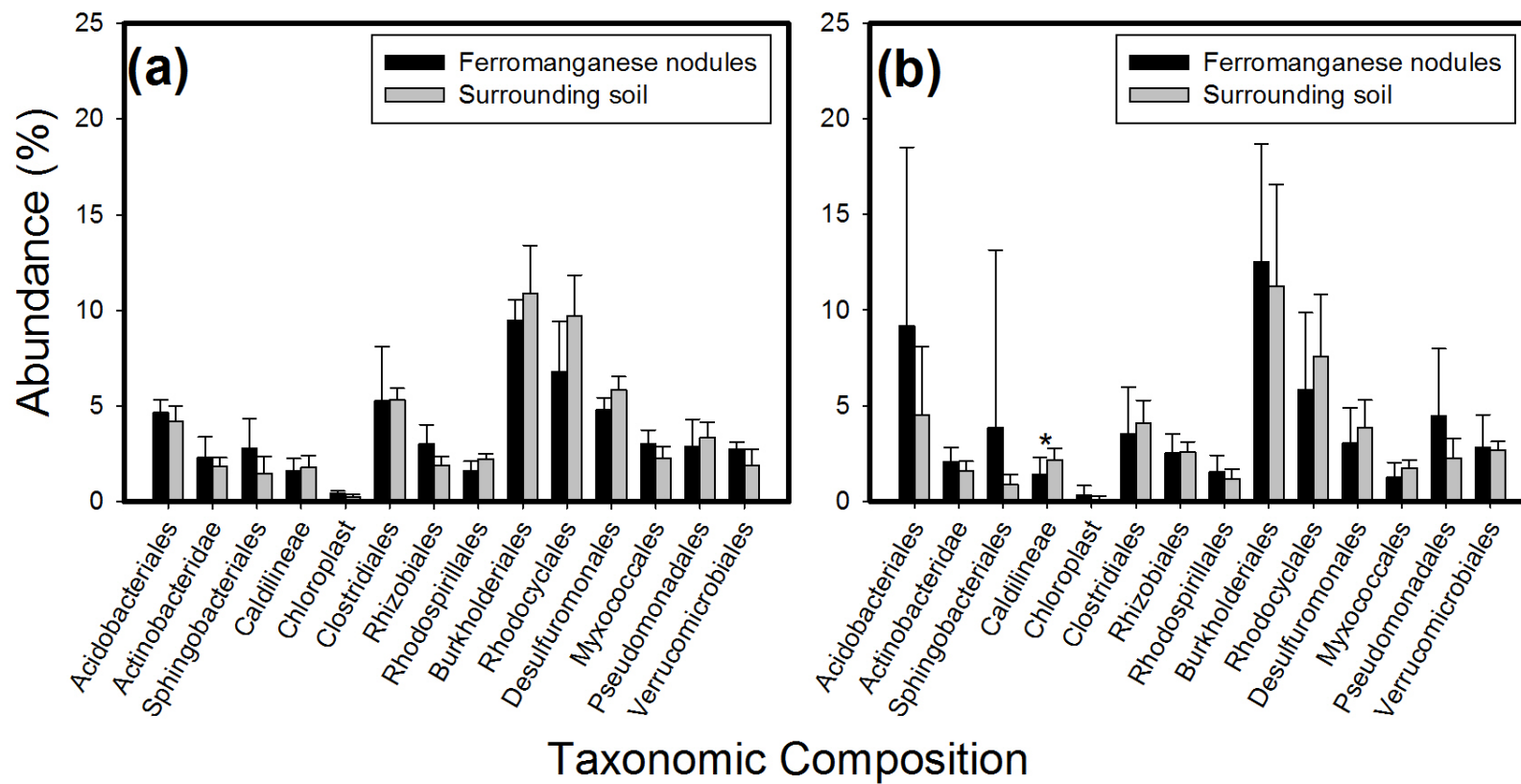


Fig. S3. Relative abundance of selected microbial taxa in the ferromanganese nodules and surrounding soil from sugarcane field (a) and paddy (b). The value was showed as mean \pm SD in sugarcane field samples (N=4) and paddy field samples (N=9). Asterisk represented significantly different ($P < 0.05$) between ferromanganese and surrounding soil examined by independent t -test. Microbial species with relative abundance higher than 1% were shown.