Supplementary material:

Table S1 Soil properties and potential nitrification rate in Experimental Station and Typical Black Soil Zone.

Site	Treatment	pH	SOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	NH_4^+ ($mg\ kg^{-1}$)	NO_3^- ($mg\ kg^{-1}$)	PNR ($mg\ kg^{-1}\ d^{-1}$)
Experimental Station	N0	6.76	8.71	0.75	9.45	0.75	7.63
	N_{135}	6.34	8.44	0.78	10.16	1.95	3.56
	N_{270}	4.96	8.66	0.86	11.58	6.22	2.77
	N_0S	7.01	9.52	0.76	13.81	1.57	10.92
	$N_{135}S$	6.52	9.22	0.88	14.59	5.1	4.67
	$N_{270}S$	6.05	8.97	0.97	20.03	7.34	2.83
Typical Black Soil Zone	Nenjing	5.64	18.25	1.67	49.27	35.83	1.84
	Wudalianchi	5.92	32.05	2.38	44.69	22.35	1.87
	Beian	5.99	34.98	2.47	31.49	10.00	2.18
	Kedong	7.37	36.61	2.60	9.04	7.86	3.30
	Baiquan	7.05	26.90	2.07	19.91	3.36	1.36
	Suileng	6.41	33.83	2.51	27.30	7.07	3.38
	Suihua	6.26	19.41	1.60	17.53	57.96	1.19
	Hulan	6.19	19.36	1.57	13.79	61.12	0.98
	Daoli	5.4	14.64	1.19	12.99	51.85	1.46
	Shuangcheng	6.38	26.43	2.05	4.74	7.18	1.71
	Yushu	8.4	16.08	1.22	4.74	89.99	0.90
	Fuyu	5.57	11.12	1.01	39.07	42.21	1.73
	Dehui	6.71	24.94	1.97	4.75	121.89	1.06
	Gongzhuling	5.9	14.15	1.29	22.21	27.97	1.52
	Lishu	6.13	18.64	1.22	25.36	4.82	2.18

Table S2 Indices of network

	Network
Number of nodes	29.00
Number of edges	51.00
Edge density	0.06
Centralization of degree	0.13
Centralization of betweenness	0.04
Centralization of closeness	0.41
Mean connectivity	1.759
Modularity	0.27

Table S3 Significant network edge correlations ($P < 0.05$)

	C/N	PNR	pH	TN	NO_3^-	NH_4^+/NO_3^-	SOC
OTU4	-	0.772	-	-	-	-	-
OTU6	0.736	0.831	-	-	-	-	-
OTU7	-	-	-	-	-	-	0.727
OTU8	-	0.727	-	-	-	-	-
OTU12	0.793	0.85	-	-	-	-	-
OTU15	0.717	0.812	-	-	-	-	-
OTU20	-	-0.703	-0.902	-	-	-	-
OTU21	0.775	0.874	-	-	-0.741	0.783	-
OTU26	-	-0.76	-0.753	-	0.787	-	-
OTU28	0.769	0.788	0.711	-	-	-	-
OTU35	-	0.828	-	-	-	-	-
OTU37	0.827	0.94	-	-	-	-	-
OTU38	-	-	0.749	-	-	-	-
OTU39	-0.796	-0.933	-	-	-	-	-
OTU41	-0.804	-	-	0.809	0.813	-	-
OTU42	-0.847	-0.707	-	0.842	0.793	-	-
OTU46	0.732	0.754	-	-	-0.774	-	-
OTU55	-	-0.701	-	-	-	-	-
OTU56	-0.894	-0.86	-	0.802	0.85	-	-
OTU58	0.731	0.812	-	-	-	0.767	-
OTU64	-	-0.718	-	-	-	-	-
OTU65	0.849	0.841	0.792	-0.714	-0.787	-	-

SOC: soil organic carbon; TN: total nitrogen; NO_3^-: nitrate nitrogen; C/N: the ratio of SOC to TN; NH_4^+/NO_3^-: the ratio of ammonia nitrogen to nitrate nitrogen. - indicate non-significant ($P \geqslant 0.05$) or weak ($|r| \leqslant 0.7$) correlations.

Table S4 Properties and specific targets of the newly designed primer sets developed in this study for quantitative PCR

Target cluster	AOA OTUs	Primer name	Primer sequence (5′- 3′)	Position	Expected length (bp)
G1	OTU35, OTU28, OTU21, OTU65	G1F	ATTCATAGTTGTAGTTGCTG	16 - 35	158
		G1R	CGGTGAATAGCATGTAAT	156 - 173	
G2	OTU37, OTU58	G2F	ACAGCACCTTACTTACTATCA	39 - 59	220
		G2R	TATCCCAAAGCGAACCAT	241 - 258	
G3	OTU39, OTU56	G3F	TACTTACTATCAACGCAGGAGACTA	48 - 72	202
		G3R	GCAAACCATGCACCCTT	233 - 249	
G4	OTU20, OTU26, OTU41, OTU42	G4F	TGGGCTTGGACRTCSTTT	89 - 106	117
		G4R	GGSTGRGTAATACGTGGC	188 - 205	
G5	OTU55, OTU64	G5F	CTTTTCATTGTCGTTGTT	14 - 31	200
		G5R	GTCATAATGGTTGCATAGTA	194 - 213	
AOA *amo*A	-	CamoA-19F	ATGGTCTGGYTWAGACG	-	629
		CamoA-616R	GCCATCCABN0RTANGTCCA		

Table S5 Mantel test analysis of potential nitrification rate and soil properties with AOA *amo*A and AOA core clusters

	Factors	r	p	p-adjust		Factors	r	p	p-adjust
	PNR	0.735	0.001	0.003		PNR	0.857	0.001	0.003
	pH	0.241	0.022	0.032		pH	0.447	0.005	0.009
	SOC	0.330	0.010	0.012		SOC	0.412	0.002	0.005
AOA	TN	0.101	0.126	0.155	AOA core	TN	0.080	0.193	0.221
*amo*A	NH_4^+	0.086	0.822	0.822	clusters	NH_4^+	0.057	0.675	0.720
	NO_3^-	0.155	0.063	0.084		NO_3^-	0.284	0.011	0.018
	C/N	0.480	0.001	0.003		C/N	0.528	0.001	0.003
	NH_4^+/NO_3^-	0.391	0.004	0.009		NH_4^+/NO_3^-	0.503	0.001	0.003

SOC: soil organic carbon; TN: total nitrogen; NH_4^+: ammonia nitrogen; NO_3^-: nitrate nitrogen; C/N: the ratio of SOC to TN; NH_4^+/NO_3^-: the ratio of ammonia nitrogen to nitrate nitrogen. P-adjust: adjusted P-values (FDR) for multiple comparisons.

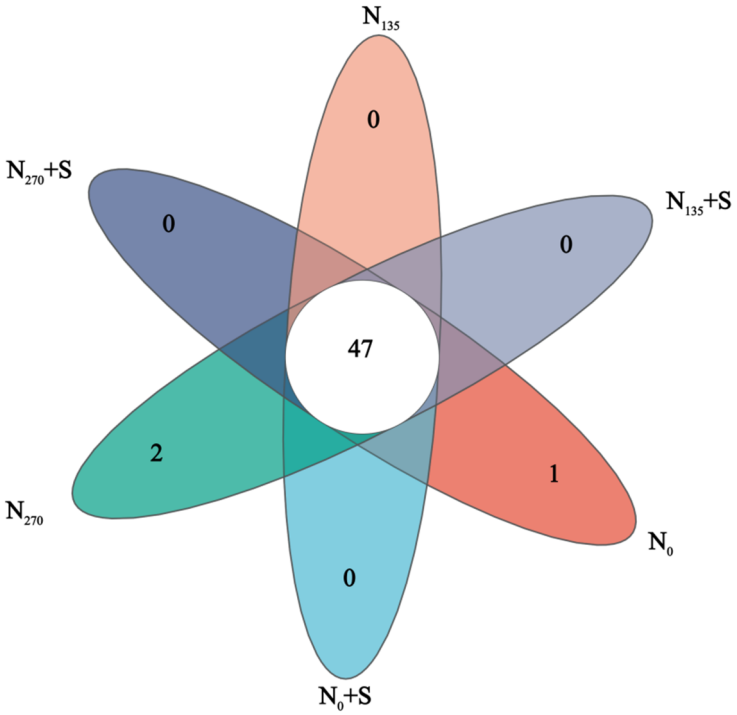

Figure S1 Flower plot of AOA community.

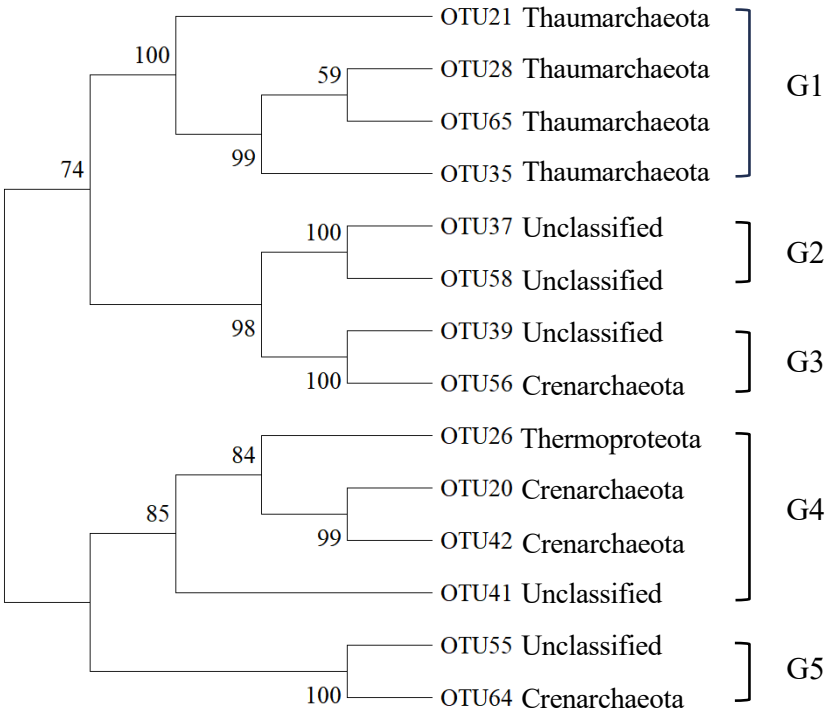

Figure S2 Neighbor-joining dendrogram derived from the AOA core clusters (with 1,000 bootstrap replications). G1, G2, G3, G4, and G5 represent different clusters within the AOA core clusters.

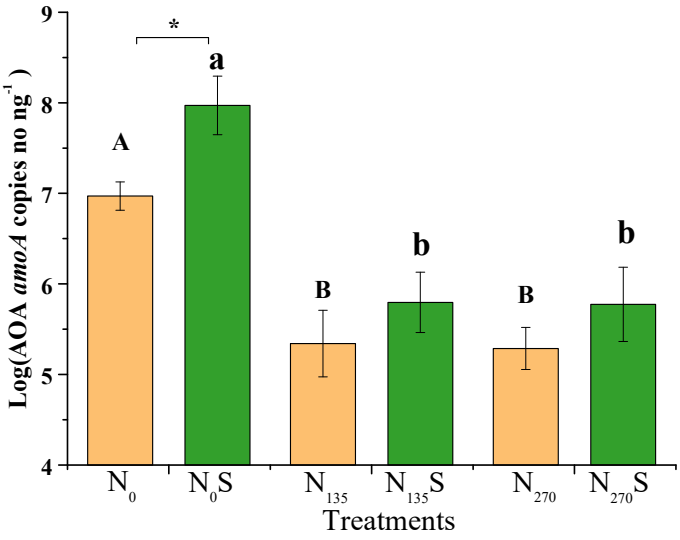

Figure S3 Quantification of AOA *amo*A in different treatments. Uppercase and lowercase letters represent significant differences between fertilization treatments without and with straw, respectively ($P < 0.05$). "*" indicates significant differences between straw samples ($P < 0.05$).

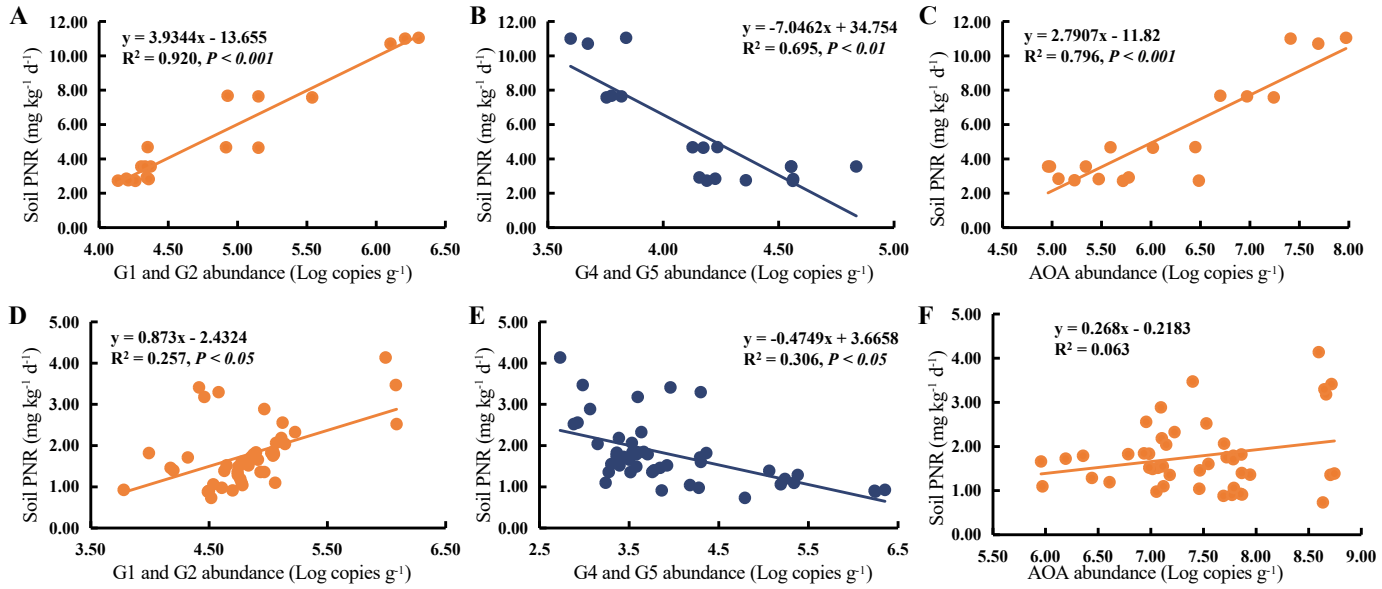

Figure S4 Linear regression analysis between the abundance of AOA communities and soil potential nitrification rate (PNR). A-C: Data from the Brown Soil Experimental Station. D-F: Data from the Typical Black Soil Zone. A, D: Relationship between the abundance of G1 and G2 and soil PNR. B, E: Relationship between the abundance of G4 and G5 and soil PNR. C, F: Relationship between AOA *amo*A abundance and soil PNR. The orange line and the blue line represent positive correlation and negative correlation, respectively.