

Supporting information

Table S1 The environmental factors across different land use types.

	Cropland	Shrubland	Woodland
pH	7.89±0.13b	8.25±0.09a	8.09±0.06ab
ST	18.93±4.68a	22.19±4.88a	18.27±5.01a
SM	17.97±1.15a	13.75±1.62a	15.85±1.34a
Bulk density	1.45±0.03a	1.31±0.03b	1.11±0.01c
TC	4.41±0.18c	10.26±0.93b	17.55±1.63a
TN	0.61±0.04b	0.57±0.06b	1.22±0.03a
C/N	7.32±0.18b	18.97±2.19a	14.3±1.07a

Note: SM, soil moisture; ST, soil temperature; TC, total organic carbon content; TN, total organic nitrogen content; C/N, soil organic C/N ratio.

Table S2 Comparison of topological parameters between random and real networks using Z-test, as well as the topological parameters of three real networks (microbial network, AOA and AOB network) using T-test.

	PLFAs		AOA		AOB	
	Random	Real	Random	Real	Random	Real
Number of Nodes	702	702	8409	8409	68116	68116
Number of Edges	63	63	320	320	586	586
Modularity Network	0.118±0.007*	0.142	0.1±0.002*	0.347	0.035±0.001*	0.063
Clustering Coefficient	0.359±0.006*	0.735	0.16±0.001*	0.686	0.397±0*	0.759
Centralization Betweenness	0.011±0.003*	0.05	0.002±0*	0.026	0±0*	0.015
Centralization Degree	0.143±0.027*	0.318	0.06±0.009*	0.255	0.063±0.007*	0.327

Note: * indicate that for each network, the topological parameter was significantly different between the random network and the real network at the significant level $P < 0.05$.

Table S3 Co-occurrence network topological features for total PLFAs, AOA, and AOB under different land use types.

	PLFAs			AOA			AOB		
	Cropland	Shrubland	Woodland	Cropland	Shrubland	Woodland	Cropland	Shrubland	Woodland
Positive percentage	74.37±4.05a	75.84±5.16a	75.83±4.74a	99.34±0.11a	97.31±1.2ab	95.07±1.34b	96.58±1.58a	99.87±0.02a	99.69±0.17a
Negative percentage	25.63±4.05a	24.16±5.16a	24.17±4.74a	0.66±0.11b	2.69±1.2ab	4.93±1.34a	3.42±1.58a	0.13±0.02a	0.31±0.17a
Number of edges	258±65a	264±62a	265±67a	5036±284a	1172±210b	1973±386b	20693±12879a	54430±7820a	34480±11493a
Number of vertices	39±4a	40±3a	40±4a	178±10a	97±13b	127±13b	220±99a	486±39a	356±77a
Modularity network	0.19±0.01a	0.2±0.02a	0.19±0.01a	0.16±0.01b	0.28±0.05ab	0.33±0.05a	0.35±0.11a	0.07±0b	0.09±0.01b
Edge connectance	0.31±0.02a	0.31±0.03a	0.3±0.02a	0.32±0.02a	0.25±0.03a	0.24±0.03a	0.24±0.06b	0.44±0.01a	0.41±0.02a
Graph density	0.31±0.02a	0.31±0.03a	0.3±0.02a	0.32±0.02a	0.25±0.03a	0.24±0.03a	0.24±0.06b	0.44±0.01a	0.41±0.02a
Average degree	12.18±2.06a	12.37±2.01a	12.13±2.05a	56.5±1.36a	23.08±3.19b	29.82±4.51b	83.38±46.7a	216.1±20.69a	152.69±38.06a
Average path length	2.03±0.05a	2.04±0.06a	2.04±0.05a	1.97±0.05a	2.21±0.13a	2.21±0.09a	2.71±0.32a	1.68±0.02b	1.75±0.04b
Centralization									
betweenness	0.05±0a	0.05±0a	0.05±0a	0.03±0a	0.03±0a	0.03±0a	0.01±0a	0.01±0a	0.01±0a

Table S4 Keystone species of total microbes and *amoA* gene communities in all soil samples.

keystone PLFAs	10Me 16:0	16:1 w7c	17:1 w8c	18:1 w5c	18:1 w7c	a15:0	a17:0	cy17:0	cy19:0 w8c	i14:0	i15:0	i16:0
taxonomy	actinomycetes	gram-negative	gram-negative	gram-negative	gram-negative	gram-positive	gram-positive	gram-negative	gram-negative	gram-positive	gram-positive	gram-positive

keystone AOA	Phylum	Class	Order	Family	Genus	Species
otu3567	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu3975	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu2319	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu5157	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu4429	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu4949	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Candidatus Nitrosocosmicus	Candidatus Nitrosocosmicus sp. Kfb
otu2157	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu5070	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu3503	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu3624	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu281	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu203	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Candidatus Nitrosocosmicus	Candidatus Nitrosocosmicus sp. Kfb
otu2330	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu2437	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu801	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu1586	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu5056	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu4410	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu1367	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu2867	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu3938	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis Ga9.2
otu1040	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu3289	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu4016	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis Ga9.2
otu2339	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis
otu4270	Thaumarchaeota	Nitrososphaeria	Nitrososphaerales	Nitrososphaeraceae	Nitrososphaera	Candidatus Nitrososphaera gargensis

keystone AOB	Phylum	Class	Order	Family	Genus	Species
otu31787	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu44364	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu29946	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu48217	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu46931	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu8141	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu29210	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu1552	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu46225	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu10234	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu37414	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu35190	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu21550	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu3222	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu3919	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu10376	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu41279	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu18288	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu44088	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu2076	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu42763	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu35069	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu4704	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu25436	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu45316	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu969	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu19734	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu21513	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu41679	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.
otu22735	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu18789	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira multiformis ATCC 25196
otu848	Proteobacteria	Betaproteobacteria	Nitrosomonadales	Nitrosomonadaceae	Nitrospira	Nitrospira sp.

Figure Legends

Fig. S1 Boxplot of the seasonal the alpha diversity (Shannon and Chao1 index) of soil PLFAs communities (a, d), AOA (b, e) and AOB (c, f) communities under different land use types. The statistical significance between land use types or seasons was determined based on T-test. The non-significant results weren't showed in the plots.

Fig. S2 Relationship between AOA (a) and AOB (b) and ecosystem functioning (nitrification rate; NR) under land use changes (LUC). The solid lines represent significant linear relationship across land use types, and the dark shaded area shows the 95% confidence interval of the fitted models, respectively.

Fig. S3 Priori generic structural equation models (SEM) used in this study. The model evaluated the influences of environmental and biotic factors on board and specialized ecosystem functioning.

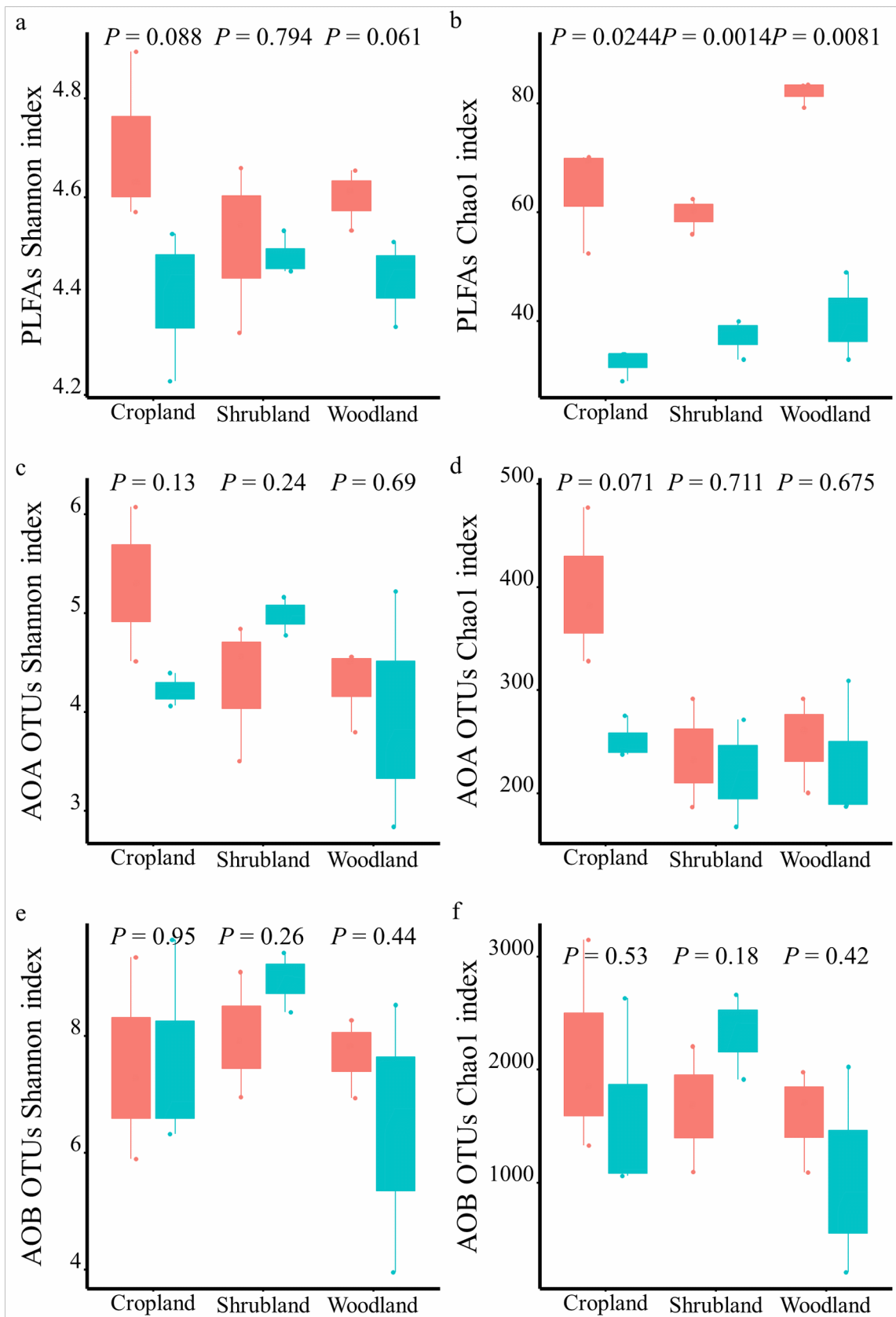


Fig. S1

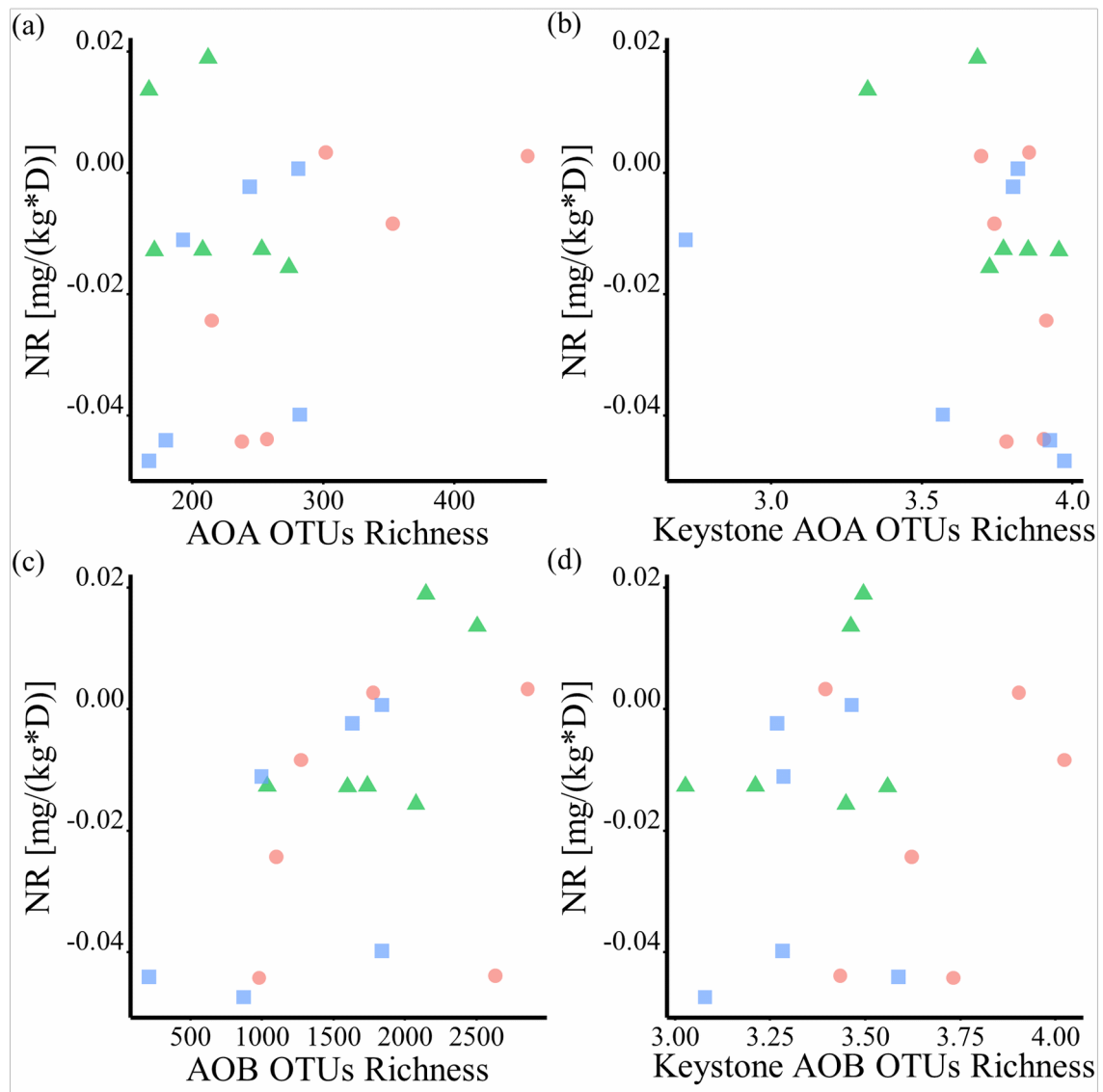


Fig. S2

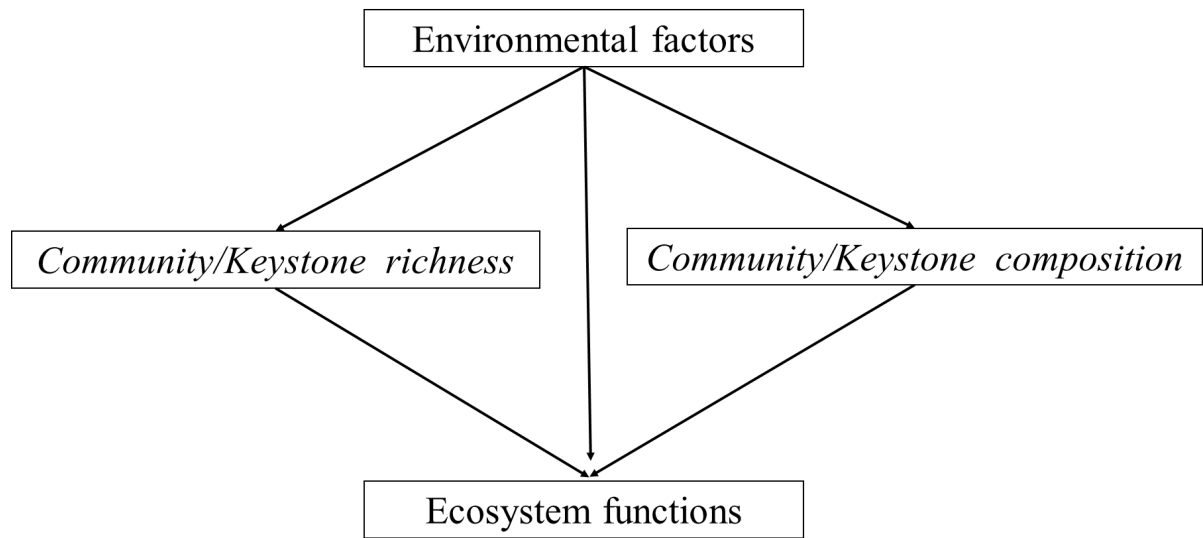


Fig. S3